CRIME AND PLACE: A LONGITUDINAL EXAMINATION OF STREET SEGMENT PATTERNS IN VANCOUVER, B.C.

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Abstract

The study of crime and place recognizes the important interplay between the physical landscape and criminal activity. In doing so, research in this area has shown substantial concentrations of crime amongst micro geographic units, such as street blocks. Despite these revelations, little research has examined whether such criminal concentrations persist over time. The developmental trajectory of criminal activity on street blocks was originally studied in Seattle, Washington. This dissertation replicates that seminal study by examining crime volumes on the streets of Vancouver, British Columbia, over a 16 year period using a group-based trajectory model (GBTM). Going further, this research also applies a non-parametric technique, termed k-means to address various limitations inherent to the GBTM method. The major findings reveal the majority of street blocks in Vancouver evidence stable crime levels, with a minority of street blocks throughout the city showing decreasing crime trajectories over the 16 year period. Both statistical techniques found comparable patterns of crime throughout Vancouver. A geographic analysis of the identified crime trajectories revealed linear concentrations of high, medium and low decreasing trajectories throughout the city, with the high decreasing street blocks showing particularly visible concentrations in the northeast part of Vancouver. Overall, the results confirm the original conclusions from the Seattle study in that many street blocks evidence significant developmental trajectories of crime and that the application of trajectory analysis to crime at micro places is a strategically useful way to examine the longevity of crime clusters. The results did not support the existence or stability of bad areas, but did find ‘bad streets’. It is recommended that police and public safety practitioners pay close attention to the varying levels of criminal activity on street blocks when developing place-based crime prevention initiatives.

Dedicated to my parents, Michael and Suzanne Nemeth. May you always know my tremendous gratitude for your unending support and invaluable encouragement.

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Introduction

The field of Criminology has evolved from asking the question, 'why criminals behave the way they do' to 'where and when does criminal behaviour take place'. The emergence of this new focus has largely resulted from the fact that the reasons for criminality are as various and complex as each individual offender. Focusing on the 'where' and when' of criminal behaviour has been termed the 'criminology of place' (Sherman, Buerger and Gartin, 1989) and has revealed that criminal activity, when viewed from a *place* perspective is highly patterned and predictable (Brantingham and Brantingham, 1978; 1991a). The field of Environmental Criminology (Brantingham and Brantingham, 1984) has dedicated itself to uncovering these patterns and in doing so provides police and public safety practitioners with practical solutions towards crime prevention and other enforcement initiatives.

One of the core findings stemming from Environmental Criminology is the existence of 'hotspots' or geographic areas that evidence a disproportionate amount of criminal activity (Brantingham and Brantingham, 1999; Block and Davis, 1996; Rhodes and Conly, 1991). Such findings drove confidence towards enforcement activities targeting specific areas labelled as dangerous or problematic. This may have been premature. As much as research revealed that geographic hotspots of crime exist, research had yet to establish whether these hotspots persisted over time. This is a key element towards ensuring the effectiveness of 'place based' crime prevention and justifying police and public resources towards such programs.

Secondly, if crime concentrations at a micro level are found to move geographically, it may question the focus of studies whose purpose is to understand criminal activity based on the characteristics of places. Variations in criminal activity have often been explained as being attributable to a non-uniform distribution of neighbourhood characteristics that translate into 'criminal opportunity'. However, if criminal hotspots are unstable geographically, then studies attempting to explain criminal opportunity based on ‘place’ may be better focused elsewhere. Many studies using a microspatial unit of analysis have found stability of crime places over time (Taylor, 1999; Shaw and McKay, 1942; Robinson, Lawton, Taylor and Perkins, 2003; Taylor, 2001). Yet, others have found a lack of stability in criminal concentrations attributable to population changes affecting demographics (Bursik and Webb, 1982, 1986; Heitgerd and Bursik, 1987). Thus, the key question within the criminology of place research is whether crime concentrations persist over time.

Within this subset of Criminology, much has been written on the various spatial units of analyses employed. Research has shown geographic concentrations of crime at micro levels, such as addresses, (Bowers and Johnson, 2005) and at higher levels in the cone of resolution, such as census tracts (Browning, Byron, Calder, Krivo, Kwan, Lee and Peterson, 2010) or state/provincial cross-sectional analyses (see Andresen, 2008, 2009a). One of the drawbacks to focussing on hotspot addresses is that it does not provide a very practical focus for enforcement activity dedicated to crime prevention. It is arguably unrealistic for police to focus solely on a problematic building, business or public facility without taking into account its surrounding area. Conversely, research showing that larger geographic areas such as census tracts that exhibit high crime rates can also be misleading and equally unpractical for enforcement purposes. Research has shown that studies focussing on larger geographic areas mask important micro level variation in criminal activity (Groff, Weisburd and Yang, 2010) and may lead to inaccurate conclusions about crime at the individual level. This is known as the ecological fallacy (Robinson, 1950; Brantingham and Brantingham, 1984) and represents a significant limitation to the external validity of geographic conclusions regarding hotspots of criminal activity.

Considering these limitations, recent research has shown the utility of the *street block* as the optimal unit of analysis in crime and place studies. The street block has been described as large enough to avoid the impractical focus of singular addresses but not as large as to lead to erroneous conclusions about crime at the micro level (Groff, Weisburd and Yang, 2010). In 2004, Weisburd, Bushway, Lum and Yang, conducted a seminal study examining longitudinal patterns of criminal activity at the street block level in Seattle, Washington. Looking at police incident reports from the Seattle Police Department from 1989-2004, Weisburd et al. (2004) employed a cluster analysis technique termed 'group-based trajectory model' (GBTM) to investigate whether street blocks evidence criminal developmental trajectories over time. Traditionally, in mathematics, a *trajectory* would be described as "the path which an object travelling through space and time follows" (Elragal and El-Gendy, 2012). Applied to a social scientific context, the term trajectory has been used to describe the long-term pattern of criminal offending behaviour (see Nagin and Land, 1993) and more recently has been used to describe the longitudinal pattern of crime volumes on urban streets (see Weisburd et al., 2004 and Weisburd, Groff and Yang, 2011).

GBTM was originally applied to the field of life-course criminology by Nagin and Land (1993) to track a panel dataset of juvenile offenders longitudinally and determine whether identifiable sub-groups of offending behaviour existed. It was not the research findings that garnered the majority of the attention, but rather, the statistical method of GBTM that generated enthusiasm within the life-course criminology field. Weisburd et al. (2004) were the first study within Environmental Criminology to apply the GBTM technique to a place-based focus, specifically, the street block. The findings revealed that street blocks do evidence distinct developmental trajectories and that these criminal trajectories remain largely consistent over time. Specifically, the majority of street blocks in Seattle evidenced stable trajectories of crime volume over time, and a smaller proportion showed significant rising or declining trajectories.

To date, the application of the group-based trajectory model to examine micro crime places over time has not been applied to any city outside of Seattle, WA. In a more recent publication that examines the developmental trajectories of street blocks, Weisburd, Groff and Yang (2011) question whether their results are generalizeable beyond the city of Seattle. They encourage other researchers to replicate their study in other jurisdictions to "build a science of the criminology of place" (p. 219). This dissertation carries out this replication and marks the first study examining the issue of micro crime places over time, outside of Seattle, WA. The methodology originally employed by Weisburd, Bushway, Lum and Yang (2004) is replicated in Vancouver, B.C. based on a 16 year dataset comprised of calls-for-service from the Vancouver Police Department. The GBTM technique is applied to investigate whether street blocks in Vancouver evidence distinct developmental trajectories of crime volume from 1991-2006. Additionally, a separate non-parametric cluster analysis technique termed k-means is conducted to augment the GBTM method. This statistic provides an efficient alternative for researchers whose datasets hold a sizeable number of cases greater than 50. The methodological implications of this process are discussed in Chapter 3. The identified developmental trajectories are also spatially analysed to investigate both their location within the city of Vancouver and their spatial density, as per the methodology employed by Weisburd et al. (2004).

The purpose of this dissertation is threefold. First, a direct replication of the Weisburd et al. (2004) study is carried out for the city of Vancouver, British Columbia, to test the generalizeability of the findings on the developmental trajectories of street blocks in Seattle, Washington. Second, to further research in the field of crime and place, this dissertation emphasizes the utility of examining crime at the street block level and the advantage of establishing longitudinal patterns of place-based criminal activity. Third, practical implications for police and public safety practitioners within Vancouver are discussed to further crime prevention efforts.

This dissertation is comprised of five chapters. Chapter One, *Theory*, reviews the central theories within the field of Environmental Criminology and the accompanying levels of spatial analysis used to test them. Chapter 2, *Literature Review,* presents an overview of both seminal Environmental Criminology literature and more recent research examining the field of crime and place. Chapter 3, *Methods*, provides an overview of the two cluster analysis techniques applied to the Vancouver Police Department dataset, the GBTM and k-means statistics. This chapter also provides a comparative overview of Seattle, WA and Vancouver, B.C. and discusses the importance of replication within the social sciences. The two spatial analysis techniques of visualization maps and kernel density estimates are also reviewed. Chapter 4, *Results*, presents the findings from both the GBTM and k-means statistics as well as the spatial analysis. Lastly, Chapter 5, *Conclusion*, discusses the implications of the findings, the limitations inherent within exploratory research and future research strategies exploring the criminology of place.

Chapter One: Environmental Criminology Theory

Introduction

The field of Environmental Criminology focuses on the movement of criminals in their surrounding space. This chapter will discuss microspatial theory within Environmental Criminology with respect to the spatial movement of criminals, at both aggregate (spatial distribution of crime in urban settings) and disaggregate levels (target selection patterns).

Microspatial Criminology considers both objective and subjective space in the analysis of criminal offender behaviour. *Objectively*, space is a fixed quantity and measurable in units such as miles, volume or square footage. In microspatial criminology, the salience of the physical environment (objective space) is observed in how the spatial distribution of crime is constrained by urban layouts, land use and the physical structure of a city (Brantingham and Brantingham 1975b; 1981b; 1991a; 1993b; 1995; 1998; 1999). In opposite, *subjective* space is entirely perceptual and varies as a function of an individual's experiences with a geographical area as well as their social settings. Brantingham and Brantingham (1984) assert that criminal behaviour reflects a bidirectional interaction between the surrounding environment of the offender and his/her subjective perception of that space: "movement patterns depend on underlying spatial mobility biases, knowledge and experience" (p. 332). Research lends strong empirical support for a subjective spatial bias in target selection, as crimes usually do not occur where people think they will (ex. in isolated, dark corners); rather, crimes occur in well-populated, highly frequented locales (Brantingham and Brantingham, 1984; Block and Davis, 1996; Roncek and Maier, 1991; Sherman, Gartin and Buerger, 1989).

It is acknowledged that viewing space from a subjective manner is far more complex than viewing it objectively. This is due to the fact that a subjective perception cannot be calculated or standardized and cannot be coordinated with objective measures of space. Thus, microspatial criminology considers environmental psychology as well as behavioural geography concepts to aid in explaining the complex behavioural patterns of offenders. Indeed, many of the concepts underlying microspatial criminology are not inherent to Criminology itself. In order to understand the spatial movements of criminals, one must first recognize that offenders are people first and criminals second. That is, for the majority, their time is not spent engaging in crime, but in carrying out routine day-to-day activities as noncriminal populations do (Cohen and Felson, 1979; Felson and Cohen, 1980). Thus, the same principles that guide noncriminal spatial behaviour are the hallmarks of criminal target selection processes.

Environmental Criminology Theory

Crime Site Selection

At the very core of microspatial criminology is the assumption that the environment interacts bidirectionally with an individual's cognition. From this perspective, the environment is not seen as a static entity, but as a multi-faceted element that embodies cues or signals about its characteristics that are interpretable by those who live and function within it. Specifically, Brantingham and Brantingham (1978) propose an information processing model of crime site selection wherein environmental cues are considered a salient component of an offender's decision making process and in the development of a crime template. This model is aspatial in that it does not discuss the spatial implications of the target selection process; rather, the salience of the environment in general within decision-making, is focused on. It is held that the environment emits numerous types of cues from its physical, social, political and psychological features that characterize the spaces in which one lives (Brantingham and Brantingham, 1984). This environmental complexity is captured in the term 'environmental backcloth' (Brantingham and Brantingham, 1993a; 1993b) and constitutes an integral aspect of the conceptual spatial target selection processes of offenders.

As is typical of microspatial theory in general, the theoretical tenets underlying crime site selection suggest a pattern at the aggregate level. Brantingham and Brantingham (1978) reiterate that, "people learn the complex social spacing of mechanisms of the culture in which they live; and people learn norms of behaviour" (p. 111). Functioning under the assumptions offered by Rational Choice theory (see Clarke and Cornish, 2001), microspatial criminology holds that criminal events are the result of a multi-staged decision making process whereby a rational offender makes a conscious decision to commit crime and has utilized the environmental cues to decide where the most 'attractive' targets may be. The bidirectional interaction between the environmental cues and offender's decision making process may be either conscious or subconscious. However, it is held that criminals, in general, apply environmental cues toward decisions regarding criminal ventures.

Environmental cues are differentiated into individual, cluster and sequential levels. An *individual* cue may inform an offender of what a 'good' target is or who appears easy to victimize (see White, 1990). A *cluster* of cues may function to inform an offender of the best 'area' to conduct criminal activity (Brantingham and Brantingham, 1978). Studies have shown that crime is disproportionately located in certain areas of a city and that such areas are consistently marked with predictable features such as the presence of bars or lounges (Roncek and Maier, 1991), industrial land use (Rand, 1984; Rhodes and Conly, 1991), public transit routes (Block and Davis, 1996; Brantingham and Brantingham, 1991b) and the presence of gang activity (Block, 2000). This area of research supports the assumption that target selection is non-random and that criminal activity is highly clustered in nature. Thus, crime site locations and areas are not perceived as embodying equal criminal opportunity levels. Certain areas emit preferential cues that offenders perceive as being amenable to the successful commission of a crime. Research has supported Brantingham and Brantingham's (1978) contention that offenders identify good target areas as much as they do bad target areas. If this were not the case, it is arguable that research throughout the last two decades in the field of Environmental Criminology would report that criminal activity is more uniformly distributed.

Additionally, Brantingham and Brantingham (1978) explain that environmental cues may be *sequential* in nature: “a sequence of cue clusters may become associated with ‘good targets’” (p. 113). An offender’s search for a target expands further than the selection of a person or place, but rather, for the best time, space and context to commit the crime. It is argued that once a criminal has identified a sequentially ordered environmental cue, it is perceived holistically or gestalt like in that it represents more than the sum of its parts (Brantingham and Brantingham, 1993a). For example, a sequential cue could include convenience stores, that are located just off major traffic arteries between midnight and 2am. Once this cue is established, Brantingham and Brantingham (1993a) hold that the offender will search for these characteristics and subsequently perceive them as a whole and will not separate the environmental cues into individual components. Research has substantiated that offenders do perceive their targets in a holistic manner. Convicted burglars have reported that when deciding which areas and homes to break into, they base their decisions on the location’s target suitability as defined by how visible it was from the road, whether they thought the occupants were home, how difficult it appeared to break into and the estimated value of the goods inside (MacDonald and Gifford, 1989). The burglars reported that such categorical considerations took precedence over individual level cues such as whether the home had a fence or easily accessible entryways.

Inherent to the bidirectional interaction between an offender’s environment (objective and subjective) and the cognitive decision making processes is the concept of *distance decay* (Brantingham and Brantingham, 1984). The distance decay phenomenon is not specific to offender populations. It refers to the fact that the rate of interactions between people and their surroundings decrease as the distance from home increases (Brantingham and Brantingham, 1984). Environmental Criminology has evidenced the distance decay phenomenon as it has established that offenders commit their crimes close to their place of residence (Townsley and Sidebottom, 2010; Alston, 1994; Curman, 2004; Canter and Larkin, 1993; Fritzon, 2001; Rossmo, 1994; LeBeau, 1987). This area of research, known as *‘journey-to-crime’*, forms an integral component of microspatial criminology. Essentially, as research shows that most people prefer to engage in routine activities close to areas that harbour familiarity; offenders also engage in target selection processes that centre on their home locations, as committing crime becomes part of their routine activities.

It is held that environmental cues perceived by offenders may be viewed as a *template* that is used in the target selection process (Brantingham and Brantingham, 1978). A template is analogous to a cognitive script and is not a concept inherent to criminology. Noncriminals form templates for everyday routine activities that serve as the layout for the most efficient manner to manoeuvre through one's physical and social environment. For example, people have a pervasive idea about which grocery store is best to shop at and which hours are best to arrive, or form pervasive ideas about which routes to take from home to work or school that avoid traffic congestion, or learn how to conduct themselves differently in various social settings. It is argued that a similar process occurs with noncriminals; the offender forms a pervasive idea of the best areas, times of day and targets to prey upon based on past experiences (Brantingham and Brantingham, 1978). The development of the crime template is an iterative process; refinements of what is perceived as usual or expected actions associated with a specific crime type or criminal event will be altered (Brantingham and Brantingham, 1993a). Thus, Brantingham and Brantingham (1984) hold that with the development of a crime template, offenders learn how to "recognize potential crime sites and situations or learn to recognize potentially poor crime sites or situations and to refrain from criminal behaviour in such settings" (p. 343).

The concept of the crime template is integral within the information processing model of an offender's journey to crime, as it represents the notion of patterned behaviour. Specifically, Brantingham and Brantingham (1978; 1991a) explain that despite seeming individual level variation within a criminal's behaviour set, there exists a predictable pattern in offender spatial movement that is a result of the bidirectional interaction between the offender's environment and their cognition. This notion is best illustrated with the following hypothetical scenario. Offender A lives in Burnaby, British Columbia (B.C.) and is motivated to steal a car. Offender B lives in Richmond, B.C. and has decided to commit a break and enter. The crime site selection model posits that despite the fact that the *exact* location and targets differ between the two criminal events, both offenders are likely to choose targets that are *close to their residential locations* as the areas are familiar and predictable; both offenders are likely to choose the time of day that poses the *least amount of detection risk* and both offenders are likely to utilize aspects of their *crime template* that have endured, based on prior successful criminal ventures. Thus, despite an expected variation between the individual offender's schema, the salience of the environment and the enduring of a crime template, is the predictable pattern in crime site selection. This represents the idea that "variation between templates constructed by different people is *not unlimited*" (Brantingham and Brantingham, 1978).

Routine Activities Theory

The three main variables involved in a criminal event are the offender, the victim and the location. As microspatial criminology focuses on offender movement patterns, it is the *intersection* of the offender and victim/target that is the unit of analysis, as it constitutes the crime site location. Microspatial criminology holds that the intersection between an offender and a victim is not a random occurrence that happens by chance alone. In opposite, it is argued that there exist spatial and socio-cultural factors that increase the likelihood of a crime occurring; this acknowledgement adds a *spatial* dimension to crime site selection and is represented by Routine Activities Theory. Cohen and Felson (1979) contributed to a paradigm shift in Criminology that altered the focus of research attempting to explain criminal activity, why it occurs and how can society minimize its occurrence. Specifically, Cohen and Felson (1979) argue that instead of focusing on individual-level variables to try and explain criminality (ex. attachment levels between parents and children), the focus should be placed on trends in the *social structure* of society that affect the likelihood of an offender intersecting with a victim in the absence of capable guardians. Also, caution was recommended against placing too much weight on studies attributing rising crime rates in the U.S. during the 1970's to a higher proportion of the offender population (males aged 18 to 25 years old) in society. Alternatively, Cohen and Felson suggest that the focus of explaining rising crime rates should be placed on the differential way in which society's routine activities have resulted in an increased convergence of both offenders and victims in the absence of a capable guardian (see Stahura and Hollinger, 1988).

Routine activities theory posits that criminals function in primarily noncriminal ways; offenders engage in routine day-to-day activities that take them outside of the home and into the public arena wherein they are exposed to potential targets (Felson and Cohen, 1980; Kennedy and Forde, 1990). Regarding direct predatory crimes such as robbery, it is held that "they must occur within the context of daily patterns of legitimate activities" (Felson and Cohen, 1980, p. 403). Of equal importance is the reality that the routine activities of noncriminal populations changed dramatically over the latter half of the twentieth century such that women were working outside of the home and people were working longer hours. Thus, residences became more vulnerable to burglary as they were left unguarded more often, and there was a greater proportion of time and locations in which a potential victim was exposed to criminally motivated persons (Felson and Cohen, 1980). Cohen and Felson (1979) found empirical support for this tenet in a statistically significant relationship between a household activity ratio (extent to which persons engage in routine activities inside the home) and official crime rates. That is, social patterns from 1947 to 1974 evidenced an increase in time spent *outside* the home and subsequently were strongly associated with an increase in the official U.S. crime rate. Felson and Cohen (1980) argue that an inverse relationship exists between the frequency of routine activities inside the home and the frequency of criminal victimization outside the home. Applying the theory to predatory crimes such as robbery and assaults, this tenet suggests that the *less* time spent engaging in routine activities inside the home, the *more* likely one is to experience criminal victimization outside of the home as routine activities are placed in a public context. Adjacent to this is the concept of a *crime occurrence space*. Brantingham and Brantingham (1984) explain that areas in which criminals, through either residential locations or routine activities, converge with low-risk targets are those that provide an opportunity for victimization. It is held that such areas "will be highly clustered and localized" (Brantingham and Brantingham, 1984, p. 365) as the potential for the intersection between offenders and victims in the absence of a capable guardian provides the grounds for the crime occurrence space (see Cromwell, Olson and Avery, 1991).

Crime Generators and Crime Attractors

The areas in which offenders and victims intersect often constitute crime clusters or hotspots (Brantingham and Brantingham, 1995; Block and Davis, 1996; Rhodes and Conly, 1991; Sherman, Gartin and Buerger, 1989). Routine activities theory attempts to explain this in its equation combining a motivated offender with a suitable target in the absence of a capable guardian; however, microspatial criminology also goes one step further in explaining *why* such interactions occur disproportionately in space. Areas that evidence clusters of criminal activity are differentiated into crime generators and crime attractors (Brantingham and Brantingham, 1984; 1995). A crime generator is an area in which large numbers of people congregate, not for criminal intentions per se, however it is argued that these areas provide conditions amenable to crime. Examples of a crime generator would be a sports facility hosting a large event, entertainment districts or major traffic arteries (see Brantingham and Brantingham, 1981b). It is argued that although a potential offender may not frequent a crime generator with criminal motivations, the large intersection of people and potential targets may lead to the exploitation of criminal opportunity (see Bennett, Merlo and Leiker, 1987). A crime attractor, on the other hand, is an area or district offenders know well and travel to with the intention to commit crime (Brantingham and Brantingham, 1995). These areas are “attractive” to criminals in that their characteristics allow for anonymity, low guardian presence, high level of alcohol or drugs and poor security measures or social control mechanisms (see Langworthy and Lebeau, 1992a). Examples of crime attractors are drug markets, transit stations or large shopping complexes.

Another example of this phenomenon is a study that looked at the frequency of both violent and property crimes in the city of Cleveland from 1979 to 1981 as a function of the characteristics of their locations (Roncek and Maier, 1991). Specifically, Roncek and Maier (1991) looked at the extent to which the presence of a bar or lounge was associated with criminal activity as measured per city block. The results supported the concept of crime attractors; the presence of a bar or lounge was associated with 2.3 more crimes per block per year than what would be expected by chance alone. It was hypothesized that an explanation for the results may be based on a routine activities framework in that such venues draw large crowds of people with high levels of anonymity and offender and victims interacting with little guardianship of any sort.

Crime generators and crime attractors can be further broken down and their specific criminogenic attributes identified. Research has shown that urban structure and the spatial layout of a city affect offender movement patterns and essentially where crime occurs (see White, 1990; Brantingham and Brantingham, 1993a 1993b; Block and Davis, 1996). When the urban layout of a city is analysed, three primary characteristics hold explanatory value toward the disproportionate spatial distribution of crime. First, it is held that offenders commit crimes close to the central locations that constitute routine activities (Brantingham and Brantingham, 1995). These are termed *nodes* or *activity nodes*; it is argued that nodal concentrations of crime include both offender residential areas but also crime attractor characteristics as previously discussed. Brantingham and Brantingham (1995) explain that the character of the *built* environment coupled with clustering of land uses and predictable temporal routines of daily life affect how both offender and victim movement is channelled and converged.

Additionally, *paths* are identified as salient within criminal movement patterns as they constitute the routes taken to and from work, school, shopping and/or entertainment (primary activity nodes). As such, paths provide a mechanism through which motivated offenders are exposed to potential victims/targets (Brantingham and Brantingham, 1993b) and thus where victimization occurs. Specifically, Brantingham and Brantingham (1993b) state that street networks and transit routes affect the distribution of crime. Crime has been shown to cluster around transit stations (Brantingham and Brantingham, 1991b), major intersections (Alston, 1994) and within neighbourhoods that are easily accessible through the road network (White, 1990). As nodes represent frequently visited locations within an offender's routine activities, the paths represent the frequented routes taken between activity nodes. Thus, commonly travelled paths are highly exposed and become part of the offender's movement patterns within crime site selection.

Lastly, the salience of *edges* is also discussed within microspatial theory (Brantingham and Brantingham 1984; 1993b; 1995). Edges are places where there is enough distinctiveness between one area and anther that a change is noticeable (Brantingham and Brantingham, 1993b). An example may be a major roadway that distinguishes residential land use from an industrial area. It is explained that edges experience high criminal activity, as it is easier to maintain anonymity there than it is within an area more perceptually homogenous. Additionally, areas close to edges formed by major roads are more likely to house businesses or apartment complexes, both of which bring large crowds of people coming into and out of the general vicinity (Brantingham and Brantingham, 1995). Brantingham and Brantingham (1975a) examined burglary rates in Tallahassee, Florida from all burglaries known to the Tallahassee police during 1970. The results supported the salience of spatial edges in crime occurrence. It was found that burglary rates differed significantly as a function of whether the street block was categorized as a border block (representing a perceptual edge) versus an interior block. Specifically, burglars favoured apartment suites that were situated on border blocks that were more heavily populated with large numbers of people commuting alongside the major traffic arteries that characterized such areas; the interior blocks which were more insulated from transient populations, experienced significantly lower rates of burglary (Brantingham and Brantingham, 1975a).

Crime Hotspots

In a discussion of hotspot generation, Brantingham and Brantingham (1999) explain how the non-random distribution of both offender residences and targets provide elements for crime clusters. Hotspots are defined as spatial concentrations of crime that either are visually recognizable to an observer through pictures/maps or are mathematically recognizable through statistical significance (Brantingham and Brantingham, 1999). It is explained that crime hotspots are the result of a confluence of predisposing environmental conditions, amongst which the residential and activity locations of offenders and the locations of vulnerable populations and targets holds significance. Particularly, concentrations of *criminal residences* pose a hotspot threat, as criminals tend to select targets close to their home locations or in close proximity to locations frequented in their routine activities (see Wiles and Costello, 2000). Additionally, it is explained that the spatial distribution of *targets* is not uniform in nature.

Differential land use and urban structures affect the distribution of victims/targets in space and time and this creates a backcloth in which targets cluster and may attract disproportionate amounts of crime (Brantingham and Brantingham, 1999; 1998). For example, in the case of auto theft, it is argued that areas where large shopping complexes are located attract potential offenders as the public congregates to shop with automobiles clustered in parking lots and parking decks. Another example may be found with prostitution. Prostitution is not uniformly distributed throughout a city; rather, it is spatially clustered in specific areas of an urban centre. Areas within or surrounding a city's downtown core are more susceptible to prostitution, arguably due to the large intersection of persons within an anonymous environment and the high presence of arterial roads making access to such areas easy. Brantingham and Brantingham (1999) argue that the environmental backcloth is a complex, ever changing set of structural and behavioural elements that collectively affect the non-random spatial distribution of crime, providing concrete explanations as to why hotspots of both offender residences and crime site locations exist in most urban landscapes (Brantingham and Brantingham, 1998; 1984; 1993b).

It is argued that the empirical salience of nodes, paths and edges in criminal activity is indicative of the bidirectional interaction between the physical and social environment and an offender's cognitive decision making process within crime selection. It may be argued that research showing clusters of crime activity around central nodes, frequented paths and distinctive edges, provide evidence toward the supposition that the environment emits cues and those are interpreted by an offender and used in target selection.

Pattern Theory

The last major Environmental Criminology theoretical perspective to be discussed is that of Pattern Theory (Brantingham and Brantingham, 1993a). Although some of the concepts within pattern theory have been discussed such as the environmental backcloth and the salience of urban spatial structure (nodes, paths and edges), this theory offers specific propositions toward explaining target selection and amalgamates many components of crime site selection theory and routine activities theory.

Pattern theory recognizes that the criminal event is highly *complex* and the result of a multi-staged decision making process whereby innumerable individual variation may exist. However, in tandem with that acknowledgement, is the understanding that crime occurs in a highly *patterned* context that is comprised of the offender's social, psychological, spatial and cultural history and surroundings (Brantingham and Brantingham, 1993a). It is argued that such factors underscore the commission of the criminal event in predictable ways and that the existence of the environmental backcloth and the fundamental role it collectively plays in the offender's decision making process *is* the pattern in and of itself (Brantingham and Brantingham, 1999). Specifically, it is held that the "likelihood of a criminal event transpiring depends on the backcloth, the site, the situation, and individual's criminal readiness, routine activity patterns, and the distribution of targets" (Brantingham and Brantingham, 1993a). Through an uninformed eye, the target selection process of a single offender may appear random in nature; perhaps the victims do not have comparable characteristics; perhaps the modus operandi was different. However, if the same seemingly random events are looked at from the perspective of Pattern Theory, then discernible continuities begin to appear. Through Pattern Theory, the Brantinghams address the evident patterns existing within a seemingly complex series of interactions between the offender and the victim.

For example, Pattern Theory holds that every person encompasses an awareness space (Brantingham and Brantingham, 1991a). This is described as the part of a city that one has knowledge of, functions within and feels a high level of familiarity. Within one's awareness space are the activity nodes, which constitute the frequented locations within one's routine activities such as work, school, a friend's house or a grocery store. Collectively, frequented activity nodes and the paths used to get between them form one's activity space (Brantingham and Brantingham, 1991a). It is argued that target selection will be centred within an offender's activity space, as this is the area he/she feels most comfortable and confident within (see Canter, Coffey, Huntley and Missen, 2000). Research has shown substantial support for this assumption. In fact, studies have shown that offenders prefer targets within their activity spaces over other, more desirable targets located in areas farther away (Rhodes and Conly, 1991).

Crime pattern theory holds that routine activities and the distribution of targets affect the journey to crime. Specifically, it is argued that within day-to-day routine activities, the crime template is formed wherein offenders interpret environmental cues (physical and social) that provide the basis from which suitable targets and crime sites are selected (Brantingham and Brantingham, 1993a). Most notable is the recognition that routine activities, activity spaces and crime templates may vary by individual offenders, however, it is reiterated that at an aggregate level, patterns exist for different categories of offenders and specific crime types. Thus, despite the fact that offender A has his/her own activity space and crime templates that may differ from offender B, the emphasis lies in the fact that, at an aggregate level, patterns will exist "for different *categories* of people and specific *types* of crime" (Brantingham and Brantingham, 1993a, p. 270).

Lastly, Pattern Theory suggests that it is the *interaction* of the event process, sufficient triggers and a level of readiness that leads to the criminal event (Brantingham and Brantingham, 1993a). Similar to routine activities theory, Pattern Theory holds that it is the *combination* of the specified factors that explains the criminal event as none alone encompasses as much explanatory capability as the elements combined. This makes intuitive sense. For example, a trigger may be present; however, without a level of readiness, the offender is unlikely to act. It may be the case that a motivated offender wants to steal a car to get home across town (sufficient trigger); however, in the presence of patrol officers, he is unlikely to experience a state of readiness. Thus, crime pattern theory holds that patterns in crime are explained when the target selection process is viewed as a function of the routine activities of both offenders and victims coupled with an "opportunity backcloth" that engenders differential motivations, levels of readiness and triggers depending on the crime type (Brantingham and Brantingham, 1993a).

Application of Microspatial Criminology

It is argued that the theoretical tenets of microspatial criminology offer numerous applied functions with respect to urban planning, crime prevention and to serial crime investigation within law enforcement. This area of research also offers insight into offender movement patterns, at both aggregate and disaggregate levels.

In the last few decades, microspatial criminology research has been furthered within the field of 'crime and place' (Sherman, Gartin and Buerger, 1989). Brantingham and Brantingham (1975b; 1991a; 1998) discuss how crime and place research can influence urban planning with the goal of crime prevention. In that "urban planning and architecture help shape the physical and social surrounds that create the backcloth for crimes" (Brantingham and Brantingham, 1998, p. 31). It is explained that city planners should consult environmental criminologists to understand how the urban layout affects criminal motivation and opportunity. The application of microspatial criminology, for example, to urban planning practice is illustrative of the applied utility of this subset of Criminology toward understanding and concomitantly reducing aggregate criminal activity. For example, it is held that urban planners pay close attention to the development and location of mass transit systems as research has shown that these structures attract large crowds of people where offenders and potential victims intersect and the potential for predatory crime may occur (Block and Davis, 1986). In addition, careful consideration toward the development of entertainment zones should be noted as research supports the tenet that such venues act as crime attractors (Roncek and Maier, 1991). The presence of high alcohol use, young persons, large crowds and the context of leisure activity combine and create a context that generates high crime risk (Brantingham and Brantingham, 1998).

Additionally, crime and place research has led to specific suggestions with respect to *preventing* criminal activity. For example, through the development of situational crime prevention, tactical strategies have been developed such as *hardening targets* by putting up physical barriers (ex. locks), *controlling access to facilities* to ensure that those who should not be in places such as private apartment buildings are kept out, and *deflecting offenders* or potentially dangerous situations (Clarke and Eck, 2006). In tandem with increasing the effort toward committing crime is decreasing the potential rewards perceived by the offender, thus reducing the extent to which a situation is perceived as opportunistic. Thus, crime and place research has proven to be particularly applied in nature with direct utility towards crime prevention efforts in urban centres. Additionally, from an Environmental Criminology standpoint, this area of research has substantiated many of the fundamental theoretical tenets from Crime Pattern Theory and Routine Activities Theory (Brantingham and Brantingham, 1993a; Felson and Cohen, 1980).

The next section will outline seminal research in the field of Environmental Criminology, with particular focus on the spatial analyses conducted at varying levels of resolution to examine ‘crime and place’. The advantage of examining criminal activity at the street block level is emphasized and recent research utilizing this unit of analysis will be reviewed.

Chapter Two: Literature Review

Introduction

For many decades, traditional Criminological study focussed on understanding the development of criminality (Blumstein and Cohen, 1979; Gottfredson and Gottfredson, 1992; Laub and Sampson, 2003). As such, research was primarily dedicated to unravelling the factors leading to criminal behaviour and deviance towards "offender centred crime prevention" (Weisburd, Groff and Yang, 2011). Attempting to explain and predict criminality from a behavioural perspective has proved to be exceedingly difficult, which led to a renewed focus on the 'criminology of place' (Sherman, Gartin and Buerger, 1989; Brantingham and Brantingham, 1990). Within this subset of Criminology, the primary tenet is that criminals do not exist in a vacuum; rather, for the vast majority of the time they function as noncriminals and exhibit patterned behaviours in terms of the spatial and temporal aspects of offending (Brantingham and Brantingham, 1984).

This chapter will provide an overview of the literature in the field of Environmental Criminology, from the early, innovative focus on crime locations, to the varying levels of spatial resolutions that have marked much of the research in this field. The limitations of such research will be discussed, leading to the argument that the more recent focus on the street block as a unit of analysis within Environmental Criminology study is highly advantageous.

The Beginnings of Crime and Place

Very early research recognized that criminal activity is unlikely to be uniformly located throughout a geographic region. One of the earliest pieces of work on the ecology of crime was published by Adolphe Quetelet (1842) in the seminal work titled, 'A Treatise on Man and the Development of His Faculties'. In this book, Quetelet dedicates a chapter to examining crime patterns throughout France and Belgium and in doing so discusses the impact that age, education, region, profession, seasons and gender have on both property and violent crimes as well as on the proportion of those condemned (i.e. found guilty and sentenced). Using government records from 1825 – 1830, summary statistics are presented and discussed that provide a snapshot of criminal activity throughout both countries. Most interesting though is Quetelet's spatial analysis of crime patterns. Quetelet (1842) meticulously examines crime volumes for each city and overall region throughout France. Accompanying these statistics are colour coded maps displaying the higher crime cities as darker in colour. For example, the greatest number of crimes was located in the city of Corsica and the areas showing greatest crime concentrations were located closest to the Rhone, Rhine and Seine rivers. Quetelet (1842) attempted to explain certain regional patterns observed. For example, expounding upon the area of Corsica that had the highest number of homicides, it is explained that the people of this region 'warmly embrace revenge', potentially explaining the higher number of violent crimes. Interestingly, the same area did not see a substantial amount of property crime. Even such early and rudimentary analysis showed that crime patterns are non-uniform in nature, complex and deserving of further assessment.

Examining the locations of offender residences, Glyde (1856) found significant regional variation throughout the county of Suffolk, England. Looking at official prisoner records from 1851-1863, Glyde analyzed the number of prisoners originating from towns and villages to assess whether either area harboured a greater propensity towards overall criminality and if so, whether such patterns exhibited additional patterns by crime type. Calculating the proportion of criminals per population, significant geographical variation was found in two main ways. First, Glyde (1856) found a greater proportion of criminals residing in unions (i.e. villages) versus towns. For example, taking a sample of 15 towns and villages, it was found that towns housed an average of 1 offender in 593 persons whereas villages housed an average of 1 offender in 317 persons. However, Glyde (1856) cautions that these patterns must be viewed with caution in that each town or union cannot be assumed equally favourable or unfavourable. This understanding illustrated a progressive perspective on the spatial nature of criminal activity. It has since been widely established that crime is not uniformly distributed, but rather is non-uniform in nature from a spatial perspective (see Brantingham and Brantingham, 1984). Despite the fact that Glyde's analysis was based on offender residences and not criminal activity, the concept of a non-uniform spatial distribution and the word of caution towards areal level conclusions is applicable and poignant. Further, Glyde (1856) assessed whether the villages were also the locations from which the most serious offenders arose. The analysis revealed that villages were the areas that most criminals resided and they also housed offenders of the most serious crime types such as arson, murder and rape.

Building on the work of Burgess (1916) which examined the delinquent propensities of juveniles based on where they lived, and Burgess' (1925a) seminal zonal model of a city, Shaw (1929) and Shaw and McKay (1931, 1942 and 1969) stimulated an ecological focus on the study of crime through their work conducted at the Illinois Institute for Juvenile Research in Chicago. Shaw and McKay published a series of studies between 1925 and 1969 that analyzed the social and ecological indicators inherent to areas inhabited by juvenile offenders throughout Chicago as well as other American cities. From this large body of work, social disorganization theory was largely borne and formed the basis of the sociological study of crime for subsequent decades.

Using census tract areas and square mile area maps, Shaw and McKay (1969) mapped the residential location of juvenile delinquents based on the following sources of data: boys brought before juvenile court (1900-1906; 1917-1923), boys brought before the Boys' Court of Chicago on felony charges (1924-1926), girls brought before juvenile court (1917-1923), truants brought before juvenile court (1917-1927) and adult offenders placed in the county jail (1920). Once again, using Burgess' (1916) zonal model as the basis for the structure of their analysis, Shaw and McKay revealed ground breaking patterns on the social ecology of crime. First, it was shown that all three dependent variables of delinquency rates, truancy rates and adult crime rates were greatest within the city's central business district and steadily decreased as the distance increased outwards from the city core. Areas on the periphery of Chicago (i.e. farthest away from the city centre) had the lowest rates. Interestingly, recidivism rates also showed similar patterns with declines noticeable as the distance increased from the city centre of Chicago. Second, once Shaw and McKay (1969) partitioned Chicago into census tracts, they found similar delinquency residence rates amongst areas within the same larger areal unit. Third, central to Burgess' (1916) zonal model, it was found that anomalous rates of delinquency residence were linked to either unusual geography or cultural/social developments that affected criminal patterns. Lastly, it was found that as areas of Chicago developed over time resulting in changes such as transitions from residential to industrial land use or changes in the cultural/social make-up of an area, that the delinquency residence rates also changed.

Attempting to explain these patterns proved more difficult than identifying them. Keeping in mind the importance of ecological fallacies within spatial research (see Robinson, 1950), Shaw and McKay (1969) were careful to not inappropriately apply conclusions towards individual delinquency based on areal findings. For example, it was found that areas with high delinquency rates also evidenced high rates of families on economic relief (i.e. welfare). However, Shaw and McKay (1969) explain that one cannot conclude that having families on welfare *causes* juvenile delinquency in a neighbourhood. There may be other extraneous factors explaining the relationship between these variables, or it may be that the relationship solely exists in a statistical sense and is illusory in explaining the real life phenomena of crime and place.

In a seminal study, Brantingham, Dyreson and Brantingham (1976) conducted research that illustrated the considerable variation in crime patterns as a function of the spatial unit of analysis chosen by the researcher. Using 1971 FBI Uniform Crime Report data, Brantingham et al. (1976) summarized the spatial results of murder and burglary patterns at five different levels of spatial resolution: national, state, city, block group level within two census tracts, and street level within one census tract. The study used the same data, yet showed how the interpretation of criminal activity can vary depending on level of analysis one uses. For example, at the U.S. national level, the maps showed that murder rates were highest in the Southern regions whereas the burglary rates were shown to be highest in the South-western part of the country. Although interesting, it is stressed that such results required a closer look at demographic and/or migration pattern data to begin to explain the patterns observed. When the same data were viewed at the census tract level in the city of Tallahassee, Florida, the results showed a bi-nodal distribution for burglary throughout the city demonstrating that criminal activity varied considerably more when viewed at a micro level. Brantingham et al. (1976) caution against researchers asserting individual level conclusions about offence patterns based on aggregate results. This is known as the ecological fallacy (Robinson, 1950)), and will be discussed further in a later section.

Area Level Research

Environmental Criminology studies mostly dichotomize the spatial analysis of criminal activity into macro level, such as census tracts or inter-state/provincial units) (see Andresen, 2008, 2009a) versus the most micro level of analysis, the address or point level (see Sherman, Gartin and Buerger, 1989). This section will summarize several of these studies to illustrate the strengths and weakness of both levels of analyses and provides the basis for advocating the utility of the street block as the optimal compromise between macro and micro resolutions within criminological research.

Focussing on census tracts, Browning, Byron, Calder, Krivo, Kwan, Lee and Peterson (2010) examined how mixed land use affects patterns of violence in communities. Specifically the research assessed the social control implications of mixed land use between commercial and residential density and violent crime in urban neighbourhoods, with respect to homicide, aggravated assault and robbery. The study was conducted in Columbus, Ohio and the crime data originated from the National

Neighbourhood Crime Study, that included reported crime counts from the Columbus Police, and sociodemographic data for the 184 census tracts analysed. Regarding homicide and aggravated assault, Browning et al. (2010) found that at low levels, increases in mixed land use were associated with increases in these types of crime. However, this occurred only to a certain point; after an observed threshold level, any level of mixed land use did not linearly affect these violent crime rates. In fact, it led to declines, albeit at insignificant amounts. A linear association was found regarding incidents of robbery though. The greater the presence of mixed land uses at the census tract level, the greater the occurrence of reported robberies. Browning et al. (2010) emphasize that “mixed land use is criminogenic with respect to the prevalence of robbery” (p.348). The research shed light on how changes in land use affect the social ecology of neighbourhoods at the census tract level. It may be argued though, that such results should be viewed with caution as it may be spurious to conclude that changes in the violent crime rates associated with variation in land use is not uniform across the entire neighbourhood; rather, that certain pockets within the larger area observed evidence significant changes in crime while others remain unphased. Browning et al. (2010) allude to the importance of conducting this type of research using a more micro unit of analysis by emphasizing that the actual social ecology of urban *streets* has been largely neglected in Criminology research and may uncover more detailed relationships between land use changes and crime patterns throughout a city.

Tita and Ridgeway (2007) explored the impact of gang activity on aggregate crime patterns at the neighbourhood level. The neighbourhood was defined as census block groups and calls-for-service data were analysed for criminal activity levels. Prior research had identified that gang membership led to increased offending at the individual level; this study sought to examine whether those identified patterns at the individual level translate into more crime at the city level overall. At the citywide level, the results showed that drug crimes and shots fired did not significantly increase for the years observed (1990-1995). However, Tita and Ridgeway (2007) accurately note that these results may mask the fact that gangs may have adversely affected smaller parts of neighbourhoods where youth gang membership was particularly high. This underscores the importance of examining crime trends at micro places, such as the street block level, in order to effectively observe spatial variations.

Many other studies have used aggregate spatial units to examine crime trends. Andresen (2007) measured criminal activity at the census tract level to assess the utility of applying the location quotient statistic for crime analysis (see also Thompson, Curman, Winterdyk and McLean, 2006). The location quotient measures the percentage of some activity in a spatial unit relative to the percentage of that same activity in the entire study area (Andresen, 2007). When assessing levels of automotive theft, break and enter and violent crime for the city of Vancouver in 1996, it was found that the location quotient was an effective measure to augment the use of crime counts and crime rates. The spatial distribution and saturation level of these crime types was presented at the census tract level primarily to accommodate 1996 census data for the analysis of sociodemographic and socioeconomic variables. Andresen (2007) stresses the utility of the location quotient for analysing criminal activity in that it captures the characteristics that may generate crime and forces the researcher to ask detailed questions linking theory and observable crime patterns at the aggregate level.

Andresen (2006) also analysed census tracts in Vancouver to conduct a comparative analysis of different crime measures. Specifically, crime counts and crime rates calculated with residential and ambient populations were used to assess the prevalence and spatial distribution of automotive theft, break and enter and violent crime throughout Vancouver, B.C. for 1996. Both the statistical and spatial results between the different crime measures are compared for all three crime types with the spatial results being presented at the census tract level. Interestingly, Andresen (2006) found that statistically, the three different crime measures presented very different findings for each crime type, however, spatially, at the census tract level; all three measures were highly comparable. Andresen (2006b) also used census tracts to analyse the spatial autocorrelation between crime rates and socioeconomic characteristics. The spatial results showed a concentration of automotive theft, break and enter and violent crime rates within Vancouver's downtown eastside. The analysis clearly shows that the downtown area harbours both social disorganization and routine activity theoretical characteristics that engender hotspots of criminal activity, at the aggregate level.

At an even higher level within the cone of resolution, Andresen (2009a) examined eleven different property and violent crimes across all Canadian provinces and territories. Andresen (2009) compared both crime rates and location quotients to test the commonly held assumption that crime activity increases as one moves westward across the country. When using the traditional crime rate, the results did show that crime does increase on average moving westward with the western provinces evidencing crime rates above the Canadian average. Interestingly, when implementing the location quotient calculation, significant variation is shown provincially. For example, both western and maritime provinces were found to be high in violent crime activity, and no particular geographic trend was found for property crimes.

Units of analysis such as the census tract are termed polygon data (Paulsen and Robinson, 2004). As described above, this research has shown to be incredibly insightful within the field of Criminology and spatial analysis. However, there exist methodological limitations with this level of resolution that cannot be overlooked. The following section will discuss these and highlight the key issues inherent to applying polygon level analyses to real-world conclusions within Criminology.

Polygon Data

The unit of analysis in polygon data is an *area* comprised of multiple points as opposed to a single location with point data. Regarding crime data, polygons usually represent aggregate counts of crime that take place in larger areas such as police districts, municipalities or census tracts (Paulsen and Robinson, 2004). As such, polygon data provides the analyst with the opportunity to standardize a spatial dataset and create rates of crime counts per areal unit selected (ex. census tract, police beat or thematic grid). Polygon data is useful in that the magnitude of identified hotspots can be established as well as substantive crime issues. Most GIS programs have functions that will merge data from one polygon source (ex. census data) with another polygon source (ex. police beats) such that cross-boundary comparisons can be made (Paulsen and Robinson, 2004). Advantages such as these do underscore the practical utility of polygon data in the field of applied Criminology. It allows for the specification of aggregate crime clusters and verification of their existence and magnitude. With respect to spatial analysis for law enforcement, polygon data can inform police departments of regional crime variation, which areas have higher or lower incidence of property or violent crime, whether crime has increased, decreased or displaced over time and what the underlying causes of criminal incident variation may be (see Hirschfield and Bowers, 2001; Leipnik and Albert, 2003; Vann and Garson, 2003; Thurman and Jihong, 2004).

Although polygon level data can generate sophisticated spatial statistical analyses, there exist significant methodological issues of which a researcher must be cognizant. The first concerns how the *boundaries* are drawn for the geographic units used in aggregate counts. When point data are aggregated into polygons, clusters may be broken into separate units and reduce the validity of the spatial representation of crime events. Many sources of spatial aggregation such as census tracts or police beats are drawn with major city streets forming the edge that discriminates between one aggregate unit to another. The distribution of crime events often clusters along such major roadways and may be split into two different cells of an aggregated map (Paulsen and Robinson, 2004). This is termed the 'modifiable areal unit boundary problem' or MAUP (Fotheringham, Brundson and Charlton, 2000).

A second problem associated with polygon data is that the boundaries drawn for aggregation remain unchanged despite the growth and change of the city in which they are drawn (Paulsen and Robinson, 2004). For example, population size may render an enumeration area to be considered a census tract or the land use of an area may change and affect the extent to which the neighbourhood is considered residential or commercial. Aggregate spatial units are rarely revised and may render the boundary lines invalid when analyzing the spatial distribution of criminal activity. For the purposes of Canada's national census, larger census areas may be partitioned into two smaller tracts as population rises. For comparability purposes from one year to the next though, the aggregate boundaries of such smaller tracts, when put together, will mirror the boundaries of the original larger census tract.

Most importantly, the use of polygon data must never be applied toward explicating variation at an individual level. This reflects the “ecological fallacy” which refers to inappropriately applying conclusions drawn from one level of analysis to those of a different level of analysis (Robinson, 1950; Brantingham and Brantingham, 1984). Caution must be exercised by analysts not to take aggregate level conclusions and use them to explain individual level variation in the criminal behaviour of offenders, victims, or any individual unit of analysis (Chainey and Ratcliffe, 2005). For example, if census tract analysis reveals that an *area* with a high unemployment rate evidences a high crime rate, one cannot then conclude that the unemployed persons in that area are committing the crimes, or even that unemployment “causes” crime to increase. The aggregate spatial relationship between high unemployment in an area, such as a census tract, and a high crime rate does not offer answers as to whether such variables are explanatory toward one another; it simply indicates that they coexist, not that they co-vary in a statistical sense.

Address Level Research and Point Data

As Criminologists gained access to police data showing the origins of calls-for-service or incident reports, point pattern analyses became widely used (see Pyle, 1976). Termed ‘point data’, it represents a specific location, x/y coordinate or object in space. The advantage of using point data in spatial analysis is that it provides a visually simplistic way to identify spatial clusters of criminal events (Paulsen and Robinson, 2004). More importantly, point data are overlaid across an entire study area and are not segregated into aggregate spatial units as with polygon data.

In a seminal study, Sherman, Gartin and Buerger (1989) examined the point locations from which all calls to police were made in Minneapolis during 1986 (n= 323,979). The study focused on calls for sexual misconduct, robbery and auto theft. The research found that over 50% of all the calls to the Minneapolis Police Department were made to only 3% of all possible addresses in the city. In fact, all the calls concerning robbery were made from just 2% of addresses, auto theft calls were made from 3% of addresses and even more dramatic, all sexual misconduct calls were made from only 1% of all addresses throughout the city. Following this research, Roncek and Maier (1991) sought to understand the characteristics of such high crime locations. Using police data for the city of Cleveland, the research analyzed the average frequency of six crimes in comparison to the total number of bars/cocktail lounges on each city block (see also Langworthy and LeBeau 1992a; 1992b). A positive correlation was evidenced in that the presence of either a bar or lounge was associated with an increased probability of crime occurring. Roncek and Maier (1991) specifically focused on murder, rape, robbery, aggravated assault, grand theft and auto theft. They found that having a bar or lounge on a city block was strongly correlated with criminal activity. Specifically, the presence of a bar or lounge was associated with an increase in crime volume by 2.3 per year, which was statistically significant. Roncek and Maier (1991) reiterated that these results may be explained through Routine Activities Theory in that such businesses draw large crowds, providing levels of anonymity for patrons who are given the opportunity to come across victims. The study provided a detailed look at what types of establishments may be labelled as ‘crime generators’ or hotspots and also seemed to support the routine activities framework in explaining why such locations are responsible for a disproportionate amount of crime.

Johnson and Bowers (2004) examined address level data to explore whether spatial patterns exist for repeat burglaries. The research revealed that homes located within 300-400 meters of a burgled home are at increased risk of victimization within a period of 1-2 months. Follow-up research based on data from the Merseyside Police from 1995-2001 provided additional detail on address level repeat burglary victimizations that had direct implications for police policy (Bowers and Johnson, 2005). Specifically, it was found that homes in lower-income areas were more likely to be repeatedly burgled overall, but homes in more affluent areas showed a stronger space-time link in terms of risk of being burgled following the initial event in the area, particularly within a one-week period. Additionally, homes that were on the same side of the street and had similar layouts to the one initially burgled faced the greatest overall risk of victimization. Short, D'Orsogna, Brantingham and Tita (2009) also used address level data from Long Beach, CA for the years 2000-2005 to determine probability distribution functions for the time interval between repeat burglary offences. The research resulted in the ability to estimate time scales for repeat burglary events in Long Beach, whereby computer simulations confirmed the validity of the statistical model created. These studies represent applied research using point level data that has direct application to policing strategies.

It is evident though, from point pattern analyses that criminal activity, when observed at a microspatial level is patterned and predictable. This is even more pronounced when looking at another micro level of analysis in Environmental Criminology: offender target selection patterns within the journey-to-crime literature. This research focuses on the target selection processes of offenders and explores the distances travelled from both their residential location and other commonly visited activity nodes to commit crimes. In particular, many studies show that offenders select targets in close proximity to their primary residence and other regularly frequented locations. Termed 'distance decay', the phenomenon documents that the rate of criminal activity for a given offender declines with distance from the home location (Brantingham and Brantingham, 1984). This phenomenon will be discussed below.

Offenders committing robbery and burglary, for example, evidence spatial patterns predicted by crime pattern theory (Capone and Nichols, 1976; van Koppen and Jansen, 1998; Laukkanen and Santtila, 2006; Wiles and Costello, 2000; Kocsis, Cooksey, Irwin and Allen, 2002; Curman, 2004). Capone and Nichols (1976) assessed the relationship between urban structure and criminal mobility. Using data from 825 robbery trips (representing 642 cleared robberies) throughout Miami, Florida during 1971, the distance between the offender's residence and the crime location was statistically analyzed. Capone and Nichols (1976) found the trip distance robbers took was a function of the spatial distribution of the opportunity offered by the targets and its level of attractiveness (in particular with respect to maximizing anonymity within the commission of the crime). Specifically, they found that the trip frequency declined with increased distance from the offender's home location, with 33% of all robberies occurring within a 1-mile radius from the robber's residence. There was a large difference found in trip distance taken depending on the target type. Robbers targeting open premises, such as parking lots, travelled smaller distances from home to commit their offences, compared to robbers targeting fixed premises, such as businesses (Capone and Nichols, 1976). Additionally, if a fixed premise offered greater attractiveness with respect to maintaining anonymity, the robber was willing to travel an even greater distance to access this target compared to a similar type that was closer in range to their home base.

van Koppen and Jansen (1998) analyzed the distances travelled to *commercial robbery* sites from the offender's home location. The commercial targets included banks, shops, post offices, and petrol stations. Using data from all convicted robbers in 1992 (n = 434 robberies committed by n = 585 robbers) in the Netherlands, two microspatial hypotheses were tested. van Koppen and Jansen (1998) tested the extent to which planning and experience affected distances travelled to crime sites. Specifically, it was hypothesized that more professional robbers, as a group, would commit robberies further away than less professional robbers would as they might feel more confident and travel distances to access particularly lucrative commercial targets. It was also hypothesized that serial robbers would travel further with every next robbery committed. The results did not support either hypothesis. The sample travelled a median distance of 3.5 km from home to commit the commercial robberies. When looking at the level of preparedness toward criminal activity, 'prepared' robbers did not travel farther than their more impetuous counterparts. Specifically, 12% of robbers categorized as making special preparations (n = 274) toward their robberies travelled less than 2 km from home to their targets and 11% of those categorized as making no preparations (n = 242) at all evidenced the same spatial pattern (van Koppen and Jansen, 1998). Both groups chose the majority of their crimes sites within 6 km or less from home and the most prepared group did not travel significantly farther than the robbers who did not prepare for their crimes beforehand. For example, only 4% of the robbers making special arrangements for their crimes travelled more than 60 km (the greatest distance interval) and only 5% of robbers who made no particular preparations travelled as far.

Moreover, when looking at the serial robbers, van Koppen and Jansen (1998) did not find evidence that experience committing robberies would equate to greater distances travelled. Out of 127 serial robbers examined in the study, 15% travelled the same distance as their previous robbery and 42% actually travelled closer to their home location than they did in their prior robberies. In assessing the journey to crime for commercial robbers in the Greater Helsinki area, Laukkanen and Santtila (2006) found comparable results. Using data from the Finnish police containing all robberies from 1991 to 2002, 76 robbery series were examined, totalling 213 journey to crime assessments. The results also evidenced a distance decay pattern; half of the journeys were less than 3.53 km from the robber's home location.

Burglars also evidence travel patterns surrounding their home locations (Wiles and Costello, 2000; Kocsis, Cooksey, Irwin and Allen, 2002). Wiles and Costello (2000) assessed burglar journey to crime patterns in an urban centre (Sheffield) and a suburban area (North Yorkshire). Using data from the Home Office, crime site locations in Sheffield (*n* =3314) and North Yorkshire (*n* =279) from 1966 to 1996 were recorded and concomitant burglar residence locations were documented at the time of offense. The results indicated that burglars from both areas did not travel far from home when selecting targets. Specifically, the majority of burglars in Sheffield selected targets less than one mile (1.6 km) from their homes (41%) and all together 78% travelled approximately 3 miles (4.8 km) or less. There was a small indication that distances travelled to commit crime increased from 1966 to 1996, however, "the consistent finding is that such journeys are still typically short" (Wiles and Costello, 2000, p.1).

Comparably, burglars in the suburban area of North Yorkshire travelled a mean distance of only 0.98 miles (1.57 km) when committing their crimes. Burglars in both urban and more remote areas evidenced a strong proclivity to remain close to home, lending significant strength to the distance decay phenomenon and the salience of an activity space in the target selection process. Interestingly, Wiles and Costello (2000) were able to corroborate police data with interviews with 70 convicted burglars in the Sheffield area. Upon inquiring about the distances travelled in target selection, it was discovered that the results were actually overestimates. The police data were based on the recorded home address of the offender and assumed that target selection ensued from this activity node. The interviews revealed that often, the burglars committed their crimes from other activity nodes such as a girlfriend's house that was actually *closer* to the crime site than their own residence. These results indicated that the average distance travelled for the Sheffield burglars was only 1.6 miles (2.5 km).

Curman (2004) analyzed the target selection patterns of both single-time and serial arsonists in British Columbia, Canada. The sample included 46 single-time arsonists charged with 32 arsons and 7 serial offenders charged with 69 arsons. The study focused on the distances travelled from home to set fires and whether a distinct spatial difference was evident between the two groups. The average distance travelled from home to set fires for the sample as a whole was only 2.17km. When examining the microspatial offense patterns of either group as a distinct entity, the single-time arsonists seems to travel greater distances to commit crimes compared to the serial offenders. Specifically, the single-time arsonists travelled 3.38km on average from home to set fires compared to only 1.49km for serial arsonists. It was hypothesized that the single-time offences may have represented more purposive acts necessitating the movement to a specific location outside of the offender's immediate surroundings. The serial arsonists may have been more likely to exhibit crimes of opportunity or emotion and evidenced spatial patterns concomitant to one's routine activities.

Similarly, in looking at the distances travelled to arson sites from the offender's home base, Canter and Fritzon (1998) found that 60% of arsons, as an aggregate group, occurred less than 1 mile (1.6 km) from the residential location. In addition, the study found a significant association between the category of expressive object arsons and being a *repeat* arsonist. As the sample included both single-time and serial arsonists, the analysis revealed that serial arsonists were most strongly associated with arson behaviour that was emotionally based with a non-specific trigger wherein the fire setting behaviour may be the manifestation of a behavioural pathology (Canter and Fritzon, 1998). Sapp, Huff, Gary, Icove, and Horbert (1998) also identified *arsonists* whose journey to crime patterns favoured the home base. In a study conducted by the National Centre for the Analysis of Violent Crime, 83 convicted serial arsonists throughout the

U.S., representing a total of 2,611 arsons were interviewed and their case files analyzed. Sapp et al. (1998) found motivations such as revenge (64%), excitement (26.5%) and emotional pathology (23%). The spatial analyses revealed evidence congruent to other journey to crime research and support for the salience of an activity space in target selection. Specifically, Sapp et al. (1998) reported that the 50% of serial arsonists travelled 1 mile (1.6 km) or less to set fires with 29.7% traveling ½ to 1 mile (0.8 to 1.6 km). Another 20.3% travelled 1 to 2 miles (1.6-3.2 km) from home to set their fires, however, only 2.7% of the cases involved target selection within one block of the offender's residence. Additionally, this percentage increased substantially from the 2-5 block distance with 12.2% of the arsons occurring in that distance interval. These data lend strength toward the existence of a buffer zone around the arsonist's residence in target selection (see Rossmo, 1995 and Brantingham and Brantingham, 1981a).

Point data provide a useful starting point within exploratory data analysis (Fotheringham et al., 2000; Murray, McGuffog, Western and Mullins, 2001). Point pattern maps allow the researcher to identify geographic patterns such as point clusters, spatial outliers and temporally based spatial trends. However, the simplistic ease with which point pattern maps are deciphered also provides the basis for their limitations methodologically. Paulsen and Robinson (2004) point out that point patterns of crime distributions make it difficult to accurately infer correlations of any explanatory value. Specifically, as point data are not aggregated, they are not standardized in any way. The crime count in a point pattern dataset is rudimentary and has not been standardized into a rate, percentage or proportion as a function of aggregated units such as census tracts. Therefore, analysts must be careful not to violate statistical assumptions when drawing conclusions from point data. One cannot compare a group of point locations of criminal events to an aggregate figure such as unemployment rates; "without standardizing point data, these types of analysis are at best only guesses about the relationships between incidents locations and aggregate data" (Paulsen and Robinson, 2004, p.213).

The aforementioned advantage of point data being easy to visualize and interpret must be qualified further. Analysts must be careful when examining point pattern maps with large volumes of data as clusters can easily appear when more than one point is located at the same location. Points may begin to ‘mesh’ together and appear as if the location/area is experiencing a disproportionate amount of crime, however, due to the fact that the data are not standardized, there is no statistical way to estimate whether or not the location constitutes a valid hotspot (Chainey and Ratcliffe, 2005). Paulsen and Robinson (2004) reiterate that point pattern maps may be able to identify potential hotspots; however, the estimation of magnitude is impossible at this level of analysis. Without knowing the underlying population data of an area, or its overall crime count, it is impossible to determine whether the perceived cluster of crime points are in fact indicative of a statistically significant hotspot (Chainey and Ratcliffe, 2005). For example, a point data distribution may show 10 sexual assault locations in 2 different parts of a city. Both areas of the city are evidencing spatial clusters of violent crime, however, if one area has a population that is 3 times as large as the other, the latter would evidence a much higher magnitude due its substantially smaller population. Thus, point patterns are useful for identifying *potential* hotspots but not for gauging magnitude of any sort.

Another logistical issue that challenges the efficacy of point data is the tenuous process of geocoding. Geocoding is “the process of taking specific street addresses of crime incidents and matching them to a reference file containing a range of addresses for a given area such as a city” (Paulsen and Robinson, p.213). In many cases the street addresses noted by police while on shift are not exact matches to the reference file on a base-map of the city in question. This is due to spelling errors of addresses or “guesstimates” noted by patrol officers (Leipnik and Albert, 2003). Additionally, police may confuse street names and cause difficulty in later GIS processes when the difference between an accurate match and a faulty one lies in the abbreviation “South” versus “North” and the two are perceived as interchangeable. It is also the case that crime does not always occur in areas that have an address attached to them (ex. in a parking lot). Many crimes occur at intersections. In such circumstances, the police officer must still note the ‘location’ of the crime. The extent to which an address has correctly geocoded onto a base map is reflected in the “hit rate” which is likely to be far less than 100% initially (Leipnik and Albert, 2003). What constitutes a minimum acceptable hit rate continues to be discussed in literature (see Ratcliffe, 2004); however, such decisions are at the discretion of the crime analyst or researcher.

Street Blocks

Due to the limitations of the spatial units discussed above, the street block has recently been recognized as an optimal compromise within crime and place research (Weisburd, Bushway, Lum and Yang, 2004; Weisburd, Groff and Yang, 2011; Groff, Weisburd and Yang, 2010; Braga, Hureau and Papchristos, 2011; Bernasco and Block, 2010). The street block is advantageous within microspatial criminology as it is small enough to see important spatial variations, but large enough to avoid the geocoding errors inherent to point analyses.

Criminologists have recognized the limitations of using larger areal units to examine crime and place and recent research has welcomed the application of street blocks to circumvent many of the limitations discussed above. Research observing criminal activity at the block level is consistent with environmental criminology theory in that crime clusters, and is stable and holds particular use for crime prevention initiatives and police enforcement strategy. This is especially important when research attempts to bridge the gap between academia and practitioners and offer practical solutions to the enforcement community on crime prevention or for government and other stakeholders engaged in urban planning. In particular, over the past decade, Criminologists have documented the utility of tracking crime volume on street blocks (Weisburd, Bushway, Lum and Yan, 2004; Weisburd, Groff and Yang, 2011). The examination of criminal activity at the block level is proving to be advantageous over smaller (ex. addresses) and larger (ex. census tracts) units of analysis. Focusing on a buildings or point locations such as addresses may evidence 'hot spots' within a city area, however, this analysis does not provide police or urban planners with practical conclusions for crime prevention- one cannot solely focus on a singular location for policy decisions. Conversely, focusing on larger aggregate units such as census tracts can lead to erroneous conclusions about crime volume in a larger geographic area, such as labelling a district as ‘bad’ versus a ‘good’ area to live, masking considerable variation in criminal activity within that region. Weisburd, Groff and Yang (2010) stress the accuracy of the street block in assessing crime volumes as well as the benefit that the street block is a “social unit that has been recognized as important in the rhythms of everyday living in cities” (p. 27). The street block is also large enough to avoid coding errors inherent in geocoding processes, but not as large as to lead to ecological fallacy conclusions.

In tandem to analysing the crime concentrations of street blocks is the issue of the stability of the identified concentrations. The geographic concentration of crime has been well documented; however, the stability of those concentrations has not. Examining the stability of criminal activity in time and place is key to underscoring the central tenets of many theories within the field and supporting crime prevention efforts and their accompanying solutions such as problem-oriented policing (see Goldstein, 1990). Do high crime areas remain so over time? If so, stakeholders involved in crime prevention can be confident that their efforts, such as those seen in problem-oriented policing, are worthy of the geographical focus. If high crime areas show considerable variation over time, then crime prevention efforts situated in geographical areas may not be warranted.

Weisburd, Bushway, Lum and Yang (2004) examined patterns of criminal activity on the street blocks of Seattle, Washington (WA) from 1989-2004. The focus of the study was to assess whether street blocks evidence developmental trajectories such that groups of micro crime places could be systematically identified in similar ways to that of individual criminal behavioural patterns as per the life-course developmental literature in Criminology. This study marked the first attempt to apply the statistical methodology of trajectory analysis to geographic places. This study was particularly insightful in that the geographic concentration of crime had been well documented, but the stability of those concentrations has not. Restrictions in accessing available data and having the statistical tools to assess micro crime places over time limited researchers in pursuing this area of study. Criminologists have stressed the importance of crime hotspots to the enforcement community, urban planners and government (Rogers, 2003), yet the issue of stability has largely been ignored.

This study propelled the field of *crime and place* in two main ways. First, the research examined longitudinal crime pattern trends over a 14 year period, which represented the longest study period examined in crime and place literature at the time. Secondly, the research implemented a relatively new (as applied within Environmental Criminology) semi-parametric statistic called group-based trajectory model (GBTM), to uncover crime trends on street blocks over the 14 year study period. Looking at over 1.4 million incident reports from the Seattle Police Department from 1989-2004, Weisburd et al. (2004) assigned each case to a street segment and used the GBTM method to identify clusters of criminal activity at the block face level. The street block was defined as “two block faces on both sides of a street between two intersections” (p.290). In linking incident reports with street segments, Weisburd et al. (2004) used “hundred blocks” for each city street throughout Seattle. As the data included all incident reports, it is assumed that the vast majority of crime types would be represented. It was shown that the top three crime types were property related (49.3%), followed by disorder, drugs and prostitution (17%) and other non-traffic crime related events (16.6%).

Weisburd et al. (2004) found that overall street segments in Seattle saw a 24% decline in the number of incident reports recorded from 1989 – 2002. More interestingly, the results showed a strong indication for the concentration of crime and the existence of ‘hot spots’. Specifically, between 4 and 5% of street segments accounted for about 50% of incidents throughout the study period. Weisburd et al. (2004) also reiterated that the overall distribution of criminal activity evidenced stability from year to year. All criminal activity was found between 48 and 53% of street segments only. The street segments with no reported crime only varied between 47 and 52% and at the opposite end of the spectrum, the street segments with more than 50 crimes per year occurred on only 1% of street segments for each of the 14 years observed.

When Weisburd et al. (2004) conducted the group-based trajectory model (GBTM), an 18 –group model provided the most stable results. This meant that all 1.4 million incident reports over the 14 year period evidenced a pattern by which they could be clustered into 18 separate groups of street segments showing similar developmental trends over that study period. To further classify the 18 groups, Weisburd et al. (2004)

divided the trajectories into three groups based on their slopes (i.e. beta values): stable, increasing and decreasing trajectories. This process involved fitting a linear curve to the average number of offences at each time point for each group. Eight out of the 18 trajectories were classified as 'stable' in nature, with slopes very close to 0. The slope represents the varying levels of criminal activity over the 14 year period; these street blocks identified as 'stable' showed minimal change in crime volume over time. They represented 84% of all street segments in Seattle, WA and evidenced low levels of overall criminal activity. Only three out of the 18 groups were identified as having noticeably increasing slopes and they accounted for only about 2% of all street segments in Seattle. Weisburd et al. (2004) noted though, that one trajectory evidenced an increase in its average crime rate of more than fourfold during the study period. The remaining seven trajectories were identified as having a decreasing crime volume pattern and accounted for about 14% of all street segments. The decreasing street segments appeared to account for the overall crime drop in Seattle during the 14 year period.

To analyse the spatial distribution of the stable, increasing or decreasing trajectories, Weisburd et al. (2004) conducted kernel density estimations. These provided a visual representation of each cluster of street segments in order to assess whether stable, increasing or decreasing groups exhibit spatial dependence or a more random distribution across the city for the 14 year period observed. The results showed that each developmental group of street segments was spread throughout the city; however, there existed pockets of concentration. For example, the stable trajectory street segments were more densely situated in the more affluent areas in Northern Seattle and clusters of both the increasing and decreasing street segments were found in the city's urban centre.

Overall, Weisburd et al. (2004) confirmed prior research by showing that criminal activity is non-uniform in nature and is tightly clustered when examined geographically. Going further, it was demonstrated through the trajectory analysis that micro places at the street block level evidenced a high degree of stability over time and that this stability was shown at both ends of the scale; street segments showing low rates of crime and street segments showing high rates of crime evidenced stability of these patterns over time. The results supported a public policy/enforcement driven approach to crime prevention that focuses on hot spots of criminal activity. Interestingly, the spatial analysis of the street segment trajectories showed a large range of geographic pattern across Seattle, WA. All three clusters of stable, increasing and decreasing street segments were found across the city's landscape- emphasizing the importance of studying criminal activity at a more micro level, such as the street block, where large geographic variation exists and may affect crime prevention and enforcement efforts dramatically. Lastly, it was shown that the crime drop in Seattle over the study period from 1989 – 2002 was confined to a specific group of street segments with decreasing trajectories. Weisburd et al. (2004) reiterated that the crime drop in Seattle, WA should not be seen as a phenomenon occurring uniformly across the city's landscape, but rather, as being driven by changes in crime volume specific to a small region of Seattle overall. This is however, to be expected considering the concentrated nature of the crime occurrence, as shown by the data. Nonetheless, this emphasized the importance of examining changes in crime volume at micro places such as street blocks.

Groff, Weisburd and Yang (2010) extend upon the earlier work of Weisburd et al (2004) by examining the spatial-temporal patterns of crime incidents throughout the city of Seattle, WA from 1989 to 2004. In particular, the research sought to answer whether crime trajectories of the same kind exhibit a non-uniform spatial distribution and whether street segments of different trajectories are more likely to be found spatially near or far from each other than one would expect by chance. It is particularly interesting to examine the spatial statistical relationship between micro crime places as both criminologists and the enforcement community are interested in whether 'known' crime hotspots are uniformly 'hot' and conversely, whether 'good' areas are uniformly low in crime, or do these neighbourhoods exhibit pockets of problematic high crime areas in what would otherwise be termed a 'safe' neighbourhood? The study examined all police reports from the Seattle, WA Police Department from 1989 – 2004.

First employing the group based trajectory model used by Weisburd et al (2004), Groff et al. (2010) found that amongst 24,023 street segments, 81.5% exhibited either a crime free or low stable developmental pattern of criminal activity. Only 1% of street segments showed a chronically high level of crime over the study period. Further spatial-statistical analysis revealed that these chronically high street segments exhibited the greatest degree of local clustering; that is, they were far more likely to be found close to one another than not. In addition, the street segments categorized as being low in crime yet slightly increasing over the study period were also more likely to be proximally close to one another followed by the low decreasing street segments. Interestingly, the streets categorized as either being crime free or low stable in nature were the least likely to be clustered, suggesting their more uniform distribution across the city over time. Further statistical analysis showed that the street segments showing crime free, low stable and low decreasing trajectories were statistically independent of one another; that is, they were no more likely to be close to one another than one would expect by chance alone. In opposite, a number of other trajectories were more likely to be close to one another throughout the city. For example, Groff et al. (2010) found that the street segments with higher crime or changing temporal trajectories (i.e. increasing in crime volume) tended to be more frequently associated with other streets that exhibited the same developmental trend. This research is particularly interesting in that it highlights the spatial variability of micro crime places. Within any given neighbourhood, one may find crime free zones, next to streets with consistently high crime, next to streets with consistently low crime, etc. Thus, the importance of understanding crime occurrence at the micro level is underscored here, emphasizing the need for both Criminologists and enforcement to recognize the limitations of labelling larger areal units of a city as either ‘good’ or ‘bad’ in nature.

Beavon (1984) conducted an in-depth examination of street segment properties and their effect on the volume of property crimes. Specifically, Beavon (1984) looked at the structural distinction of streets (i.e. the length of a street and whether it was curved or straight and included measures of accessibility) throughout Maple Ridge and Pitt Meadows, British Columbia during 1971. Controlling for volume of traffic and potential opportunities offered by the street segment, the volume of reported property crime was assessed. The results showed no statistically significant difference between the amount of crime on a curved versus straight street, nor between a cul-de-sac versus a dead-end street. However, significantly more property crime occurred on streets with high traffic volume. For example, Beavon (1984) reported that 'feeder streets' (i.e. those with lower traffic volumes) averaged 1.36 crimes per block versus 11.59 crimes per block for highway streets that incur the highest volume of traffic flow. Implementing a multiple regression, Beavon (1984) showed that the three strongest variables affecting the amount of property crime on a street segment were the number of commercial establishments, the average improvement value of transient accommodations and the presence of a high school. In focussing on the properties of street segments and their effects on criminal activity, Beavon (1984) recognized the importance of this micro unit of analysis towards understanding the spatial distribution of crime. The results show how variable criminal activity can be when viewed at the street segment level and more interestingly, began to explain why such variability may be.

Braga, Papachristos and Hureau (2010) employ a different type of statistical analysis to assess the developmental trends of gun violence at the street block level in Boston from 1980 – 2008. Using a growth curve regression model where each street segment is allowed to have its own slope and intercept in order to model different patterns of gun violence and different rates of change, the results showed that Boston had two main types of street units- those that had volatile levels over time and those that exhibited stable levels of gun violence over time. Specifically, only 1.9% of street units were categorized as 'stable' in terms of concentration of gun violence, but accounted for 21.3% of all firearm incidents over the study period. The volatile street units comprised 2.9% of all segments but made up 52.5% of all firearm incidents. The majority of street units, 6.7% evidenced only one incident over the study period and comprised 26.1% of the 7,359 total firearm incidents. As opposed to the grouped-based trajectory model used by Weisburd et al. (2004) which assigns a slope and intercept for clusters of street segments evidencing similar developmental trends, the growth curve regression model employed by Braga et al. (2010) allows each street segment to have its own parameters as the primary research interest was not to group street segments into specific classes, but to assess how firearm trends in Boston were affected by individual street units. The study also described the descriptive results of the distribution of firearm incidents over the 29-year study period, which resembles those of Weisburd's (2004) results concerning overall crime distribution in Seattle. For example, Braga et al. (2010) report that only 11.5% of street units in Boston exhibited at least one gun violence incident over the 29-year period, 4.8% of street units generated 73.87% of firearm incidents and only 1.17% of street segments saw five or more incidents (accounting for 37.53% of all incidents between 1980 and 2008). Braga et al. (2010) reiterated the importance of understanding crime trends at micro places such as street segments and intersections, as opposed to larger areal units, such as neighbourhoods, which can obscure important place-based crime variations. Gun violence in Boston, MA, showed considerable concentration at the block and intersection level that led to the authors suggesting that hot spot policing be focused on specific locations within a larger neighbourhood to increase visibility and engage in the community as opposed to larger scale police presence tactics.

Using the same statistical method of growth curve regression, Braga, Hureau and Papchristos (2011), analyzed the spatial distribution of robbery throughout Boston from 1980 – 2008. Specifically, over 140,000 incidents were investigated at the street block level to uncover developmental trends in robbery incidents. As with the investigation of gun violence in Boston, MA, this study implemented the growth curve regression (as opposed to the group-based trajectory model approach) because the primary focus was not to group street segments into classes of developmental trajectories, but rather, to assess if robbery trends exist at individual level geographic units (Braga et al., 2011). The results were also divided into quartiles of the predicted linear slope and intercept from each regression model and produced three distinct groupings – low, medium and high activity robbery streets. Interestingly, it was shown that only 8.8% of street units generated 68.2% of total robbery incidents in Boston between 1980-2008. Additionally, all of the commercial robberies were located on only 9.1% of streets and intersections. Overall, the research showed that the concentrated street blocks with a higher number of robbery incidents remained high throughout the 29 year study period. Braga et al. (2011) point out that like Weisburd et al.'s (2004) findings in Seattle for total crime, declines in robbery incidents throughout Boston can be attributed to a very small number of hot spot locations in the city that are responsible for a disproportionate amount of crime consistently from one year to the next.

An epidemiological study was conducted at the street block level by Wei, Hipwell, Pardini, Beyers and Loeber (2005) to validate an index of neighbourhood physical disorder and compare that index to that of census based neighbourhood poverty for predicting rates of crime, firearm injuries and homicide, teen births and low weight births. Eighty-two neighbourhoods, comprised of 5,670 blocks were observed across the City of Pittsburgh, Pennsylvania for the years 1998 – 2000. The results showed that measuring crime and disorder at the block level proved useful to support the reliability and validity of the epidemiological neighbourhood physical disorder index. Specifically, higher levels of neighbourhood disorder were associated with increased risk for firearm related injuries and homicide.

Johnson and Bowers (2010) examined the spatial distribution of 12,806 burglaries throughout the Merseyside region in England, occurring from 1998-2002, and the concomitant characteristics of the 10,760 street segments they occurred on. The research sought to answer whether the risk of burglary was greater on major roads, whether burglaries would be more prevalent on street segments that are connected to high-use streets and whether the risk of burglary is lower in cul-de-sacs. The analysis showed that the risk of burglary was highest for those streets that were considered high usage roads, also, the risk was approximately 40% higher for local roads that were permeable, or connected to major roads. Conversely, the risk for burglary was lower for cul-de-sacs and private roads, particularly those that were not visible down the road from those streets to which they were connected. The research shows how both criminal activity and risk of victimization varies at the street block level and underscores the utility of examining micro crime patterns at the block level.

Recently, Bernasco and Block (2011) investigated the spatial distribution of street robbery across census blocks throughout Chicago. The study sought to establish whether the presence of crime generators, such as high schools or crime attractors, such as gas stations, affect the volume of street robbery. Over 75,000 street robbery incidents reported to the Chicago Police were assigned to one of 24,594 census blocks in Chicago. The study then identified the number of crime generators (i.e. whether the block is located along at least one main surface street and whether there is a public transport station on the block) and crime attractors (i.e. presence of bars, restaurants, barber shops, liquor stores, grocery stores, merchandise shops, gas stations, laundromats, pawn shops and check-cashing services) present on those blocks. Additionally, Bernasco and Block (2011) measured the concentration of offender anchor points per census block, which is defined as offender residences. The results showed that blocks that had a crime generator, attractor or offender residence, had the highest robbery counts. Blocks with such attributes on adjacent streets only, had fewer robberies. Also, the lowest numbers of street robberies were found on blocks that had none of these properties and were not adjacent to streets with such properties. Specifically, Bernasco and Block (2011) revealed that blocks with illegal drug markets, accessibility facilitators (defined as main streets or public transport stations), and offender residences created an "ecological disadvantage" (p. 51) whereby street robbery occurred in greater frequency. Interestingly, the blocks with a high volume of street robbery also affected nearby blocks by elevating the risk of crime on these blocks due to their close proximity to the high crime blocks themselves.

In similar fashion to the analysis performed in 2004, Weisburd, Morris and Groff (2009) examined whether juvenile arrest incidents evidence spatial concentrations at the street block level and whether developmental trajectories of juvenile crime could be identified throughout Seattle's streets. Juvenile arrest incidents from 1989-2002 were analyzed amongst Seattle's street blocks and the findings revealed a 41% decline in such incidents over the study period. Approximately 3-5% of the street segments were responsible for all juvenile arrests during any given year and less than 1% of the total streets were responsible for 50% of the crime. Weisburd et al. (2009) reiterated that such findings highlight the strong concentration of juvenile arrest incidents throughout Seattle; however, such results were hypothesized to occur due to the limited activity spaces of juveniles and the attraction of this group towards specific venues and locales. Weisburd et al. (2009) conducted the group-based trajectory model to ascertain whether different groups of street segments evidenced divergent patterns of juvenile arrest incidents over time. The results identified eight groups of distinct subpopulations of street segments with respect to juvenile offending. The majority of those evidenced minimal juvenile criminal activity, with one group constituting 85% of all street segments but only 12 of all arrest incidents for the study period. Weisburd et al. (2009)'s results underscored the intense stability of micro crime concentrations over time; three trajectories accounted for about a third of all juvenile arrest incidents, yet included only 86 (or 0.29%) of all streets in Seattle. The results also showed that the trajectories identified for juvenile arrest incidents evidenced similar patterns to overall criminal activity trajectories (see Weisburd, Bushway, Lum and Yang, 2004) in that the majority could be linked to a decreasing trend over the study period which mirrors the decline in criminal activity experienced by Seattle, WA during that time. Weisburd et al. (2009) emphasized a routine activities explanation for their findings by explaining that juvenile activity spaces are concentrated and that young persons are likely to congregate in specific areas where opportunity for criminal activity may be higher with the absence of capable guardians.

Harries (2006) illustrated the utility of using street blocks to examine micro-level spatial variations in Baltimore, Maryland. Using 97,880 police incident records for the year 2000, criminal activity was aggregated to the census block level, which constituted approximately 8,031 blocks throughout the city. The focus of the research was to examine the existence and density of steep-crime gradients, defined as the "juxtaposition of blocks in the highest and lowest quintiles in terms of crime densities" (Harries, 2006, p.404). The results showed that 3.2% or 259 street blocks in Baltimore, MD evidenced a steep crime density gradient by having both the highest and lowest crime blocks adjacent to one another. Further analysis revealed interesting characteristics of differing types of adjacencies such as those harbouring a socioeconomic contrast, or a residential density contrast or land use anomalies. The results confirm the hypotheses by Brantingham and Brantingham (1978) regarding the effects urban form on criminal activity. In that research, burglaries in Tallahassee, Florida during 1970 were analyzed to investigate whether residential characteristics within a neighbourhood affected crime rates. The results showed significant neighbourhood variation in burglary rates depending on the extent to which the area encompassed border blocks versus interior blocks. Specifically, Brantingham and Brantingham (1978) found that neighbourhoods comprised of border blocks had substantially greater amounts of burglaries than those with primarily interior blocks. A mathematical model was formed to systematically test this phenomenon (see Brantingham and Brantingham, 1978) termed a ‘topological technique’, and remains highly explanatory towards such inter-block variation of criminal activity, as found in Harries (2006) research. Harries (2006) discusses how steep crime gradients at the street block level are an important phenomenon to observe as they may be indicators of significant local environmental inequalities, or may harbour implications for fear of crime issues with those in the low crime areas in constant fear that they may become victimized by criminal activity that is ‘just around the corner’, and that a steep crime gradient may imply a perceived failure of police for those in the nearby high crime area. The emphasis on the utility of the street block to measure differing crime gradients throughout the city is discussed at length and the difficulty with larger areal units in visualizing such micro-level variations is highlighted.

Street blocks have also been applied to assess fear of crime issues within Criminology. For example, Taylor, Gottfredson and Brower (1984) sought to shed light on why some blocks exhibit more crime or have higher residential fear levels than other blocks. Sampling 687 households amongst 63 street blocks throughout Baltimore, Maryland, Taylor et al. (1984) found three key features regarding fear of crime at the street block level. First, defensible space features, such as the proportion of surveillance opportunities within the area decreased the fear of crime, however, not as strongly as the researchers would have predicted. Secondly, having strong social ties decreased both criminal activity levels and fear of crime at the street block level and lastly, those blocks with residents evidencing strong territorial links to their neighbourhood contributed to the development of group-based norms regarding what was normative behaviour on their block-settings. This study highlighted why street blocks are an advantageous unit of analysis to examine criminal activity, and in the above case, fear of crime (see Taylor, 1997). The street block organizes life within a city region in that residents are visually close to one another and their routine activities are interrelated in that everyone knows the normative behaviour of those around them. Harbouring both behavioural characteristics and physical features such as appearance of the block and how close or far it is from major road networks, the street block is a useful unit of analysis to examine crime and place issues (Weisburd, Groff and Yang, 2011). Additionally, the street segment minimizes errors that are typical within point level spatial analyses whereby addresses by police or dispatch may be miscoded.

Robinson, Lawton, Taylor and Perkins (2003) also examined fear of crime issues at the street block level with respect to the impact of incivilities within neighbourhoods. One street block, each within 50 different neighbourhoods, was analyzed with household interviews conducted across two separate time periods (1987 and 1988). The results showed that those residents who saw more problems on their block initially were also more likely to report increased feelings of vulnerability the year later. In addition, those who saw crime and incivility problems increase on their block were also more likely to report becoming increasingly fearful and worried about their safety. On the blocks where residents thought incivility problems were getting worse were more likely to report that their block was becoming less safe and agreed that block safety was slipping (Robinson et al., 2003). The study revealed that block satisfaction and local safety trends did vary across neighbourhoods; street blocks showed variation in residential safety perceptions.

Smith, Frazee and Davison (2000) used street blocks to analyse levels of street robbery from a routine activities and social disorganization perspective. The research emphasized the utility of street blocks as "providing a more accurate view of the role that variables play in affecting the likelihood and frequency of street robbery" (p. 497). Using 1993 police department crime-incident data from a midsized south eastern U.S. city, Smith et al. (2000) found that 92% of street blocks experienced no robberies during the study year. Thus, at the street block level, the geographical concentration of this crime type was significant. The results also showed that the higher the number of residents on a street block, the less robberies occurred. The opposite effect was found with the presence of places per street block (such as buildings) in that for every 10 places located on a block, the likelihood of robbery increased by 1%. Smith et al. (2000) uncovered a diffusion effect at the street block level as well. Street robberies were most prevalent in the city centre and each mile outside of that range resulted in a 2% reduction in the number of street robberies. Additionally, the presence of a single-parent household increased the likelihood of street robbery by 1% per block. Overall, Smith et al. (2000) concluded that both social disorganization and routine activity variables determined street robbery at the street block level. Specifically, they argued that robbers would commit crimes on street blocks with which they are familiar with a diffusion effect being present where the likelihood of robbery occurring decreases as the distance from the robber's awareness space increases.

Most recent research by Weisburd, Groff and Yang (2011) marks the most comprehensive examination of crime and place in Seattle, Washington, thus far. Once again, defining the street segment as 'both sides of the street between two intersections' (p. 27), Weisburd et al. (2011) utilize Seattle Police Department data, as implemented for the 2004 original research, to re-conduct a trajectory analysis for criminal activity for the years 1989-2004. Going beyond this, the research involves a detailed spatial analysis of the identified trajectory patterns and examines the social ecological characteristics of the areas evidencing high chronic levels of criminal activity. Such an examination led Weisburd et al. (2011) to develop an overall model explaining the factors that influence the developmental trends of micro crime places over time. The following section will detail these findings.

In the seminal book, 'The Criminology of Place: Street Segments and our Understanding of the Crime Problem', Weisburd, Groff and Yang (2011) argue the advantage of examining criminal activity at micro places. In particular, the street block is purported to be a "useful compromise because it allows a unit of analysis large enough to avoid unnecessary crime coding errors, but small enough to avoid aggregation that might hide specific trends" (Weisburd et al., p. 30). Key questions are raised as to whether micro crime places are a unique entity in terms of crime trends and whether criminal opportunity and activity patterns vary at the street block level. More importantly, Weisburd et al. (2011) seek to understand the characteristics of hot 'streets' and whether they remain stable over time, investigating what sort of opportunity or social disorganization characteristics these particular areas may exhibit. Weisburd et al. (2011) used a geographically-based file to create the street segments throughout Seattle to ensure that each street started and ended between two intersections. Using incident reports from the Seattle Police Department (1989-2004), approximately 1.6 million crime incidents were aggregated to 24,023 street segments throughout Seattle, WA with the exclusion of intersections, addresses linked to police precincts and addresses found outside the city limit.

First, it was found that between 1989 and 2004, the City of Seattle experienced a 24% decline in crime incidents overall. The distribution of criminal activity was found to be highly concentrated. Approximately 9.2% of streets experienced no crime at all and the average amount of crime per street was 4.42. Weisburd et al. (2011) report that between 4.7% and 6.1% of the street segments each year accounted for about 50% of the total crime incidents. All of the incidents were found between 60-66% of streets. This concentration exhibited stability over time in that the proportion of streets exhibiting varying levels of criminal activity remained that way throughout the study period. For example, the street segments with more than 50 crime events per year remained at about 1% across all 16 years and the proportion with no crime at all only varied between 34% and 41%.

These findings led Weisburd et al. (2011) to question whether the street segments found to produce the stable proportions of criminal activity over time were the same or differed from year to year. If different street segments were responsible for these various crime proportions over time, the results would indicate a strong ‘law of concentration’ but not of ‘stability of place’ (Weisburd et al., 2011). To test this, the same group-based trajectory model implemented in Weisburd’s earlier 2004 work was conducted. A 22-group model was identified by the GBTM method and showed considerable stability of crime through the trajectories over time. Out of those 22 groups, four trajectories evidenced ‘no crime’, but distinct developmental patterns over the study period. These trajectories included almost 50% of the street blocks in Seattle, WA. Five trajectories were categorized as having low and stable levels of criminal activity- these constituted approximately 32% of all street blocks. This finding reinforced the central tenet that most areas throughout a city have either absent or very low levels of criminal activity (Weisburd et al., 2011). Only one trajectory was categorized as having a moderate level of criminal activity yet remained stable over the study period and constituted approximately 1.2% of all street segments.

Weisburd et al. (2011) found that only 1% of street blocks evidenced a chronic level of high criminal activity over the study period. This was identified by only one trajectory whose streets had an average of 80 crimes per year. It was pointed out that these streets did experience a 14% decline in criminal activity over the 16 years, however, despite that they remained the most serious crime locations at both the beginning and end of the study. An additional three trajectories evidenced a low rate pattern that decreased over the study period and constituted approximately 9% of streets. Each of the three trajectories decreased about a third by 2004. Conversely, another three trajectories evidenced high rates of criminal activity, but were also found to decline significantly over the study period. These trajectories made up 2.4% of streets in Seattle and ranged from having 20-40 crime incidents on average per year, but declined by almost 50% by 2004.

The group-based trajectory model identified five trajectories with an increasing pattern; three of these evidenced low levels of criminal activity and the remaining two showed high levels of crime. The low increasing trajectories constituted about 4% of streets and the high increasing trajectories included only 0.9% of streets. Weisburd et al. (2011) point out that one of these trajectories evidenced an increase from an average of 10 crimes per year in 1989 to more than 60 crimes by 2004. This underscored the conclusion that despite the city of Seattle experiencing a crime drop in the 1990's, there still existed areas that were not only high in crime, but remained that way or even substantially increased during the general declining period. Specifically, it is noted that 221 street segments saw serious increases in crime during the crime drop evidenced throughout the study period. Overall, the group-based trajectory model as conducted by Weisburd et al. (2011) showed that most areas throughout the city evidence little or no crime, that crime concentrations are stable over time and can be seen as harbouring developmental trajectories and that only a small proportion of street segments were responsible for the crime drop experienced in Seattle during the 1990's.

Weisburd, Groff and Yang (2011) spatially analyzed the trajectories identified by the group-based trajectory model to see where these clusters were located and to establish whether certain trajectories are more likely to neighbour one another. The results showed that the high crime trajectories were, for the most part, located in the northern section of Seattle, with a particular concentration following a main or arterial road. The southern portion of Seattle evidenced a mixture of different types of trajectories; however, the presence of chronic high crime street segments was particularly evident. The downtown area of Seattle evidenced two interesting geographical trends. The first was a strong degree of clustering for the highest crime rate street segments, and second, was considerable street-by-street segment variation of differing developmental trajectories. Overall, Weisburd et al. (2011) found that hot spot street blocks were interspersed throughout Seattle, and that high rate streets were often interspersed amongst low rate street segments, evidencing a strong micro concentration of criminal activity, only visible at the street block level.

Further, Weisburd, Groff and Yang (2011) sought to understand *why* certain street blocks evidenced chronic levels of criminal activity versus those that remained relatively crime free. The research revealed that both opportunity related variables and social disorganization related variables evidenced concentrations at the street block level. However, what remained unknown was whether these characteristics were systematically related to certain developmental trajectories. Using a multivariate statistical model (logistic regression), Weisburd et al. (2011) analyzed these variables and their effect on the eight trajectory classifications established by the group-based trajectory model. Beginning with variables specific to opportunity theory, the results showed that the presence of high-risk juveniles, as motivated offenders, increased the likelihood of a street being in a high rate chronic trajectory twofold. With respect to suitable targets, Weisburd et al. found that for every additional employee on a street segment (perhaps representing an industrial/business area), the likelihood of that street showing a high chronic crime pattern increased by 8%. The presence of a public facility, such as a community centre or high school, within a quarter mile of any given street increased the likelihood that a street segment would be part of a chronically high crime trajectory by 25%. In addition, the larger the residential population, the more likely a street segment was to be clustered into the chronic high crime pattern. Variables alluding to the convergence of a motivated offender and a suitable target also showed to be significant predictors of high crime chronic street blocks. Specifically, every additional bus stop doubled the likelihood of that particular street evidencing that particular trajectory. Perhaps not surprisingly, any street segment that was an arterial road was also far more likely to be labelled as high chronic in criminal activity. One of the most significant predictors of high chronic crime patterns at the street block level was the percent of vacant land. A 1% increase in the amount of vacant land increased the likelihood of a street segment being categorized as high chronic by almost 50%.

Weisburd et al. (2011) also measured the influence of various social disorganization variables on the high chronic street segments.   The results showed, for example, that a unit increase in the residential property value on a street was associated with a 30% decrease in the likelihood of that street being labelled as a chronic crime trajectory, whereas the presence of subsidized housing was associated with a 10% increase. Significant effects were found with the presence of physical disorder and a higher likelihood of a street being in a chronic crime group, as well as with respect to the presence of truant juveniles. Specifically, truant juveniles were found to more than double the likelihood of a street segment being labelled into the chronic crime pattern. Lastly, Weisburd et al. (2011) looked at the percent of active voters on a given street block as an indicator of collective efficacy and found enormous effects. Comparing streets with no active voters to those with all active voters, the probability of being in the chronic trajectory group compared to a no crime trajectory group decreased by almost 96%. Thus, it was concluded that those streets with residents involved in public affairs have far lower levels of criminal activity.

In sum, Weisburd, Groff and Yang's (2011) research represents seminal work in the crime and place arena. Not only does the research significantly contribute to emphasizing the utility of examining micro crime places at the street block to fully understand crime patterns over time, but it also goes a step further in attempting to explain why such developmental patterns exist. Both opportunity theory and social disorganization characteristics were found to be significant in their explanatory value. This research marks the first attempt in Environmental Criminology to develop an explanatory model for micro crime variation on street blocks within an urban setting and as such, furthers our understanding of developmental trajectories of criminal places over time.

This chapter has reviewed seminal research within Environmental Criminology and the progression of crime and place research. Studies conducted at both the areal level and point or address level were reviewed, along with the application towards journey-to-crime research. The limitations of conducting microspatial criminology research at such levels were discussed with the argument that the more recent application of the 'street block' offers an optimal compromise between the two disparate levels of analysis. It was argued that the street block offers two main advantages towards the systematic examination of crime and place. The first is that the street block, as a unit of analysis, is large enough to avoid common geocoding errors inherent within point level data that occur as a product of inaccurate or incomplete police reporting. In tandem, the street block is small enough to circumvent the risk of applying inaccurate conclusions regarding criminal activity within a geographic region, as is common with the analysis of areal units such as census tracts or dissemination areas. Secondly, it was argued that the street block is a representative unit regarding the social organization of a city. In concordance with Weisburd et al. (2011), it was stressed that street blocks are highly likely to reveal important social ecological patterns potentially explicative of crime trends, as they embody distinct characteristics within themselves that are specific to those that reside, travel on and frequently visit them.

The seminal work conducted by Weisburd and colleagues in the city of Seattle has offered the field of the 'criminology and place' tremendous insight into understanding the disproportionate distribution of criminal activity that is inherent to major cities. The research in its entirety, and in particular the group-based trajectory model based on street blocks, has never been replicated outside of Seattle, Washington. This dissertation accomplishes this by conducting a comparable study of crime and place, based on Weisburd, Bushway, Lum and Yang (2004). Based in Vancouver, British Columbia, the conclusions will extend those offered by Weisburd et al. with respect to understanding crime and its place in society. The following chapter outlines the methodology implemented with Vancouver Police Department (VPD) data.

Chapter 3: Methods

Introduction

To further the research in the area of ‘crime and place’, this dissertation replicated the trajectory analysis methodology utilized by Weisburd, Bushway, Lum and Yang (2004) for the city of Vancouver, British Columbia. Weisburd et al. (2004) employed a group-based trajectory model (GBTM), which resembles a cluster analysis technique in that it allows the researcher to identify classes of individuals within a dataset that share similar characteristics over time that differentiate each group from one another. Weisburd et al. (2004) applied this technique to street blocks as the unit of analysis and sought to investigate whether street blocks evidenced developmental trajectories of criminal activity over time. Group-based trajectory modelling is a semi-parametric technique that most often is performed in SAS, through an application called Proc Traj (see Nagin and Land, 1993). As discussed in the previous chapter, much of the literature on micro crime places within the field of Environmental Criminology has either focused on point locations/addresses (Sherman, Gartin and Buerger, 1989; Roncek and Maier, 1991; Langworthy and LeBeau 1992a; 1992b; Rogerson and Son, 2001; Bowers and Johnson, 2005), or larger units such as census tracts, regions or provinces/states (Block and Davis, 1996; Andresen, 2006; Andresen, 2007; Andresen, 2009a) and is often cross-sectional in nature with only a snapshot of how criminal activity varies over a short period of time (Pyle, 1976; Browning, Byron, Calder, Krivo, Kwan, Lee and Peterson, 2010; Johnson, Bernasco, Bowers, Elffers, Ratcliffe, Rengert and Townsley, 2007).

This dissertation extended Weisburd et al.’s (2004) research in two main ways. First, the study spans a 16-year period, providing a longitudinal examination of crime trends in the city of Vancouver. Outside of the research done in Seattle, WA, this represents the largest examination of crime at micro places in Environmental Criminology conducted thus far. Second, in addition to utilizing the Proc Traj method demonstrated by Weisburd, this dissertation also implements a non-parametric statistical technique called *k-means,* to provide a different lens from which to view Vancouver's criminal street segment patterns over time. The k-means statistic functions in a similar manner to the GBTM Proc Traj method, yet allows for the inclusion of cases with counts greater than 50. The salience of this issue will be discussed further in this chapter. Thus, this dissertation will expand on Weisburd et al.'s (2004) earlier work by implementing an alternative to the group based trajectory model for the developmental trend analysis.

This dissertation will seek to answer three main questions regarding criminal activity in Vancouver, B.C. from 1991 – 2006 at the street segment level:

1) What is the distribution of criminal activity over time?
2) Do street segments evidence developmental trends over time?
3) What is the spatial distribution of street segment clusters of criminal activity across the city over time?

Importance of replication

It is a well-known fact in natural science that replication is a necessary step to validating a set of results; especially when the findings are considered innovative. In the social sciences, replication is equally important when attempting to establish the reliability and validity of a statistical tool or survey (Kruger, 2011; Fava, Hwang, Rush, Sampson, Walters and Kesler, 2010; Fava, Rush, Alpert, Carmin, Balasubramani, Wisniewski, Trivedi, Biggs, and Shores-Wilson, 2006). For example, the personality disorder of psychopathy and its concomitant diagnosis scale, the Psychopathy Checklist, is an established tool used to diagnose incarcerated populations with psychopathic tendencies. The spectrum of this disorder and its accompanying Checklist has been re-evaluated in numerous studies for the purpose of corroborating the disorder's symptoms and establishing the scale's validity in predicting deviant affect and behaviour within this particular population (Poythress, Lilienffeld, Skeem, Douglas, Edens, Epstein and

Patrick, 2010; Endrass, Rossegger, Urbaniok, Laubacher and Vetter, 2008; Swogger and Kosson, 2007). The practice of replication continues to carry significant importance in the field of social sciences when researchers attempt to validate/re-examine conclusions in the area of personality development (see Stoeber, 2011), and Environmental Criminology (see Sidebottom, Thorpe and Johnson, 2009).

Weisburd et al.'s (2004) examination of micro crime places over time is considered a landmark study within the crime and place literature of Environmental Criminology. At the time of its publication, Criminologists had not directed much attention to the longevity of crime hotspots- only towards their existence and prevalence within the spatial distribution of criminal activity. In fact, in 2004, Weisburd et al. noted that there were only two other studies that had examined the longitudinal patterns of micro crime places (see Spelman, 1995; Taylor, 1999) at that time. Since then, other research has explored this phenomenon within the field of Environmental Criminology, however in different contexts than what was originally focused on by Weisburd and his team in the city of Seattle, WA (see Wei, Hipwell, Pardini, Beyers and Loeber, 2005; Braga, Papachristos and Hureau, 2010; Weisburd, Morris and Groff, 2009; Browning, Byron, Calder, Krivo, Kwan, Lee and Peterson, 2010). To date, no other study has replicated Weisburd's model and examination of overall criminal activity in a city based on the street block and attempted to identify developmental trends of micro crime places over time, outside of Seattle, WA.

If Weisburd et al.'s (2004) methodology is replicated in a similar city and context and yields comparable results, that the key findings that (1) micro crime places show stability of crime volume over time and (2) only a small proportion of a city evidences significant variation in crime volume over time, will be further substantiated. This is important to pursue as the field of Environmental Criminology has not fully established whether the results gleaned by Weisburd and his team in 2004 are generalizable to micro crime places or if the results are specific to Seattle only. As Weisburd et al.'s (2004) results supported crime prevention initiatives aimed at hotspots, it is imperative to substantiate the results to validate these policy implications. Conversely, if the replication in Vancouver yields vastly different results, the policy implications for urban planners and the enforcement community may be in question.

The unit of analysis in this dissertation is the 'street block' or street segment defined as the two block faces on both sides of a street between two intersections (Weisburd, Bushway, Lum and Yang, 2004). This exact unit of analysis was utilized by Weisburd et al. (2004) and differs from a census block definition, which may also be considered within micro crime research. Census blocks, or dissemination blocks consist of an area bounded on all sides by roads and or boundaries of standard geographic areas (source: Statistics Canada). It is important to note that this would be equivalent to four street blocks. Thus, not all micro geographical units are synonymous with one another at the street level.

Replication in Vancouver, British Columbia

Vancouver, British Columbia (B.C.) is situated approximately 200km north of Seattle, WA. Both cities are located on the Northwest coast of North America and have a similar population size (see Table 1). Additionally, both cities share comparable climates, demographics and both are regulated by a citywide police department (i.e. a Municipal Police Department). Seattle, WA operates the Seattle Police Department and Vancouver, B.C. operates the Vancouver Police Department (VPD). Vancouver is one of the few municipalities in British Columbia that is not policed by the Royal Canadian Mounted Police's, "E" Division. One marked difference between the two cities lies in population density. As Table 1 shows, Vancouver is almost half the geographic size of Seattle, yet has almost double the population density.

Equally important are the similarities between the two cities with regard to the police data available to conduct a longitudinal examination of crime at micro places. Weisburd et al. (2004) chose the Seattle Police Department as it offered a comprehensive official dataset on crime records in a computerized format. Specifically, the Seattle PD had records of *incident reports* dating back to 1989; these are records generated by police officers after an initial response to a request for police service.

Weisburd et al. (2004) explain that Seattle's police department was guided by a police administrator who was committed to research on crime places, which made conducting the study and gaining access to data straightforward. Similarly, the Vancouver Police Department (VPD) is also known for keeping meticulous computerized records of all police requests for service, their crime category, time and location dating back to the 1980s.

The VPD's *calls-for-service* data are comprehensive in scope and were made available for this dissertation via an affiliation with the Institute for Canadian Urban Research Studies (ICURS) at Simon Fraser University's School of Criminology. Calls-for-service data are generated in two ways. First, when a member of the public phones 911 and is directed to the VPD's dispatch centre to report criminal activity, each call is logged, categorized and responded to by the police department. Secondly, when police initiate responses to criminal activity first hand, these are also logged within the same dataset. Calls-for-service data are commonly used in Environmental Criminology research (Andresen, 2009b; Sherman, Gartin and Buerger, 1989; Braga, Papachristos and Hureau, 2010; Smith, Frazee and Davison, 2000; Andresen, 2006; Klinger and Bridges, 1997) and Weisburd et al. (2004) explained that although the Seattle PD had this type of data, they were not utilized because Seattle only kept it for four years at a time. In general, it has been found that both incident reports and calls-for-service data are comparable sources of data and generate similar spatial distributions of crime (see Lum, 2003). Additionally, using calls-for-service data within Criminology research is widely accepted as a reasonable measure of criminal activity within a city (see Braga, Papchristos and Hureau, 2010; Klinger and Bridges, 1997; Andresen, 2009b; 2006; Smith, Frazee and Davison, 2000; Sherman, Gartin and Buerger, 1989).

Due to the substantial similarities between the two cities and the comparability between the datasets used for Weisburd et al. (2004) and that which is available from the Vancouver Police Department, it is held that Vancouver, BC is a comparable city in which to replicate Weisburd's original research on the trajectories of crime at places.

Table 1. Comparative Datasheet on Seattle, WA and Vancouver, BC.

Category	Seattle, Washington, USA*	Vancouver, BC, Canada**
Population	612,000	578,041
Metro Population	3,707,400	2,501,699
Population Density	2,821 per square km	5,335 per square km
Geographic Location	Pacific Northwest, 182km south of Canadian Border	Pacific Northwest, 53km north of US border
Land Area	217 square km	114 square km
Climate	Moderate with average rainfall of 92cm per year.	Moderate with average rainfall of 119cm per year.
Police Department	Municipal: Seattle Police Department	Municipal: Vancouver Police Department

*Source: Office of Intergovernmental Relations, City of Seattle, 2011
**Source: Wikipedia, 2011

Vancouver Police Department Data

Since the early 1980s, the Vancouver Police Department (VPD) has been keeping computerized records of each call-for-service that has reached their dispatch centre. Each call from the public or police initiated call is noted by the dispatcher with the following details entered as data into the VPD system: the category of the incident (ex. robbery), the date, time it was received, time it was dispatched to the police, the location, the priority level of the call, the longitude and latitude coordinates, the district location and whether the location was situated in the city's downtown eastside area. For the purposes of this dissertation, the years 1991 to 2006 were chosen as the point of focus for two main reasons. First, these years constituted the majority of data available through the ICURS that was in a useable format. ICURS houses calls-for-service data from the Vancouver Police Department dating back to April 1988. The year 1991 was chosen as the starting point for analysis as it (as well as 1996 and 2001) coincides with Canadian census data and may be useful for future analysis purposes. Second, as Weisburd et al. (2004) had analyzed a 14-year dataset, for the purposes of replication, it was believed that this 16-year period would provide an equitable comparison for study.

The following 22 calls-for-service categories were selected for inclusion and were subsequently geocoded for street segment analysis: arson, assault, assault in progress, attempted break and enter, attempted theft, break and enter, break and enter in progress, drug arrest, fight, alarm, holdup, homicide, purse snatching, robbery, robbery in progress, shoplifting, stabbing, stolen vehicle, sexual assault, theft from vehicle, theft and theft in progress.

These data were further narrowed down by excluding calls-for-service that were either located at an intersection, were specified as having occurred at the police precinct or did not specify any known location. The decision to exclude those incidents occurring at intersections is supported by Weisburd's (2004) earlier work where intersections are noted as not belonging to any particular street segment and technically could be linked to four different ones[1]. The final sample size for the Vancouver PD dataset for this dissertation is 1.08 million calls for service from 1991 – 2006.

Descriptive analysis of the data was conducted and is displayed in Table 2, that shows the total number of calls for service from 1991 to 2006 inclusive. The highest volume of crimes was seen in 1996, with 89,143 calls for service to the Vancouver Police Department. Conversely, the lowest level of crime was noted at the most recent year of 2006, with only 46,079 calls for service recorded. Overall, from 1991 to 2006, criminal activity for the above mentioned 22 categories decreased by almost 40% (see Figure 1). It is interesting that Vancouver's crime volume over the study period exhibits a similar downward trend to that of many other major cities in North America and Europe during the same time frame (Ouimet, 2002; Mishra and Lalumiere, 2009; Levitt, 2004).

[1] For Vancouver, approximately 25% of calls-for-services amongst the 22 index crimes examined from 1991 to 2006 were located at intersections and subsequently excluded from the analyses.

Table 2. ***Vancouver Police Department Calls-for-Service counts***

Year	Total Calls for Service
1991	76,963
1992	78,176
1993	75,824
1994	75,041
1995	85,122
1996	89,143
1997	80,973
1998	71,817
1999	67,676
2000	62,539
2001	56,942
2002	57,828
2003	56,459
2004	56,360
2005	52,950
2006	46,079

Figure 1. ***Vancouver Police Department Calls-for-Service Counts***

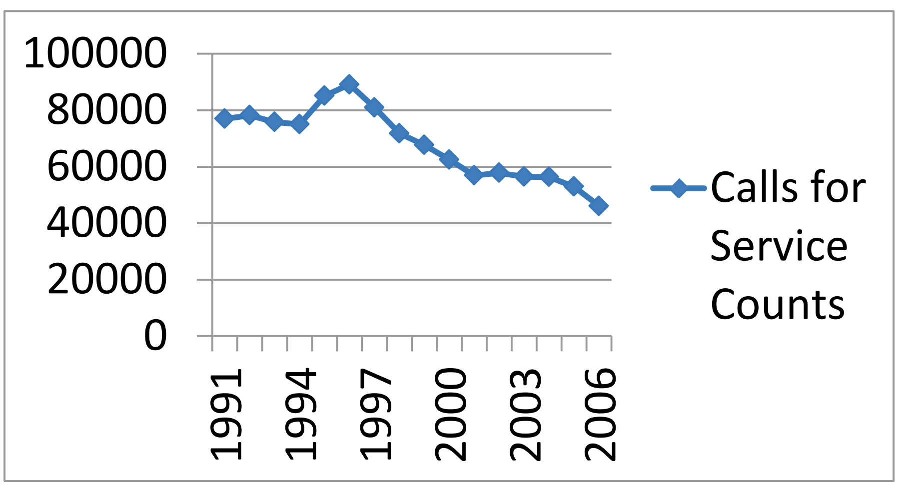


Table 3 displays the comparison between the Weisburd et al. (2004) data and the Vancouver, BC data used for this dissertation.

Table 3. Comparative Details of Seattle PD and Vancouver PD data

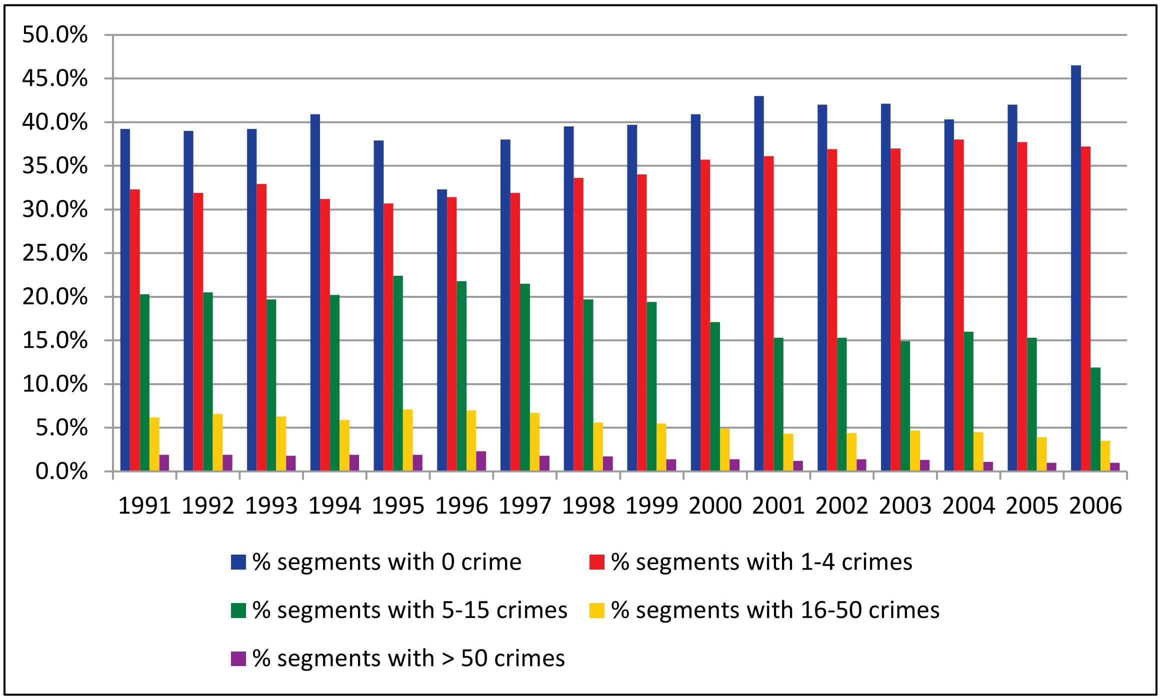
Category	Weisburd et al. (2004) and Seattle Police Data	Curman Dissertation (2011) and Vancouver Police Data
Years Included	1989-2002 (14 years)	1991-2006 (16 years)
Data Source	Incident Reports	Calls-for Service Reports
Sample Size	1.5 million incident reports	1.08 million calls-for-service
Unit of Analysis	Street Segments	Street Segments
Number of Street Segments	29,849	12,980
Location Exclusions	Intersections, police precinct and places without a geographic identifier	Intersections, police precinct, and 'no known location'
Crime Decline over study period	-24%	-40%

In keeping with the methodology outlined by Weisburd et al. (2004), the next step was to fit each of the 1.08 million calls for service to a street segment in Vancouver, BC in order to aggregate the data for the proposed longitudinal trajectory analysis (see next section) . Street segments were identified using hundred blocks, in which Vancouver, BC has 12,980. The average length of a street block in Vancouver is 409 feet with a standard deviation of 288 feet. Each call for service was geocoded and aggregated to this street segment network, with a hit rate of 98%.

Descriptive results show that on average, 40% of street blocks in Vancouver did not experience any calls-for-service during the 16-year study period. This establishes that all criminal activity (i.e. for the crimes analyzed) was located on only 60% of all possible streets throughout the city (approximately 7,724 out of 12,980). Additionally, only 7.8% of streets evidenced 60% of all the criminal activity, 34% of streets exhibited 1-4 calls for service, 18% saw 5-15 calls for service and 5% saw 16-50 calls for service. Approximately 3.6% of street segments experienced over 50 calls for service during this

16-year period. Tentatively, these results indicate that criminal activity appears concentrated at the street segment level throughout Vancouver and that this concentration is stable over time. Figure 2 displays these descriptive results.

Figure 2. Crime Concentration Stability across Vancouver Street Segments



It is clear from Figure 2 that the proportion of street segments exhibiting a specific amount of criminal activity remains quite constant from year to year. This finding supports the tenets of Environmental Criminology that crime is not randomly distributed throughout a geographic area, but rather non-uniform in nature. However, what is not entirely clear from this descriptive analysis is whether it is the same street segments within each of these thresholds over time? Do the street segments, for example, exhibiting over 50 crimes and conversely no crime in 1991 remain similarly high and low the following year, and each subsequent year after that? Weisburd, Groff and Yang (2010) reiterate the importance of answering this question to establish whether such patterns are indicative of simple concentrations of crime or a *stability* of crime concentrations over time. Beyond theoretical significance, this question holds great policy implications for enforcement and urban planners whose resources are often guided toward (or away from) ‘problem areas’ throughout a city, on the assumption that a micro location evidencing ‘high crime’ will remain so over time. In order to shed light on this area of research, Weisburd et al.’s (2004) group based trajectory model will be replicated, in addition to another trajectory analysis technique, k-means, as summarized in the following section.

Group-Based Trajectory Model (GBTM)

In 1993, Nagin and Land published a seminal study exploring the criminal career debate. Specifically, the research explored whether the individual pattern of offending over the life course was marked by periods of stagnation, whether offending rates differed with age and whether chronic offenders differed in systematic ways compared to less active offenders. They used a panel data set that was originally assembled by Donald West and David Farrington, whereby over 400 males from a working class area of London were tracked from the age of 8 to 32 years old. This seminal data set looked at psychological and socio-cultural variables such as parental supervision, attachment, family size and income and sought to shed light on the development of criminality as measured by convictions (see West and Farrington, 1973; Farrington, 1986). In furthering this research, Nagin and Land (1993) were pioneering a new technique based on a nested, mixed Poisson model that allowed them to systematically track 403 males from the West and Farrington panel data set. The study sets out in detail the ‘generalized Poisson process model’, the accompanying equations and the theoretical background to the statistic. The technique allowed the researchers to identify four ‘classes’ of offenders/non-offenders as well as individual level characteristics that were unique to each group. The number of criminal convictions was tracked and the boys along with their parents, teachers and friends were interviewed every two years until they were 18 years old. The article was meant to shed light on the criminal career debate, however, the methodology utilized and trajectory analysis carried out to identify clusters of criminal career patterns was far more discussed in the field of Criminology, than the theoretical implications of the research. It marked the first time that this type of group based cluster analysis was utilized in this fashion in Criminology. In fact, the implementation of the group-based trajectory model to the panel dataset of over 400 males led to this statistical technique being applied in Criminology for other research with large, longitudinal datasets.

Most often termed ‘group-based trajectory model’ (GBTM), this semi-parametric statistic is used to identify a distinct subgroup of individuals following a similar pattern of change over time on a given variable (Andruff, Carraro, Thompson, Gaudreau and Louvet, 2009).   Jones and Nagin (2007) argue, “charting and understanding developmental trajectories is amongst the most fundamental and empirically important research topics in the social and behavioural sciences and medicine” (p. 543). Only recently has GBTM been applied ‘outside of the box’ to analyse changes in geographic places over time, as opposed to changes in individual level behaviour. It has become one of the most useful techniques within the study of crime and place to identify clusters of micro crime places that follow similar progressions of criminal activity over time (Weisburd et al., 2004; 2010).

The model employs a mixture of probability distributions that are used to describe the data and assumes that there is unobserved subpopulations that differ in their parameter values (in this case, the y-intercept and slope) and that this heterogeneity can be explored through model estimation (Jones, Nagin and Roeder, 2001). The first step involves identifying which case belongs to which trajectory. Using the expectation-maximization (EM) algorithm, the maximum likelihood values for each case are calculated and establish which trajectory each observation ‘belongs to’.   The log value for each case is used, and the data follows a Poisson distribution. The EM algorithm is an iterative process that computes both the expectation of the log-likelihood and the parameters maximizing the expected log-likelihood (Genolini and Falissard, 2010). These parameter values are then imputed again in the next step, as the process repeats itself until each case has been assigned to a trajectory that ‘best fits’ its observed pattern on the variable of interest.

The second step involves establishing the model itself in terms of the number of trajectories identified within the longitudinal dataset. Specifically, this process identifies the number of clusters of individual cases showing similar progressions of an outcome variable over age or time (Jones and Nagin, 2007). Traditional models analysing change over time often have the statistical assumption that all individuals in a given sample are expected to change in the same direction across time with only the degree of change varying between cases. This may mask important individual level differences and can lead to the incorrect conclusion that people, or the variable of interest is not changing longitudinally. The advantage of GBTM is that the magnitude and direction of change between individual cases (i.e., trajectories) can vary over time. To accomplish this, a set of parameters is assigned to each identified trajectory; the y-intercept and the slope (Andruff et al., 2009). Maximum likelihood estimation (via the expectation maximization algorithm) is used to identify the value of the model parameters and multiple starting points are chosen by the researcher and specified to ensure a reasonable expectation that the maximum likelihood is located (Jones and Nagin, 2007).

The most popular measure of ‘best fit’ for GBTM is the Bayesian Information Criterion (BIC) (Weakliem and Entner Wright, 2009; Raftery, 1995; Jones, Nagin and Roeder, 2001). The BIC provides a best-fit index that is estimated for each model and compares competing models with differing numbers of trajectories through an iterative process. The fit of each model is compared to the fit of the previous one until the data indicate that there is no substantial improvement in model ‘fit’ with the addition of more trajectories (Andruff et al., 2009). Weakliem and Entner Wright (2009) describe the BIC process and reiterate that the differences in the BIC statistic with each round of calculations can be interpreted as a “measure of the weight of evidence provided by the data in favour of one model against another” (p. 153). The process begins with one trajectory and one BIC score and continues from there with the addition of each new group until the BIC value begins to increase. One of the advantages of the GBTM model overall, is that the process does not require the researcher to specify beforehand the number of trajectories for the model, but allows the ‘best fit’ number to emerge from the data through the BIC process. The results provide the researcher with an identified set of clusters, each of which encapsulates a set of cases showing similar patterns over time on the variable of interest.

Group-based trajectory modelling is most often performed in the statistical software, SAS, through an application called Proc Traj (see Nagin and Land, 1993; Weisburd et al., 2004; 2010, Groff, Weisburd and Yang, 2010; Andruff et al., 2009). The GBTM process for this dissertation was also performed in SAS, through the Proc Traj program. Although this software performs GBTM accurately, the process can take a significant amount of computational time, depending on the size of the dataset. Weisburd et al. (2004) notes that the 18-group model established in the study on Seattle, WA, took over 8 hours to converge in SAS. The Vancouver dataset also took a similar amount of time to converge.

Group-based trajectory modelling offers certain advantages for researchers seeking to differentiate a large number of observations over time by type of category (see Raftery, 1995). First, as discussed previously, the statistical process as performed by Proc Traj does not require the researcher to specify beforehand the number of clusters to be tested, but allows for that number to emerge from the BIC process (Andruff et al., 2009). Over and above cross sectional designs, it allows one to measure trajectories at more than just two time points, instead, one can observe these cases across multiple time points. Many researchers have pointed out the advantage of GBTM in terms of the simplicity in which the results are displayed. Andruff et al. (2009) notes that results from Proc Traj provide both graphical and tabular formats, which are easily presented to a wide range of audiences and efficiently summarizes large datasets with significant population heterogeneity (see also Jones and Nagin, 2007). Nagin and Odgers (2010) stress the utility of GBTM for research dealing with large datasets that seek to test theories that have a taxonomic dimension, and discuss how the use of the statistic has advanced theory and methodological development in Criminology. Specifically, the authors reiterate that GBTM has advanced Criminologists' knowledge of the heterogeneous pattern of the age-crime curve and in the field of developmental Criminology overall with established researchers such as Farrington and Moffitt utilizing GBTM to analyse theories of antisocial and delinquent behaviour (see Nagin and

Odgers, 2010 for description). Nagin and Odgers (2010) note that during the last two decades, since the original Nagin and Land (1993) article was published, more than 80 applications of GBTM have been utilized in Criminology alone. Outside of Criminology, the authors stress that GBTM has been applied by clinicians within Psychology, Medicine, and Epidemiology (see Bohnin, Dietz and Schlattmann, 2000). It is interesting to note though, that within their discussion of the utility of GBTM and how the use of the statistic has advanced the study of Criminology, the application of GBTM toward crime and place research is not recognized. It is arguable that this particular application of GBTM is not as well known within Criminology and provides a solid argument for expanding its use and highlighting its utility within crime and place studies.

Limitations of the Group-Based Trajectory Model (GBTM)

GBTM is a semi-parametric statistic; as such, it functions on a certain set of assumptions regarding the nature of the data (see Weakliem and Entner Wright, 2009). GBTM assumes independence between repeated measures over time for each observation. With regard to this dissertation, this means for example, that the number of crimes for a group of streets in one particular trajectory for one year (ex.1995) is completely independent of the number of crimes on those same streets for the following year (ex. 1996)(Nagin, 2009). This assumption may be problematic in that Criminologists are aware that neighbourhoods display relatively stable characteristics from one year to the next and that short of major changes (ex. development of transit routes, gentrification or re-zoning), crime levels are likely to resemble one another from one year to the next due to the similarity of neighbourhood level characteristics.

In addition, GBTM does not account for any spatial correlation. In terms of the crime data for this study, this would mean, for example, that the crime count for the ‘300 block of Kingsway’ is completely independent of the crime count from its neighbouring blocks- the 200 or 400 block of Kingsway. Once again, this assumption may be problematic as Criminologists are aware that criminal activity does not exist in a geographic silo; rather, that problematic streets are often directly adjacent to one another due to mirroring neighbourhood qualities.

Lastly, GBTM assumes that the variance seen between different trajectories is a reflection that these groups are completely distinct subpopulations. For example, if one were to extrapolate this statistical assumption to Weisburd's (2004) findings, it would infer that Seattle, WA is comprised of 18 entirely distinct subpopulations of street segments that exist independently of one another and evidence unique crime patterns over time (Harlan Campbell, personal communication, February, 2011)[2]. One must view these results with caution, as the chosen model for GBTM is based on the best, most stable BIC score, and may not necessarily reflect the true 'reality' of distinct subpopulations of crime volume throughout a city.

Perhaps the most notable challenge of GBTM is the inability of the application Proc Traj to accommodate counts greater than 50. When faced with these counts, the software treats them as outliers and truncates these cases to 50. Weisburd et al. (2004) discusses this difficulty by stating that previous studies employing GBTM did not note concern over this as the variable of interest for many of these studies was the number of convictions for individual offenders, and coming across more than 50 would be a rarity. However, when applying GBTM to crime counts of street segments, the prevalence of cases greater than 50 is inevitably larger. Having said that, this affected only one percent of Weisburd et al.'s (2004) street segments over the 14-year period. The Vancouver dataset has approximately 3.6% or 468 out of 12,980 street segments with at least one entry above 50. The GBTM replaced all of these streets with a count of 50. Weisburd mitigated this shortcoming by estimating the number of trajectories based on the truncated data, but then graphically displaying the un-truncated, actual data for presentation purposes.

Due to the fact that the Vancouver dataset evidenced a significant proportion of street segments with crime counts greater than 50, it was decided that an alternative

[2] Harlan Campbell is a researcher with the Interdisciplinary Research in the Mathematical and Computational Sciences (IRMACS) Centre at Simon Fraser University.

trajectory analysis method be employed that would not require the counts for these 468 streets to be truncated at 50. Arguably, with the focus of this dissertation on micro crime places, the streets exhibiting large volumes of criminal activity over the 16-year period are the most interesting to explore and one would want to ensure that their existence is part of the final trajectory results. It is held that the truncation limitation may display trajectory results that are not entirely representative of Vancouver's crime volume picture. In order to ensure that the trajectory analysis produced a valid result for this dissertation, an alternate technique was carried out to augment the GBTM method. Specifically, the non-parametric statistic, k-means, provides a valid means by which to carry out the same type of trajectory analysis offered by the software Proc Traj, yet does not require a truncation of cases greater than 50. KmL is the specific statistic that uses the *k-means* approach, which is designed to specifically analyse large, longitudinal datasets (Genolini and Falissard, 2010). The next section will discuss the k-means approach at length. It is important to note that all the figures presented in this Dissertation will show un-truncated data, strictly for visualization purposes. However, as discussed above, the generation of the GBTM model involves truncated data, at a maximum count of 50.

K-means and Trajectory Analysis

K-means is a non-parametric statistical technique used to analyse longitudinal data with the goal of identifying clusters of cases that share similar traits (Genolini and Falissard, 2010). The technique was originally developed by Calinski and Harabasz (1974) where a 'dendrite method for cluster analysis' (i.e. the k-means approach) was discussed at length. Calinski and Harabasz reiterate that this dendrite method was developed out of the shortcomings of other cluster analysis techniques, which at the time did not provide a precise definition of cluster groupings. Additionally, the authors stress that k-means was a technique developed to get around the problems identified with the 'within-group sum of squares' cluster analysis in that the k-means technique ensures that each data point is connected with its nearest neighbour. Calinski and Harabasz (1974) also discuss the development of the 'variance ratio criterion', as the method by which their 'dendrite method' identifies the optimal number of clusters. This later became known as the *Calinski Criterion* (see Genolini and Falissard, 2010) and functions in a similar way to the Bayesian Information Criteria discussed in the previous section on GBTM.

K-means functions on an ‘expectation – maximization algorithm’ in which each observation is initially assigned to a cluster, and the expected group membership for each value based on the average value of other cases in the same group is repeatedly determined with each iteration, until the number of clusters/groups remains stable and does not change (Harlan Campbell, personal communication, January, 2011). The optimal number of identified clusters is represented by the Calinski Criterion score, as is the case with the BIC in the GBTM. Genolini and Falissard (2010) reiterate that the optimal Calinski Criterion score for any k-means model is one that “maximizes the between-matrix variance and minimizes the within-variance” (p. 320).

There are various versions of the k-means statistic that exist, however, Genolini and Falissard (2010) explain that many have considerable drawbacks in that they cannot deal with missing values and require the user to manually re-run the statistic several times in order to find the optimal number of clusters. In order to ameliorate these limitations, the authors developed KmL, which is a package, designed to implement the k-means statistic in the programming language, *R*, and took approximately 3 hours for the model to converge. This was considerably faster than the process observed in SAS for the group-based trajectory model. It is explained that KmL allows the user to run the expectation – maximization algorithm many times while varying the starting point or the number of clusters one is looking for. In order to compare the more widely used group – based trajectory model (GBTM), with the results from k-means, Genolini and Falissard tested both methods on both an artificial and real dataset and critically review the results. In the first comparative analysis, the authors worked on 5,600 datasets varying the shape of the data, the number of subjects in each cluster and the personal variations of each case. The results showed that for the most part, k-means and Proc Traj “gave very close results” (Genolini and Falissard, 2010, p. 323). The next comparative analysis was based on two real datasets. The first stemmed from the Quebec Longitudinal Study of Child Development, which sought to investigate the association between sleep duration of children and cognitive functioning at school. Approximately 1,492 families participated in the study until the children were 6 years of age. Both Proc Traj and k-means identified a four cluster solution with the dataset, showing that cognitive functioning seem to vary between groups of children which were sleeping consistently less than 10 hours per night, versus those whose sleep duration increased over time, versus those who consistently slept 10 hours per night versus those who consistently slept 11 hours per night (Genolini and Falissard, 2010). The last comparative analysis was based on a study of adolescents hospitalized for anorexia nervosa. The data originated from a study seeking to examine how hospitalization for this disease affected social integration in adulthood and was comprised of 311 subjects aged 0 to 26 years. Genolini and Falissard (2010) report that the k-means statistic found an optimal solution within four clusters of adult integration patterns. Proc Traj was unable to identify any clusters, either stating that the data showed a ‘false convergence’ or gave incoherent results.

The k-means statistic has been commonly used in Criminology as a form of cluster analysis to identify trajectories of similar patterns with longitudinal datasets. Huizinga, Esbensen and Weiher (1991) implemented the k-means statistic to examine the offending trends of 1,530 Denver youth over a two-year period (1987-1988). Neighbourhood characteristics, parental attitudes towards deviance and peer influences were examined amongst two age groups; those aged 7 – 9 and those aged 11 – 15. In the first group, the k-means statistic identified the existence of six clusters of developmental behaviour. For example, one cluster contained children who had parents with above average views about the wrongness of children’s deviant behaviour and displayed less than average levels of impulsivity. For the second age group, k-means identified five clusters that were stable and robust. As with Weisburd et al. (2004), the clusters were given categorical names to develop a sort of nomenclature of offending patterns; ‘pro-social’, ‘parent attitudes’, ‘pro-delinquent’, ‘delinquent beliefs’, ‘impulsive/hyperactive’ and ‘delinquent friends’. Similar to the clusters of ‘stable’, ‘increasing’ and ‘decreasing trajectories’, the analysis allowed for a simplistic identification of patterned behaviour from a large dataset over time.

In a more recent article, Mowder, Cummings and McKinney (2010) implemented the k-means statistic to explore the resilience of 215 male and female juvenile offenders who were committed to a juvenile facility. Each participant completed the Resiliency Scales for children and adolescents. This scale consisted of three subscales: Optimism, Self-Efficacy and Adaptability. The k-means statistic identified a four-cluster solution, which was chosen based on the "theoretical interpretation of the clusters and the model's performance in stability, reliability and validity assessments" (pg. 328). The results led to insight and discussion on the extent to which individual, environmental and protective risk factors affect juvenile resiliency in incarcerated youth populations.

It appears that the k-means statistic may be the more accurate trajectory analysis to implement when the data are non-polynomial in nature. As a non-parametric statistic, it does not require data to fit a specific distribution, and appears to be able to accommodate larger counts better than the GBTM in Proc Traj. This is particularly important for this dissertation, as the data do not entirely meet the parametric requirement of the GBTM in fitting a linear pattern. Genolini and Falissard (2010) stress that when the k-means statistic is supplemented by GBTM, the researcher is given a thorough picture of longitudinal patterns within a large dataset and if the two statistics reveal comparable results, one can be very confident in the validity of the clusters identified. However, as a non-parametric statistic, one must observe the findings from k-means with caution as it an exploratory tool and does not statistically test for the 'reality' of the groupings it generates. By implementing both techniques, this dissertation provides a thorough and valid representation of the data and offers conclusions towards crime prevention efforts, including problem-oriented policing as well as contributes to the crime and place literature within Environmental Criminology.

Spatial Analysis

Kernel Density Estimation

Once the group-based trajectory model was completed and 18 separate trajectories of criminal activity over the 14 year period in Seattle, WA were identified, Weisburd et al.(2004) conducted a geographical analysis of the stable, increasing and decreasing trajectories. In order to determine whether these trajectories were randomly distributed across the city or whether they exhibited spatial dependence in some manner, a kernel density estimate was conducted. The kernel density estimate provides “a visual interpretation of the number of events across a geographic area, estimated at every point in that area” (Weisburd et al., 2010, p. 304). This allowed Weisburd et al. (2004) to determine whether the street blocks identified as stable, increasing or decreasing in criminal activity were located, for example, in affluent versus lower income areas of Seattle or whether they were found in many regions of the city. Upon investigation, it was found that all three types of street segments were located throughout the city, but stable trajectories were more densely located in affluent areas, whereas both increasing and decreasing trajectories were somewhat concentrated in the urban center of Seattle.

For this dissertation, a kernel density estimation was also carried out in order to examine the spatial distribution of trajectories identified as either stable, increasing or decreasing throughout Vancouver, B.C. from 1991 – 2006. The statistical output of the kernel density estimation provides a visual representation of the study area with varying degrees of crime density that are color coded and easily analyzed. The process begins by aggregating point data to uniform grids (cells) to smooth the surface of the density of points across the study area (Chainey and Ratcliffe, 2005). A specified radius, called a bandwidth, is then generated and the statistical program will calculate a weight for each point on the grid’s radius (Moller, 2003). The points that are closer to the center of the cell receive a higher weight and thus contribute more to the cell’s total density value. This process provides a ‘kernel estimate’ (Chainey and Ratcliffe, 2005). Kernel estimates are calculated for all cells in the study area and are summed to provide a continuous or smooth estimation of crime density for the entire study area. For this dissertation, the kernel density estimates were completed in Crimestat. The map units were set in meters with an output cell size of 100m^2. The bandwidth interval was 100m to 1000m (1km) for each estimation produced.

Visualization Maps

In addition to the kernel density estimates which will provide an indication of the intensity of any stable, increasing or decreasing 'street block clusters' throughout Vancouver, B.C., a simple visualization map was also produced. Weisburd, Groff and Yang (2011) as well as Groff, Weisburd and Yang (2010) generated visualization maps of the Seattle trajectories, by dividing the city into its Northern, Eastern, Southern and Western regions and then displaying the locations of the identified street block crime trajectories, as per the group-based trajectory model analysis. For example, Weisburd et al. (2011) found that in the Central area of the city, which includes the downtown core, a sizeable number of the high crime trajectory street blocks were located as well as an increased variation of all types of street block trajectories. The importance of presenting such visualization maps is stressed as they provide a simplistic manner in which to examine micro geographic patterns, in this case at the street block level. When Weisburd et al. (2004) and Groff et al. (2010) display the visualization maps of Seattle, WA, one is reminded of the utility of using the street block for crime analysis, as opposed to more macro units, that may mask any hot spot patterns identified and dilute the heterogeneity of observed patterns at micro places.

The following chapter will present the results of the group-based trajectory model replication from Weisburd et al(2004) based on Vancouver Police Department data, as well as the results from the additional cluster analysis technique, k-means. The spatial results will also be presented.

Chapter Four: Results

This chapter will display the results of this dissertation. The chapter is divided into three components. First, the descriptive statistical results regarding the overall distribution of criminal activity on Vancouver's street blocks from 1991 – 2006 will be summarized. This will be followed by a presentation of the trajectory analyses for both the group-based trajectory model and k-means methodologies. As per the methodology employed by Weisburd et al. (2004), any street segment with cases greater than 50 were truncated to 50 when analysed by the group-based trajectory model (GBTM). However, for the purposes of presentation, all figures displaying the results for the GBTM will present the actual crime counts. Lastly, the geographic display of both the street segment trajectories and their corresponding density estimates will be examined.

Describing the Overall Distribution

The yearly distribution of these crimes is displayed in Table 4, from 1991-2006. The data in this table are also displayed in Table 2 and Figure 1. As discussed in the previous chapter, the crimes analyzed include 22 index crimes spanning both property and violent offences reported to the Vancouver Police Department. The highest volume of crimes was seen in 1996, with 89,143 calls for service to the Vancouver Police Department. Conversely, the lowest level of crime was noted at the most recent year of 2006, with only 46,079 calls for service recorded. In 1991, for the above-cited calls for service, the Vancouver Police Department received 76,963 calls. By 2006, this had declined to 46,079, representing a 40% decrease. Figure 3 displays this downward trend. It is interesting that Vancouver's crime volume over the study period exhibits a similar downward trend to that of many other major cities in North America and Europe during the same time frame (Ouimet, 2002; Mishra and Lalumiere, 2009; Levitt, 2004).

Table 4. Vancouver Police Department Calls-for-Service counts

Year	Total Calls for Service
1991	76,963
1992	78,176
1993	75,824
1994	75,041
1995	85,122
1996	89,143
1997	80,973
1998	71,817
1999	67,676
2000	62,539
2001	56,942
2002	57,828
2003	56,459
2004	56,360
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Figure 3. Vancouver Police Department Calls-for-Service counts

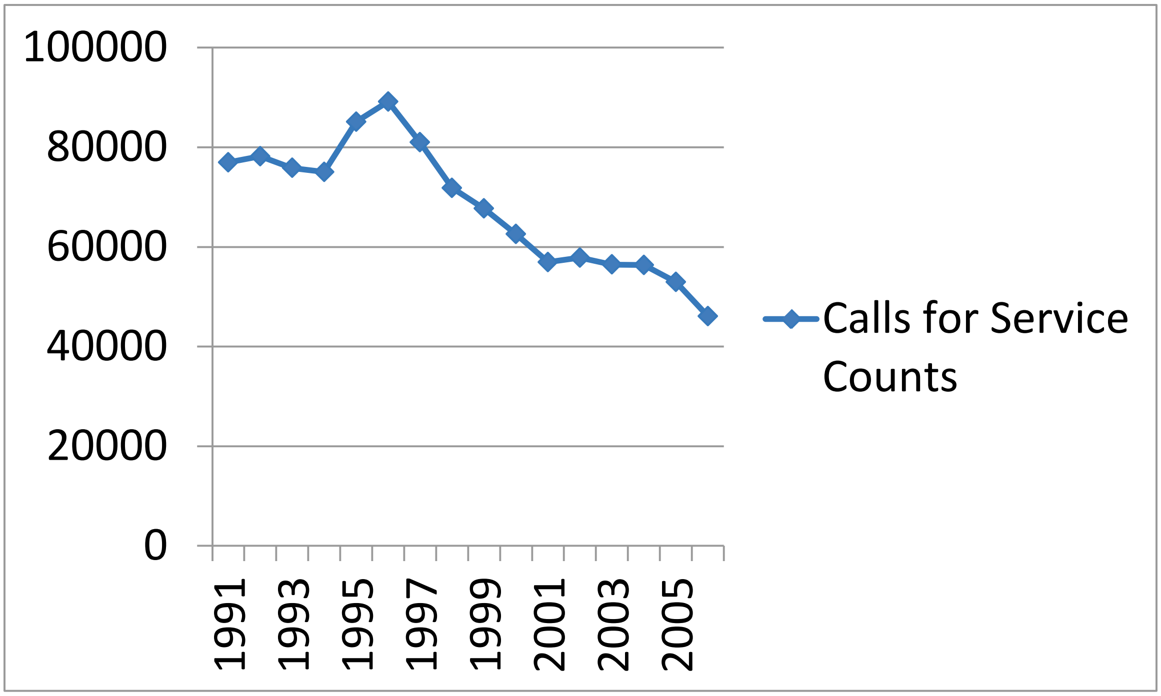


Table 5 displays the comparison between the Weisburd et al. (2004) data and the Vancouver, BC data for this proposed dissertation.

Table 5. Comparative Details of Seattle PD and Vancouver PD data

Category	Weisburd et al. (2004) and Seattle Police Data	Curman Dissertation (2011) and Vancouver Police Data
Years Included	1989-2002 (14 years)	1991-2006 (16 years)
Data Source	Incident Reports	Calls-for Service Reports
Sample Size	1.5 million incident reports	1.08 million calls-for-service
Unit of Analysis	Street Segments	Street Segments
Number of Street Segments	29,849	12,980
Location Exclusions	Intersections, police precinct and places without a geographic identifier	Intersections, police precinct, and ‘no known location’
Crime Decline over study period	-24%	-40%

Table 6 provides the overall distribution of the crime types over the 16-year period. The top five crime types constitute almost 80% of the criminal activity in the city. The most common category was theft from automobile (24.5%), followed by break and enter (22%), theft (19%), assault (7.7%) and stolen automobile (6%).

Table 6. Overall Distribution of Crime Types (1991-2006)

Crime Type	Percent (%)
Theft from Auto	24.5%
Break and Enter	22%
Theft	19%
Assault	7.7%
Stolen Auto	6%
Other	20.8%
Total	100%

In keeping with the methodology outlined by Weisburd et al. (2004), the next step was to fit each of the 1.08 million calls for service to a street segment in Vancouver, BC in order to aggregate the data for the longitudinal trajectory analysis (see next section) . Vancouver, BC has 12,980 street segments and each call for service was geocoded and aggregated to this street segment network, with a hit rate of 98%. Over this 16-year period, there was an average of 5.25 calls for service per street segment.

Descriptive results show that on average, 40% of street blocks in Vancouver did not experience any calls-for-service during the 16-year study period. This indicates that 100% of all the criminal activity was located on only 60% of all possible streets throughout the city (approximately 7,724 streets out of 12,980). Further analysis reveals that out of the 7,724 street segments evidencing criminal activity, only 7.8% of those streets accounted for 60% of all crime over the 16-year period. Additionally, 34% of streets exhibited 1-4 calls for service, 18% saw 5-15 calls for service, and 5% saw 16-50 calls for service. Only 3.6% of street segments experienced over 50 calls for service throughout the 16-year period. These results indicate that criminal activity appears concentrated at the street segment level throughout Vancouver, supporting the conclusion of the existence of hotspots within the city.

Figure 4 reports the percentage of street segments in each year evidencing a specific number of calls for service made to the Vancouver Police Department. Although there is variability, the trend is consistent in that the street segments with no recorded calls for service over the study period ranges minimally from 32.3% (1996) to 46.5% (2005). Comparatively, the range of street segments experiencing the majority of crime (i.e. 60%) ranged from a low of 6.4% of street segments in 2005 to a high of 8.49% of street segments in 1995. Figure 4 displays these descriptive results.

Figure 4. Crime Concentration Stability across Vancouver Street Segments

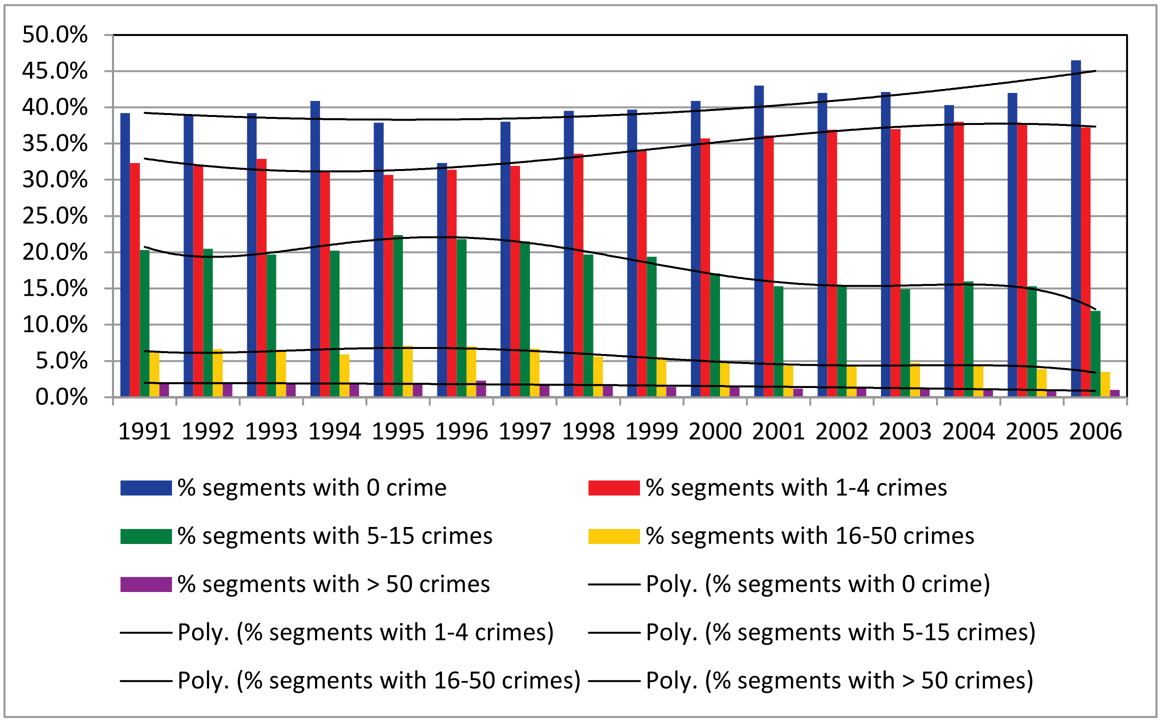
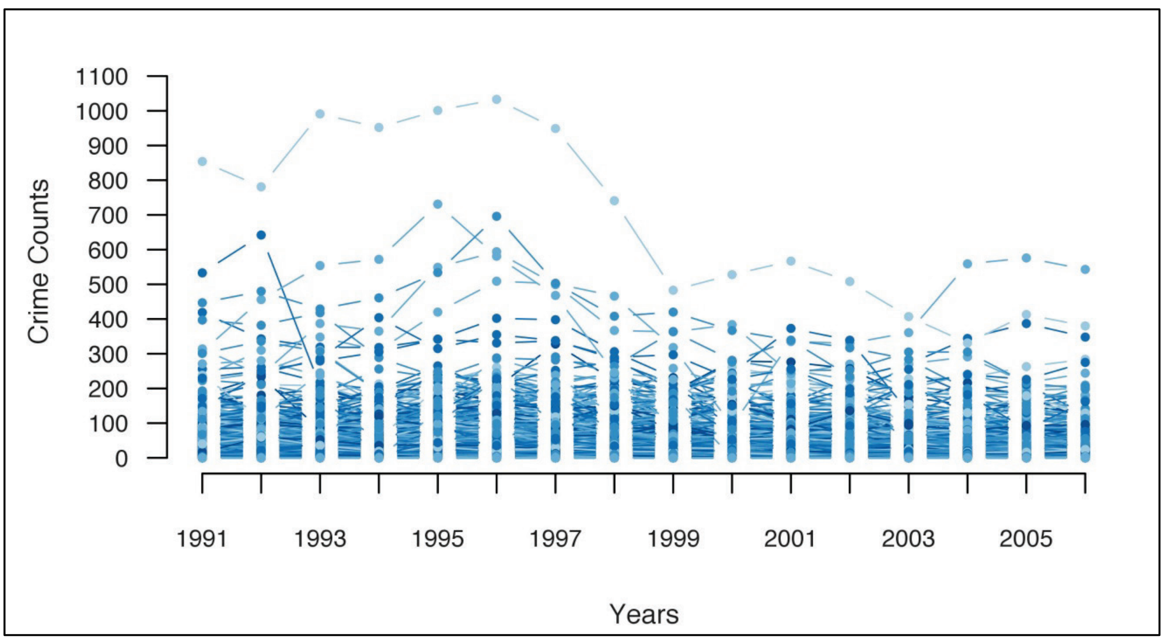


Figure 4 shows that the proportion of streets with fewer than 5 crimes per year rose during the study period whereas the proportion of streets with crime counts between 5 and 50 decreased. However, in general, it is clear that the proportion of street segments exhibiting a specific amount of criminal activity remains quite constant from year to year. This finding supports the central tenet of Environmental Criminology that crime is not randomly distributed, but rather is non-uniform in nature. However, what is not clear is whether these concentrations of criminal activity exist on the same street segments from one year to the next. More specifically, do these crime concentrations persist over time at the street block level, or do differing street segments account for the various proportions of criminal activity from one year to the next? Weisburd, Groff and Yang (2010) reiterate the importance of answering this question to establish whether such patterns are indicative of simple concentrations of crime or a *stability* of crime concentrations over time. In order to shed light on this area of research, Weisburd et al.'s (2004) group based trajectory model was replicated, in addition to another trajectory analysis technique, k-means, as summarized in the following section.

Group-Based Trajectory Model (GBTM)

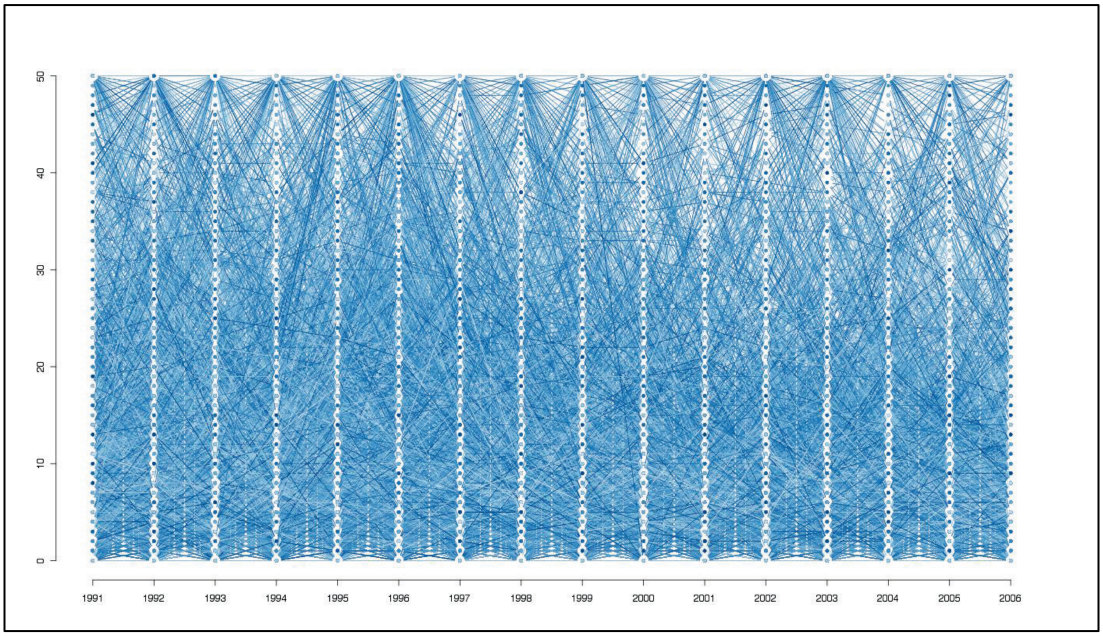
This section details the trajectory results using the group-based trajectory model (GBTM) in SAS, through the Proc Traj application. Figure 5 displays the yearly crime counts for all 12,980 street segments from 1991 to 2006.

Figure 5. Yearly crime counts for 12,980 street segments in Vancouver, B.C. from 1991 to 2006.



As discussed in Chapter 3, SAS Proc Traj requires the truncation of any data count greater than 50. This affected 3.6% of the street segments. Figure 6 displays the crime counts for all 12,980 street segments with 467 streets truncated at 50 to accommodate the limitations of the software.

Figure 6. Yearly crime counts for 12,980 street segments in Vancouver from 1991 – 2006, with counts above 50 truncated to 50.



When applying the group-based trajectory model to the Vancouver dataset, it was found that the quadratic shape was a better fit than the linear model. The exercise began with fitting the data to only two trajectories and then increasing the number of clusters from there. Additional groups were added, each time showing an improved Bayesian Information Criteria (BIC) score. When reaching a 10 group solution, the process was stopped due to a warning of convergence problems and flawed results. For example, SAS Proc Traj would yield trajectories with '0' crime counts. This was interpreted to indicate that the solution with more than 10 groups was not feasible (Harlan Campbell, personal communication, February, 2011).

The next step involved testing the viability of the 10-group solution. This involved re-running the ten-group model with different initial starting values. The results showed different solutions; that is, differing number of trajectories each time. This indicated that the ten-group solution was neither stable nor reliable in nature. Following that, nine-group, eight-group and seven-group solutions were similarly tested and only the 7-group solution evidenced stability (Harlan Campbell, personal communication, February, 2011). The eight and nine-group solutions did not converge to the same solution when the initial starting values were altered, whereas after testing the seven-group solution, each result yielded seven groups with stable and comparable slopes and intercepts. Therefore, the seven-group solution was chosen as the final model for this study with a BIC score of -388,726.68. Table 7 displays the average range of crime counts for each trajectory within the study period of 1991 – 2006 and Figure 7 shows these results for each year for all seven trajectories.

Table 7. Average Lowest and Highest Crime Counts for Trajectories 1 – 7 (1991-2006)

Trajectory	Lowest Crime Count	Highest Crime Count	% of all Street Segments
3	0.04	0.08	27%
1	0.6	1.0	22%
2	1.5	3.3	21%
4	3.2	7.4	16%
5	7.0	12.9	7%
6	14.6	29.9	4%
7	55.1	97.6	3%

Figure 7. *Average crime counts for 1991-2006 for Trajectories*

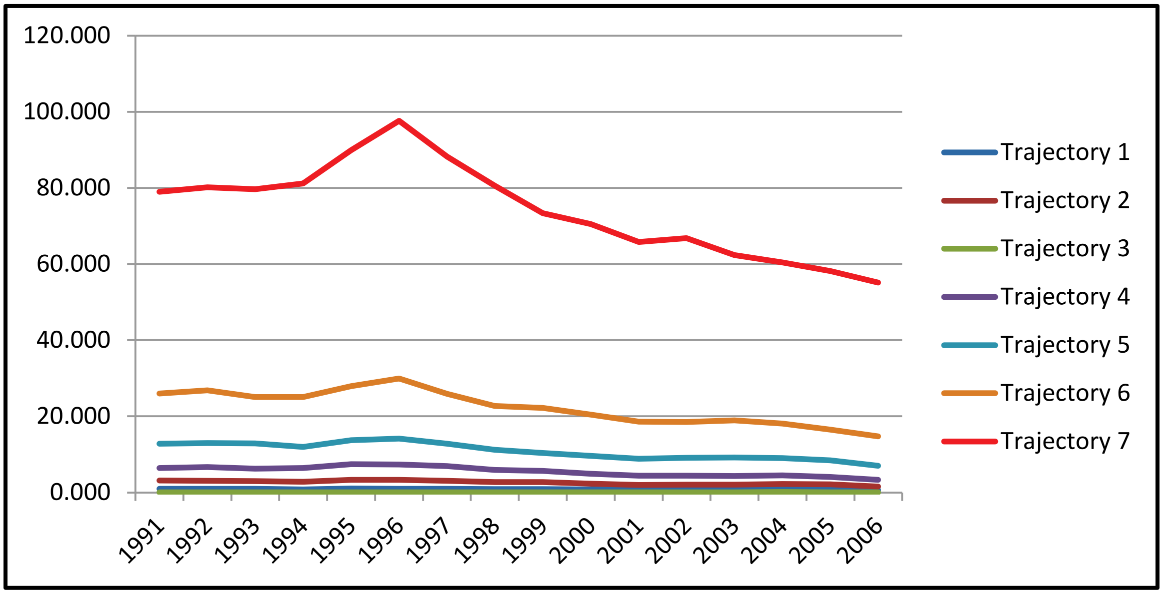
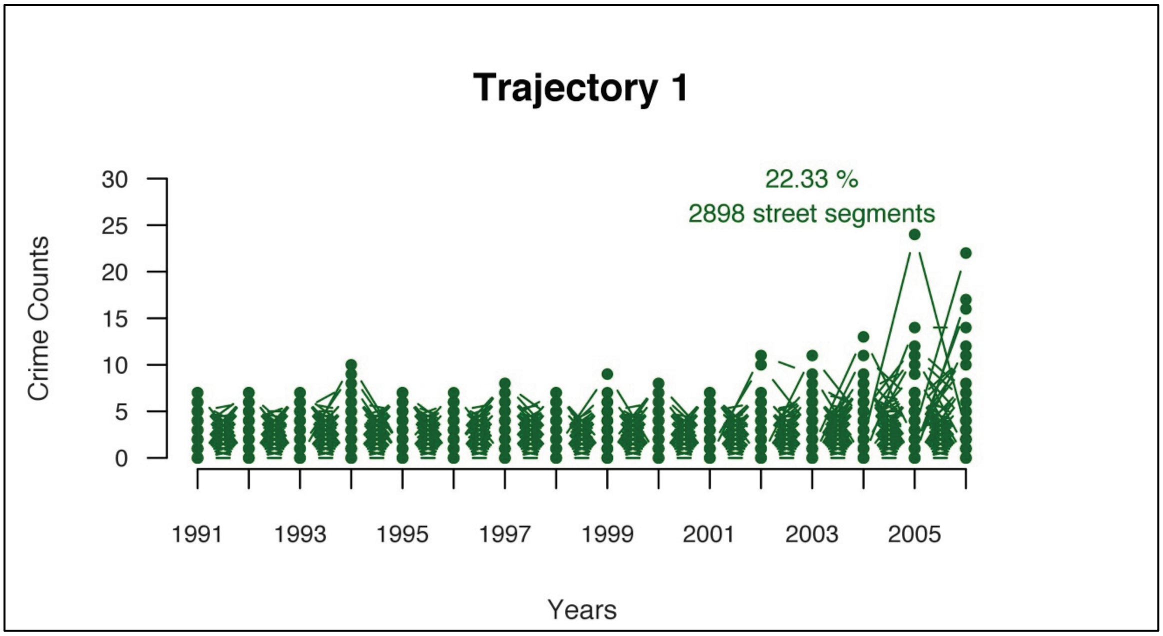


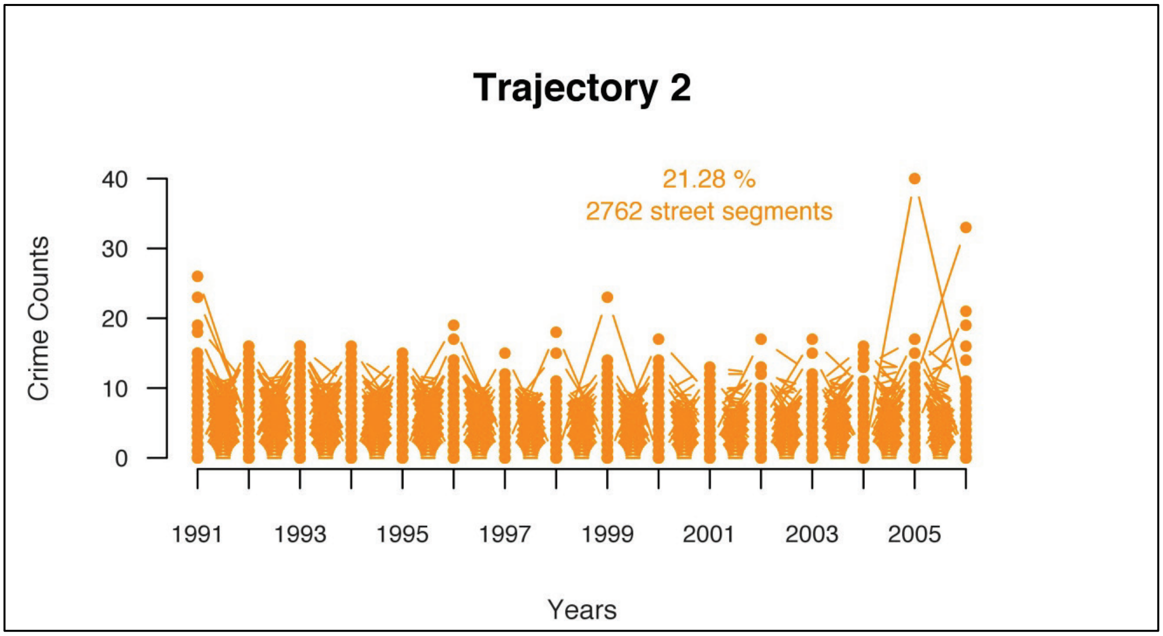
Figure 8 displays the results for Trajectory 1. This first group includes those street segments with the second lowest crime counts in the dataset and is comprised of 2,898 (22%) of Vancouver's street segments. These street segments experienced an average of 0.87 crimes over the study period.

Figure 8. Trajectory 1 in SAS Proc Traj.



Trajectory 2 included slightly higher crime counts and was comprised of 2,762 (21%) street segments. These street segments evidenced an average of 2.59 crimes from 1991-2006. Figure 9 displays the results for Trajectory 2.

Figure 9. ***Trajectory 2 in SAS Proc Traj.***



The street segments identified with Trajectory 3 evidenced the lowest levels of criminal activity. This trajectory included 3,528 (27%) street segments and evidenced an average of 0.06 crimes over the 16-year period. Figure 10 displays the results for Trajectory 3.

Figure 10. Trajectory 3 in SAS Proc Traj.

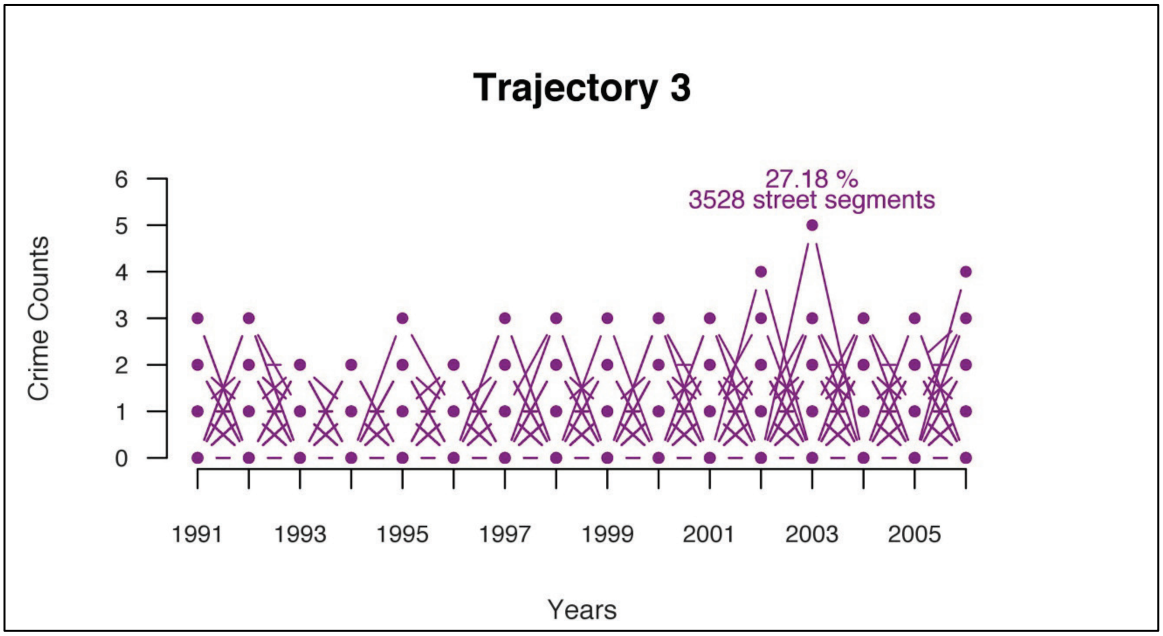


Figure 11 displays the results for Trajectory 4, which has the fifth highest crime counts in the dataset with an average of 5.55 crimes over the study period. Trajectory 4 included 2,010 street segments or 15% of the sample.

Figure 11. Trajectory 4 in SAS Proc Traj.

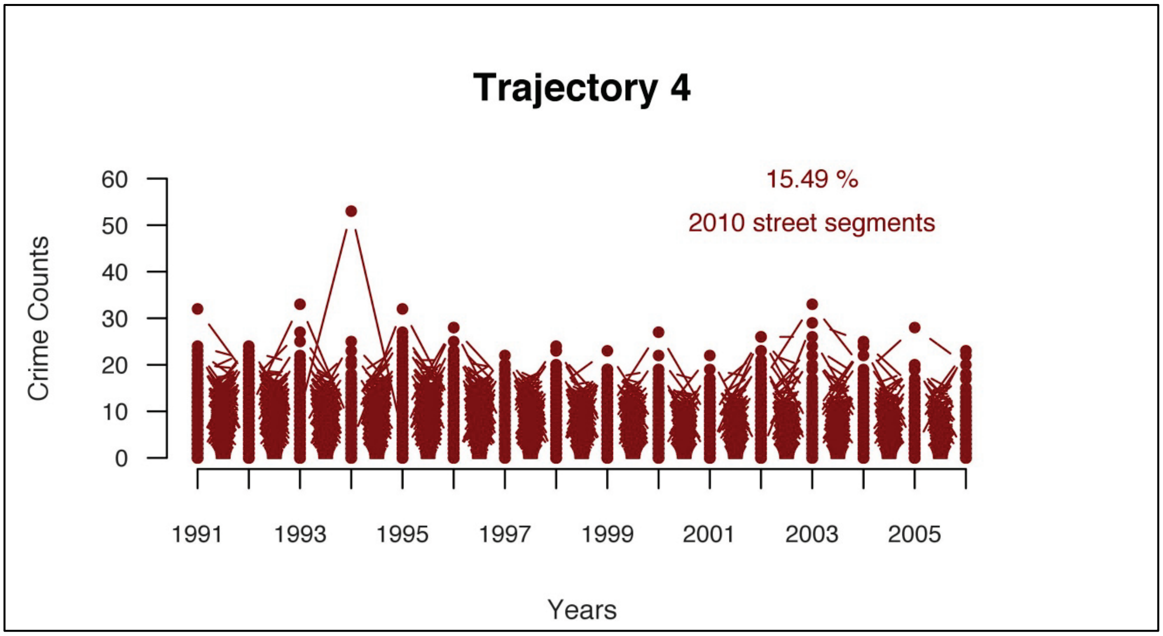


Figure 12 displays the results for Trajectory 5. This trajectory included 919 street segments (7% of the sample) and has the fourth highest crime counts with an average of 10.88crimes from 1991-2006.

Figure 12. Trajectory 5 in SAS Proc Traj.

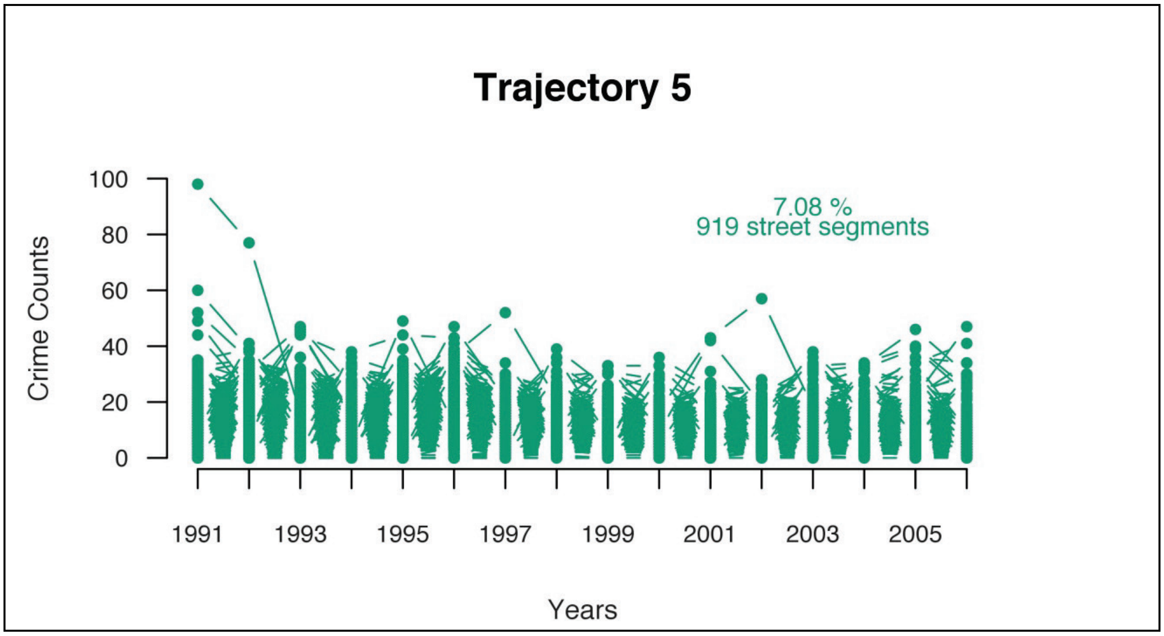
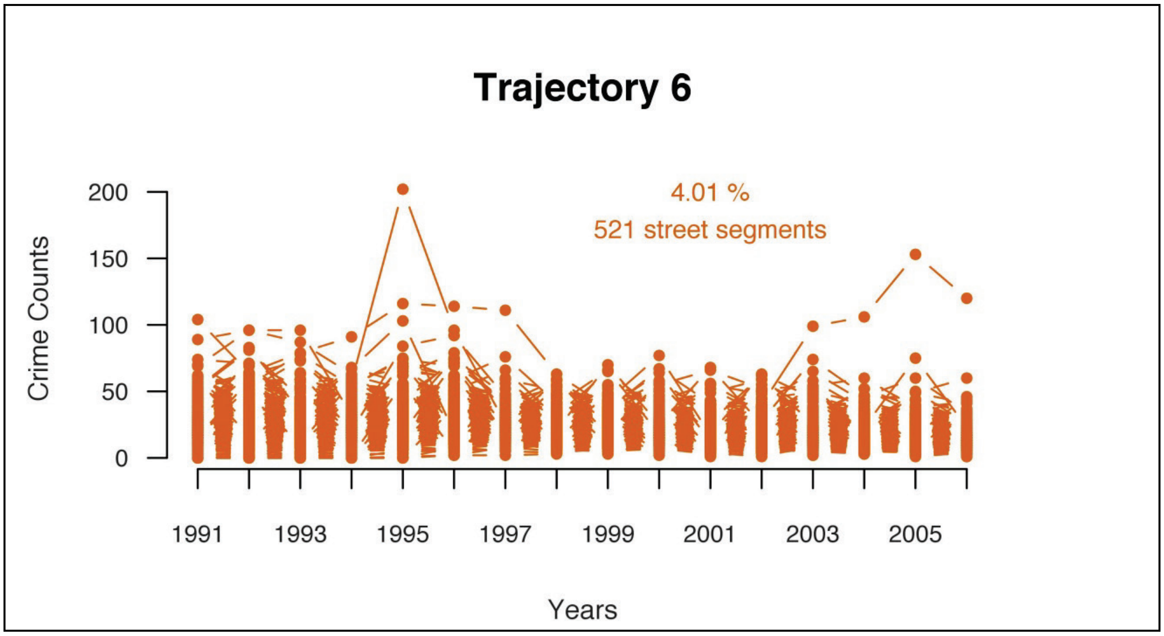


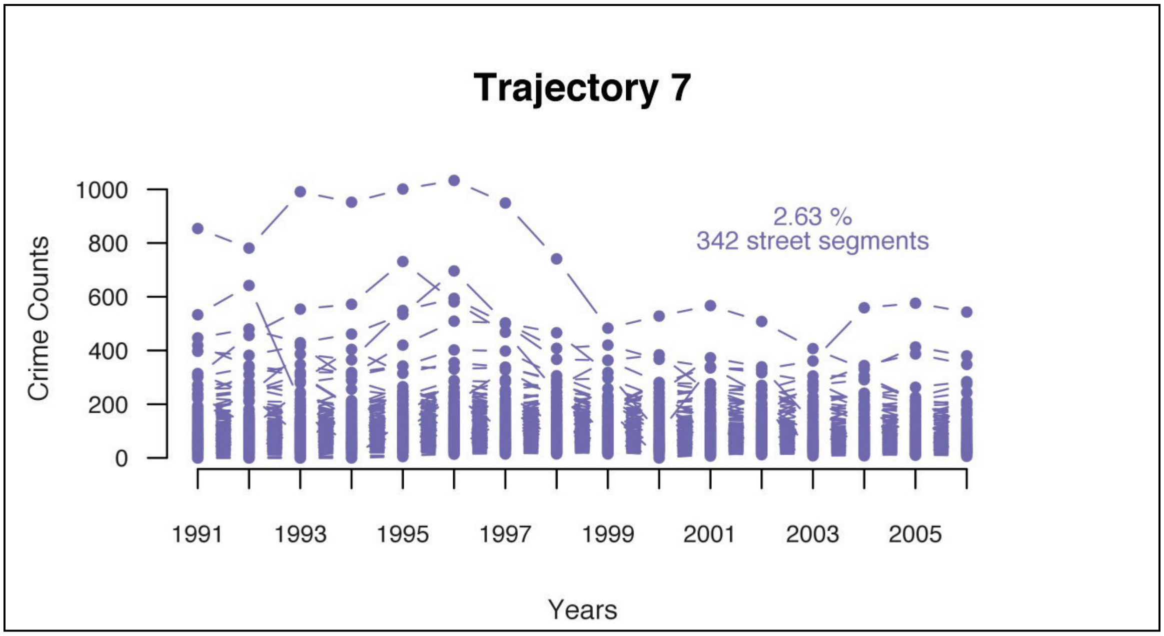
Figure 13 displays the results for Trajectory 6. This trajectory included 521 street segments or 4% of the sample and averages 22.35 crimes per year over the 16-year period.

Figure 13. Trajectory 6 in SAS Proc Traj



Lastly, Trajectory 7 has the fewest number of street segments, yet evidences the highest value of crime counts. This trajectory included 342 street segments or only 2.6% of the sample. These 342 street segments averaged 74.30 crimes per year from 1991-2006 and clearly represents the highest concentration of criminal activity in the city of Vancouver. This trajectory has the highest number of cases that had to be truncated to 50 as it exhibited the largest proportion of street segments with an average crime count greater than 50. The results are displayed in Figure 14.

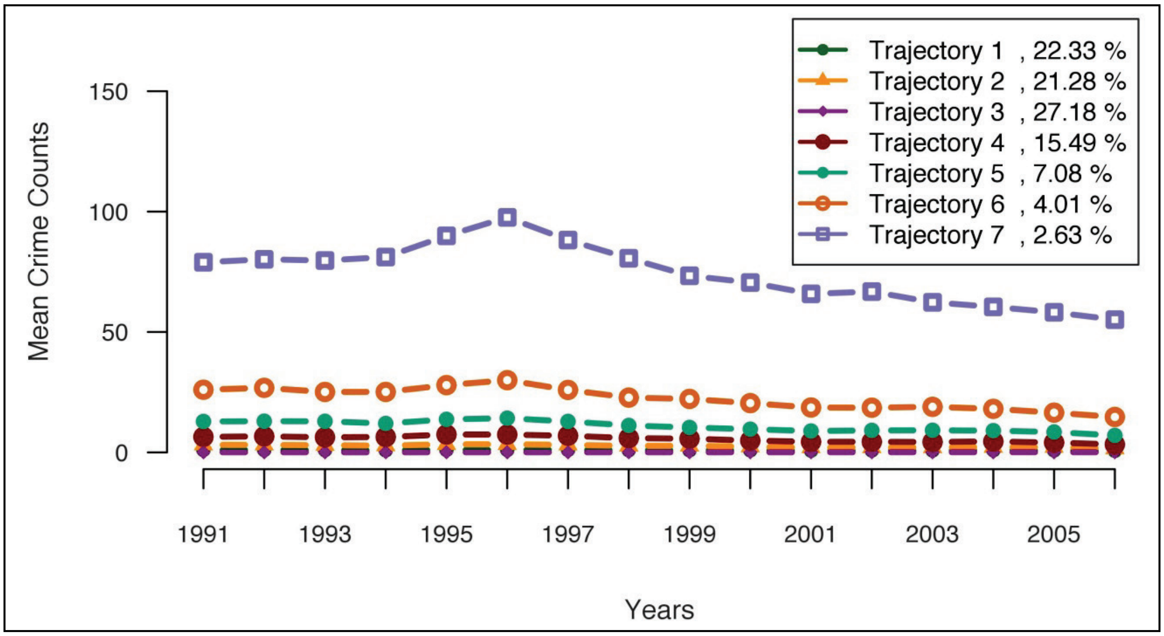
Figure 14. Trajectory 7 in SAS Proc Traj



Similar to Figure 7, the yearly averages for each Trajectory are displayed in Figure 15. The data show that all but one Trajectory (Trajectory 3) evidences a decrease in the average number of crimes occurring at the street segment level. In particular, Trajectories 2 and 4 show an almost 50% decrease in the average crime count over the 16 year period. Trajectory 3 shows a slight increase in the average crime count, however, this increase is marginal, from an average of 0.05 crimes per year in 1991 to an average of 0.06 crimes per year. As is evident in the following section, this did not constitute an 'increasing trajectory'. Perhaps most interesting from Figure 15 is the uniformity of the longitudinal trend at the street segment level. Although the trajectories have differing initial intercepts, they evidence similar slopes over time. This means that the *variation* in the average crime counts from 1991 – 2006 is comparable for each trajectory. The following section discusses this finding in detail and summarizes the method by which each trajectory was further classified as stable, increasing or decreasing in nature based on the statistical parameters provided by the software Proc Traj and the methodology outlined by Weisburd et al. (2004).

Figure 15. Average Crime Counts for Trajectories 1 through 7.

(Note: the figures in parentheses represent the per cent of street segments found in that Trajectory).



Trajectory Classifications

To further discern the patterns from Figure 15, Trajectories 1 through 7 were broken into categorical groups. A linear curve was fitted to the average number of crimes at each time point for each trajectory. This created seven linear trends that could be identified as increasing, decreasing or stable in nature depending on their slope. This process was replicated from Weisburd et al. (2004) whereby if a slope value for a trajectory was less than -0.2, it was classified as 'decreasing' in its developmental pattern; if a slope value for a trajectory was greater than -0.2 to +0.2, it was classified as 'stable' in its developmental pattern and if a slope value for a trajectory was greater than +0.2 it was classified as 'increasing' in its developmental pattern. This led to the identification of only two classifications: a stable group (see Figure 16) and a decreasing group (see Figure 17).

Trajectories 1, 2 and 3 evidence a stable trajectory in that their slopes are very close to 0 (ranging between -0.102 and +0.002). Figure 16 displays the results for the stable trajectories. Table 8 displays the corresponding fitted linear slopes and intercepts for each.

All together, these three stable trajectories represent 70% of all the street blocks throughout Vancouver, B.C. This suggests that the majority of street segments did not follow the general declining crime trend evidenced by the city of Vancouver as a whole during this time period; rather, that the majority of streets demonstrated minimal change. Despite the fact that Trajectories 1 and 2 showed negative slopes, their range was very small and could not be categorized as decreasing in nature. It is also important to note that these trajectories showed low intercepts ranging from 0.04 to 3.36. This means that for 70% of street segments in Vancouver, the crime volume was relatively low to begin with in 1991 and due to the marginal change over time; these low levels of crime remained stable over the 16-year period.

This finding is interesting in two main ways. First, it supports the central tenet of Environmental Criminology by showing that crime occurrence is not uniform throughout a city; rather, the majority of street blocks in Vancouver evidenced minimal crime volumes indicating that the majority of crime must be occurring on a minority of street segments. Secondly, this finding also supports the central tenet of crime and place literature by showing that the identified crime volumes at the street block level evidence stability over a long period. All three stable trajectories not only showed low levels of criminal activity, but minimal change in these low levels of crime, as evidenced by the fitted linear slopes.

Figure 16. Stable Trajectories

(Note: numbers in parentheses represent the per cent of street segments found in that trajectory)

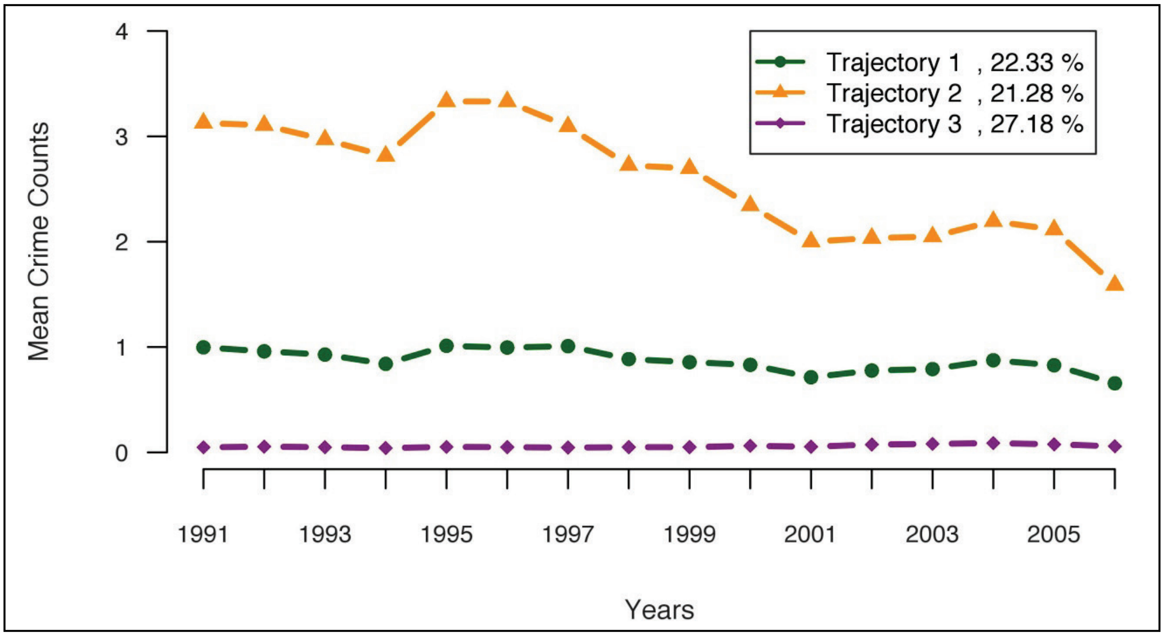


Table 8. Slopes and Intercepts for all Stable Trajectories.

Trajectories	Group	Slope	Intercept
1	Stable Low Crime	-0.017	0.999
2	Stable Moderate Crime	-0.102	3.360
3	Stable Very Low Crime	0.002	0.042

Trajectories 4, 5, 6 and 7 were all classified as showing a decreasing trend with slopes ranging from -2.068 to -0.237. These trajectories constitute almost 30% of the segments examined throughout Vancouver, B.C. Figure 17 displays the results for the decreasing groups and shows the average crime count for each year for each trajectory. Table 9 displays the corresponding fitted linear slopes and intercepts for each trajectory.

Figure 17. Decreasing Trajectories

(Note: numbers in parentheses represent the percent of street segments found in that trajectory).

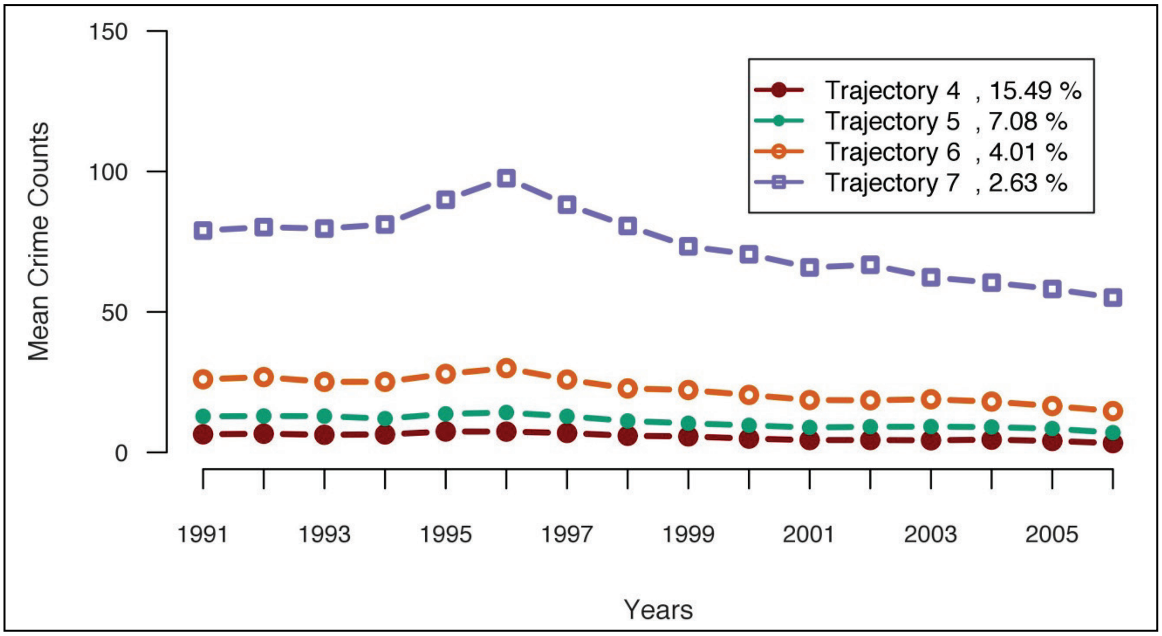


Table 9. Slopes and Intercepts for all Decreasing Trajectories.

Trajectories	Group	Slope	Intercept
4	Moderate Decreasing Crime	-0.237	7.328
5	High Decreasing Crime	-0.416	14.003
6	Very High Decreasing Crime	-0.847	28.703
7	Extremely High Decreasing Crime	-2.068	89.808

When looking at the intercepts, one finds the greatest range within these decreasing trajectories, from an average low of 7.32 crimes in 1991 for Trajectory 4 to an average high of almost 90 crimes in 1991 for Trajectory 7. As these trajectories harbour the fewest number of streets, this finding shows that very few trajectories were responsible for the majority of criminal activity in Vancouver during the study period. Additionally, the small slopes continue to support the finding that crime volume patterns are consistent over time at the street block level.

In 1991, the City of Vancouver recorded 76,963 calls for service (amongst the categories analysed). Sixteen years later in 2006, this had declined to 46,079, representing a 40% reduction in calls for service to the Vancouver Police Department. Figure 18 shows that the decreasing street segments appear to account for the overall drop in recorded crime over the 16-year period in Vancouver. What is equally notable though, is that both trajectories, stable and decreasing show a comparable pattern of overall decline during the study period. That is, both trajectories evidence a decline in recorded crime with decreasing trajectories declining 39% and stable trajectories also decreasing 40% from 1991 to 2006. This indicates that all areas throughout Vancouver evidenced similar declines in crime volume at the street segment level and that the decline in crime seen for the city overall cannot necessarily be attributed to one 'high crime area'.

Figure 18. ***Vancouver Crime Drop Analysis in crime counts***

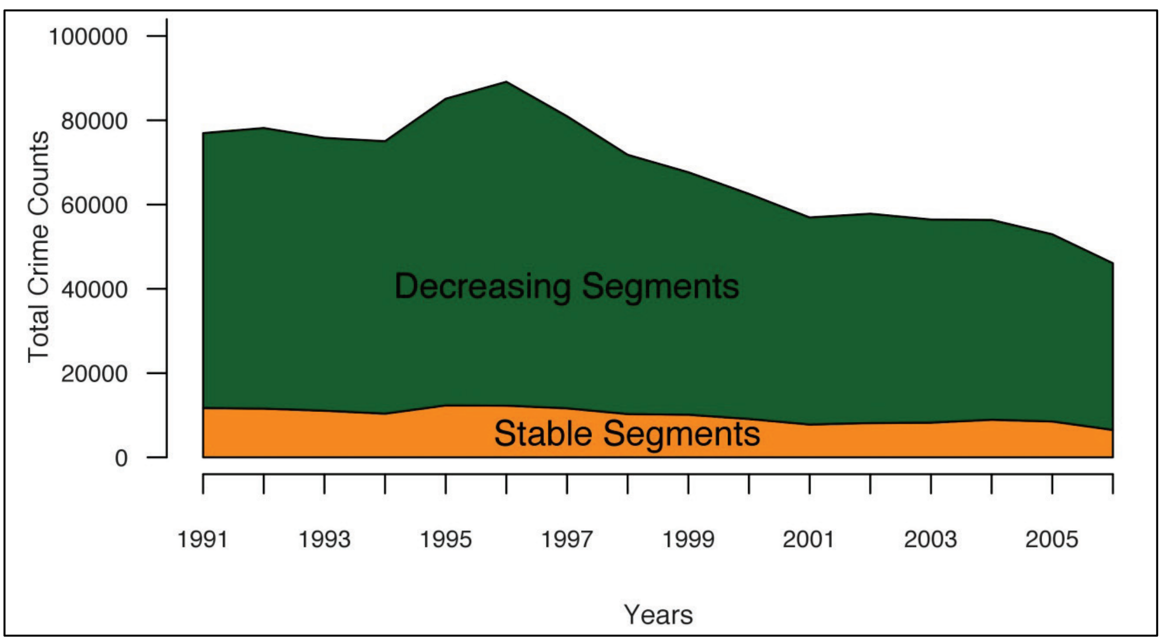
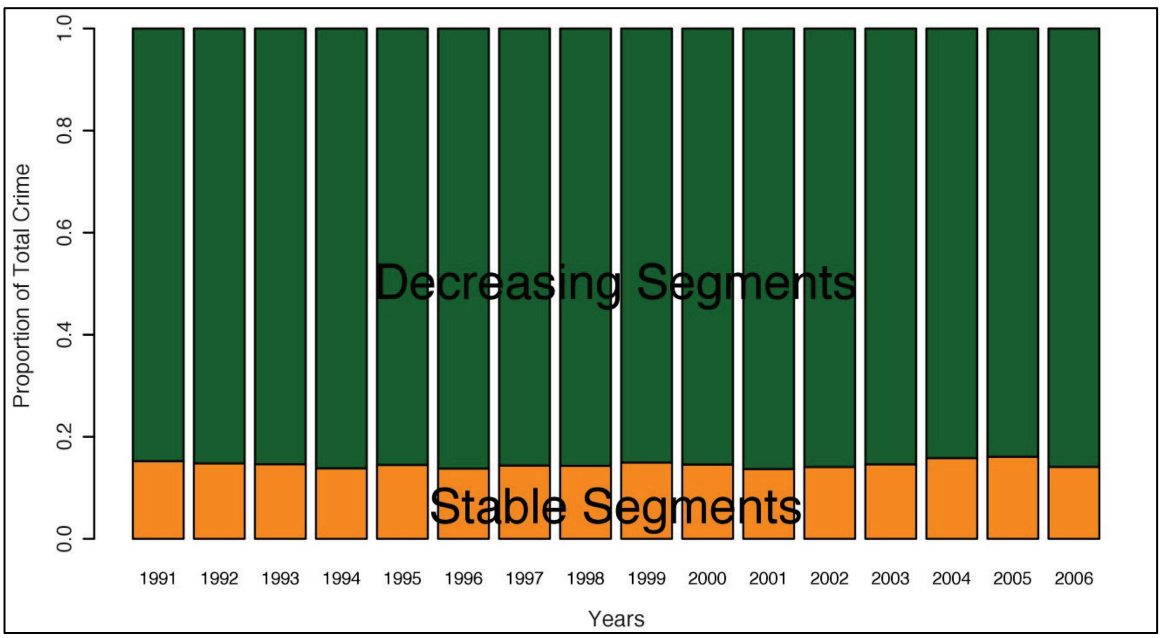


Figure 19 shows the proportion of crime accounted for by each trajectory over the 16-year period. In 1991, the street segments categorized as decreasing accounted for approximately 85% of Vancouver's crime volume and this remained largely constant throughout the study period. In tandem, the segments categorized as stable accounted for approximately 15% of the city's crime volume and this remained constant as well, with the exception of 2005 where these street segments accounted for 16% of the city's crime volume.

The next section will detail the results of the k-means statistic.

Figure 19. Vancouver Crime Drop Analysis in proportions



K-Means Results

This section details the results of the trajectory analysis using the k-means statistic. K-means utilizes the 'Calinski Criterion' (Calinski and Harabasz, 1974) to establish the optimal number of groups or trajectories within a model. For the Vancouver longitudinal crime data, the k-means statistic identified a four-group model. Figure 20 displays the Calinski Criterion scores for up to an 11-group model. It is evident that the best Calinski Criterion score fits a four-group model, and that the score declines thereafter. At four groups, the Calinski Criterion score was 12,970.71.

Figure 20. Calinski Criterion score results for k-means analysis.

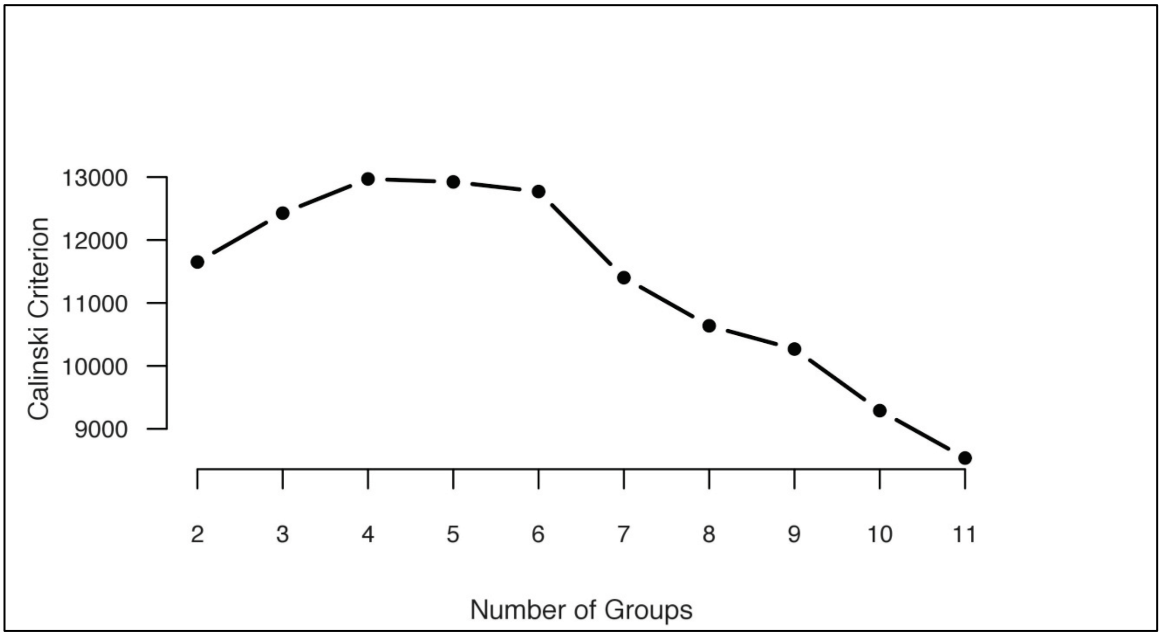
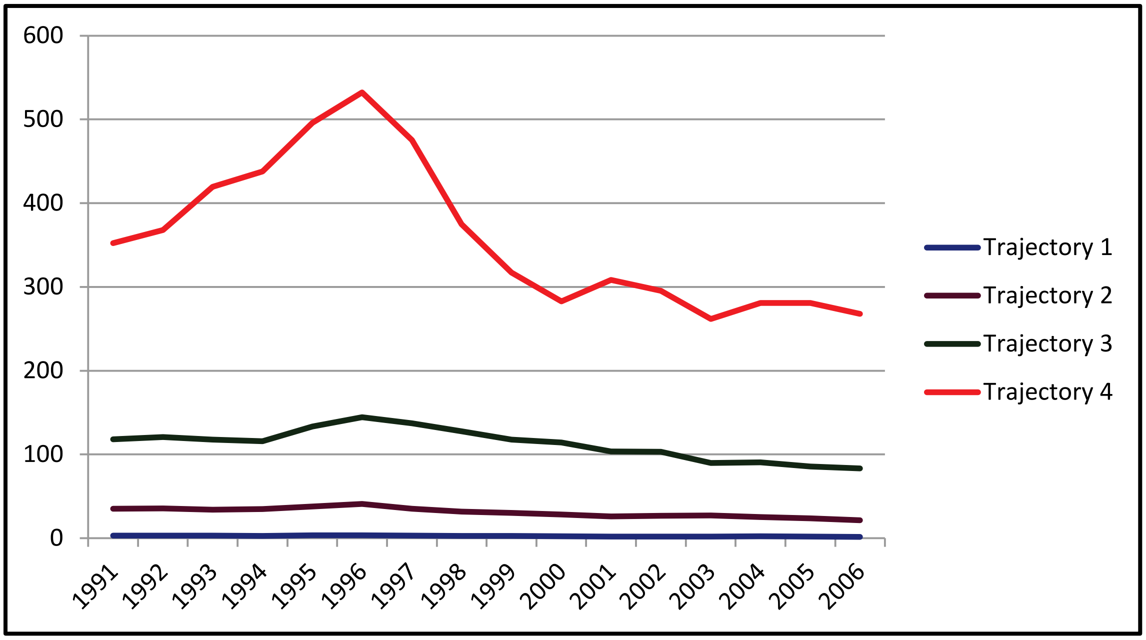


Table 10 provides the average range of crime counts for each trajectory, with Figure 21 plotting these values for visual representation. The k-means results identified a four-group model and Figures 16 through 19 display the results for Trajectories 1, 2, 3 and 4.

Table 10. Average Lowest and Highest Crime Counts for Trajectories 1 – 4 (1991-2006)

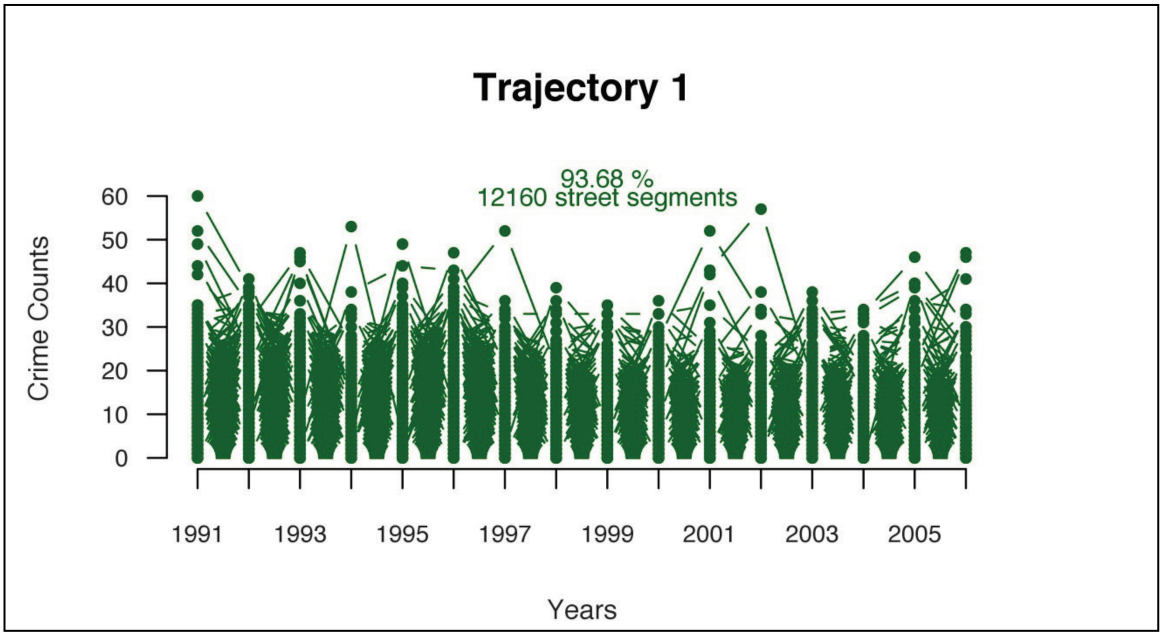
Trajectory	Average Lowest Crime Count	Average Highest Crime Count	% of all Street Segments
1	2	3	94%
2	22	41	5%
3	83	145	0.76%
4	262	532	0.07%

Figure 21. Average Yearly Totals for Trajectories 1-4.



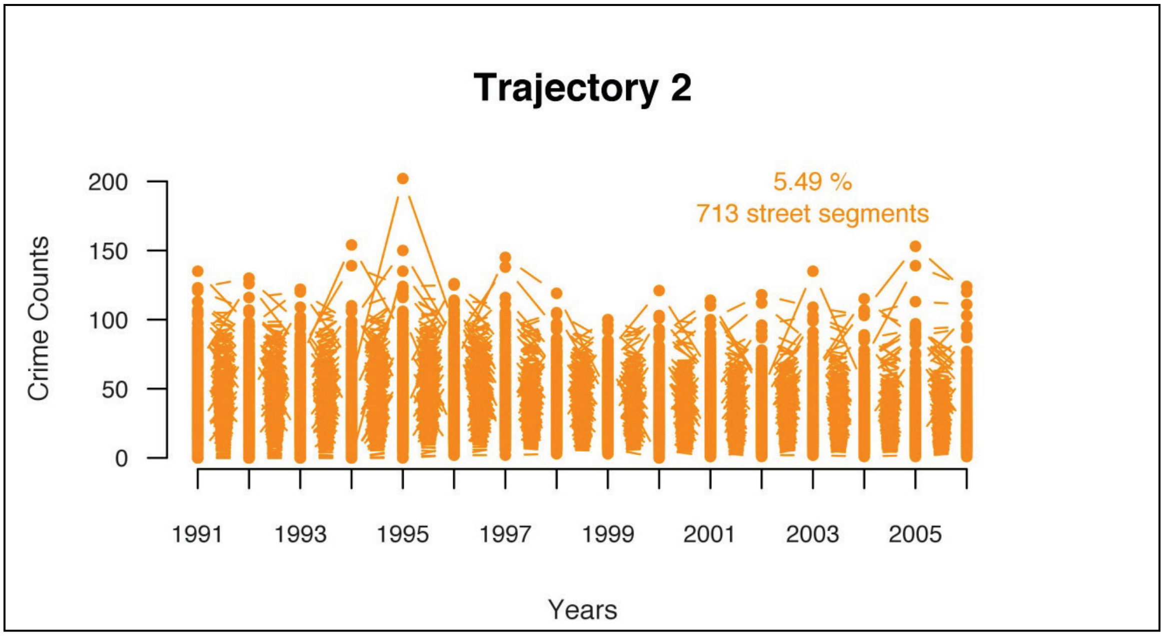
Trajectory 1 depicts ‘very low crime’ counts for each street segment over the study period and is comprised of 12,160 segments or 93.7% of the sample (see Figure 22). These street blocks evidenced a yearly average of three crimes over the 16-year period.

Figure 22. Trajectory 1 in k-means; 'very low crime'



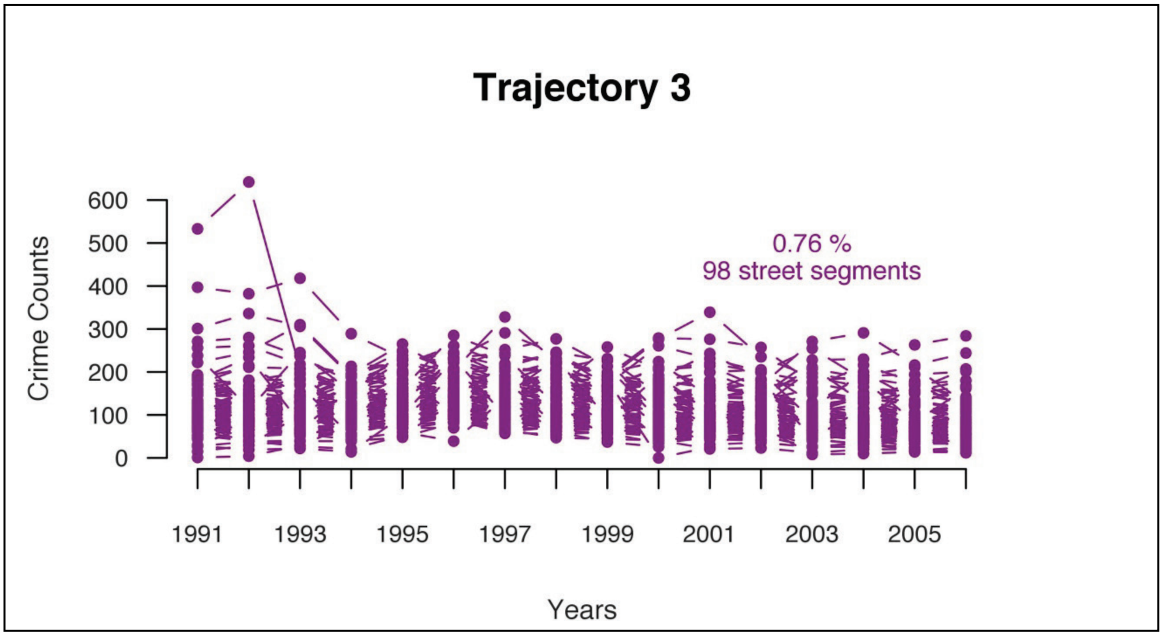
Trajectory 2 depicts 'low crime' volumes over the study period; somewhat higher values than those found in Trajectory 1. Trajectory 2 is comprised of 713 street segments, or 5.5% of the sample. These street segments show a yearly average of 31 crimes over the 16-year period. Figure 23 displays the results for Trajectory 2 in the k-means results.

Figure 23. Trajectory 2 in k-means; 'low crime'.



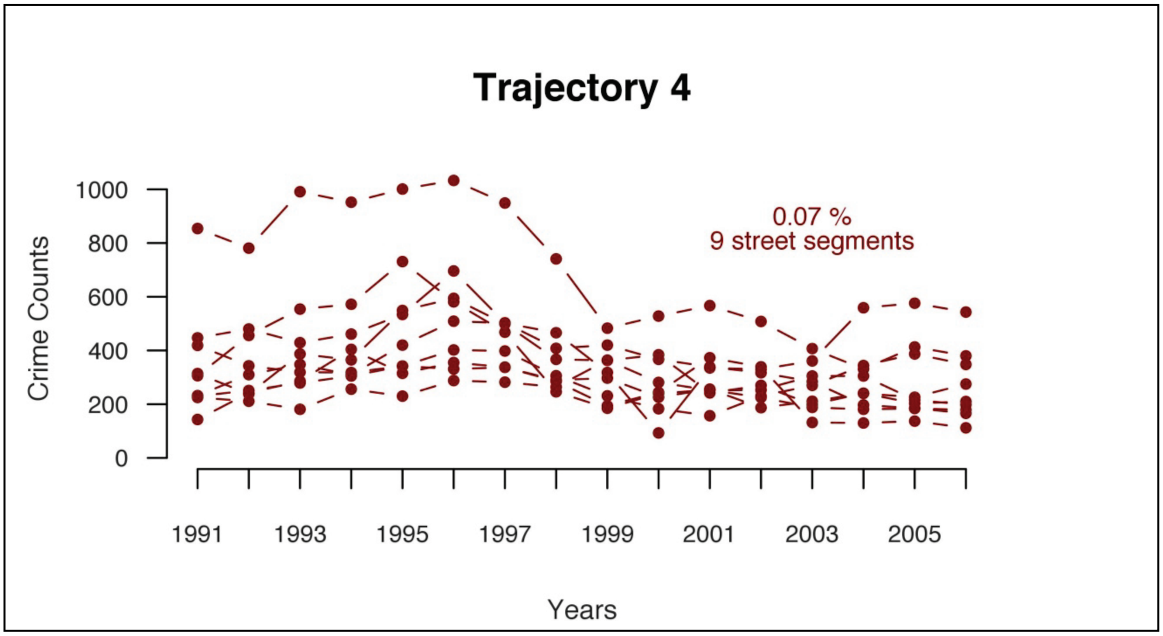
Trajectories 3 and 4 depict 'high crime' and 'very high crime' street segments and encompass the patterns not discernible through the SAS Proc Traj methodology, due to the requirement to truncate any street segment above 50 to 50. Figure 24 displays the results for Trajectory 3, which depicts 'high crime' street segments. These 98 street segments constitute 0.8% of the sample and averaged 113 crimes across the 16-year period.

Figure 24. ***Trajectory 3 in k-means; 'high crime'.***



Trajectory 4 depicts the 'very high crime' street segments, and is arguably the most interesting result. This group is comprised of only nine street segments, yet shows the highest crime volumes by far and is displayed in Figure 25. These nine streets evidenced an average of 359 crimes over the 16-year study period. Proportionally, these were the most active street blocks in the city during that period.

Figure 25. Trajectory 4 in k-means; 'very high crime'.



Trajectory Classifications

To further categorize the four-group model identified through k-means, the groups were classified as either decreasing or stable trajectories according to the methodology in Weisburd et al. (2004). Figure 26 displays all four trajectories and Table 13 shows the slope and intercept data for both groups. Trajectory 1 exhibited a stable trajectory, with a slope of -0.098. The number of calls for service on these street segments did show a decline over the 16-year period from 37,043 in 1991 to 20,131 in 2006, however, the slope of -0.098 would register as a stable trajectory, according to Weisburd et al.'s (2004) standards. One potential explanation for the minimal slope value may be that this group consists of 93.6% or 12,160 street segments and the large numbers in this group may minimize the effects of the decline in calls for service over the study period. Table 13 shows that in 1991, the stable trajectory group, comprised of the majority of street segments (93.6%) evidenced an average of 3.35 calls for service and declined to an average of 0.09 crimes with year successive year.

Trajectories 2, 3 and 4 were classified as decreasing trajectories, according to Weisburd's (2004) criteria. Figure 27 displays the results for these groups and Table 13 provides the data. The data show all three trajectories decreasing in crime volume over the study period, with more significant slopes compared to the stable trajectory. Trajectory 2 shows that in 1991, 5.49% of street segments evidenced an average of 38.69 calls for service, with an average yearly decline of 1.03 calls for service until 2006. These 713 street segments evidenced 25,175 calls for service in 1991 and declined to 15,360 by 2006. Trajectory 3, comprised of 98 street segments evidenced an average of 134.82 calls for service in 1991 with an average decline of 2.95 crimes per year until 2006. This involved 11,575 crimes in 1991, with a decline to 8,177 by 2006. Trajectory 4, comprised of only 9 street segments evidenced an average of 454.99 calls for service in 1991 with a yearly average decline of 12.74 crimes until 2006. These street segments evidenced 3,170 calls for service in 1991 with a decline to 2,411 crimes by 2006.

Figure 26. Trajectories 1 through 4 identified by the k-means statistic.

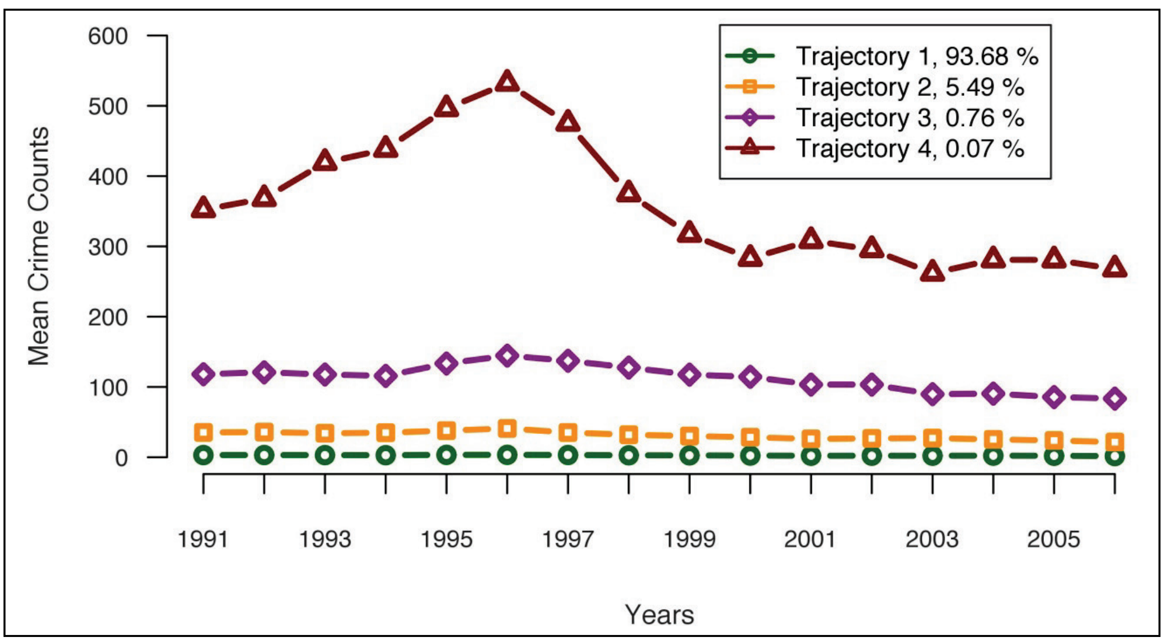
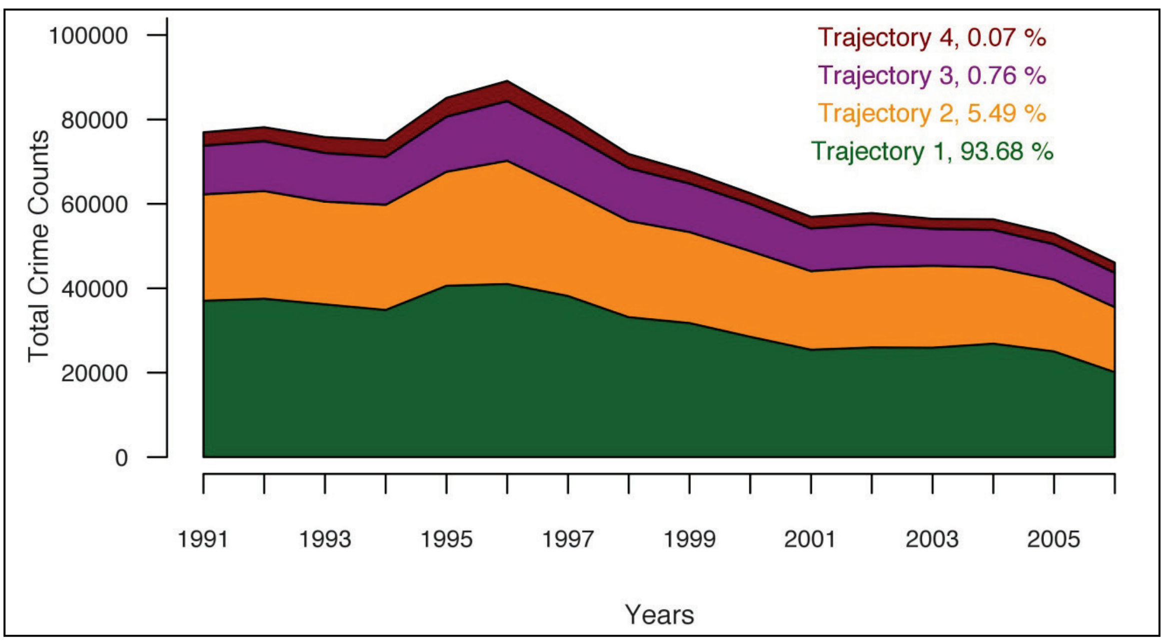


Table 13. Stable and Decreasing Trajectory data from k-means statistic.

Trajectory	Group	Slope	Intercept
1	Low Stable	-0.098	3.35
2	Low Decreasing	-1.03	38.69
3	Moderate Decreasing	-2.95	134.82
4	High Decreasing	-12.74	454.99

Overall, as displayed in Figure 27, all four trajectories identified by the k-means statistic evidenced a decline in calls for service throughout the 16-year study period. Unlike Weisburd et al. (2004), there is no identifiable trajectory that may account for Vancouver's decreasing crime volume from 1991 to 2006; in contrast to that study's findings it appears that all street segments saw a decrease in crime and all may have contributed to the substantial drop in the city's crime rate.

Figure 27. Vancouver Crime Drop Analysis



Geographic Analysis Results

The statistical results of this dissertation have revealed two main findings. First, is that crime is concentrated at the street block level. It appears that criminal activity on street blocks varies tremendously throughout the city of Vancouver. Both the group-based trajectory model (GBTM) and the k-means methods show that the vast majority of blocks evidence minimal crime, while a select few harbor a disproportionate amount of criminal activity. Secondly, it appears that the varying levels of concentration evidence stability over time. That is, the streets with no crime, low crime, moderate and high levels of crime remain as such for long periods.

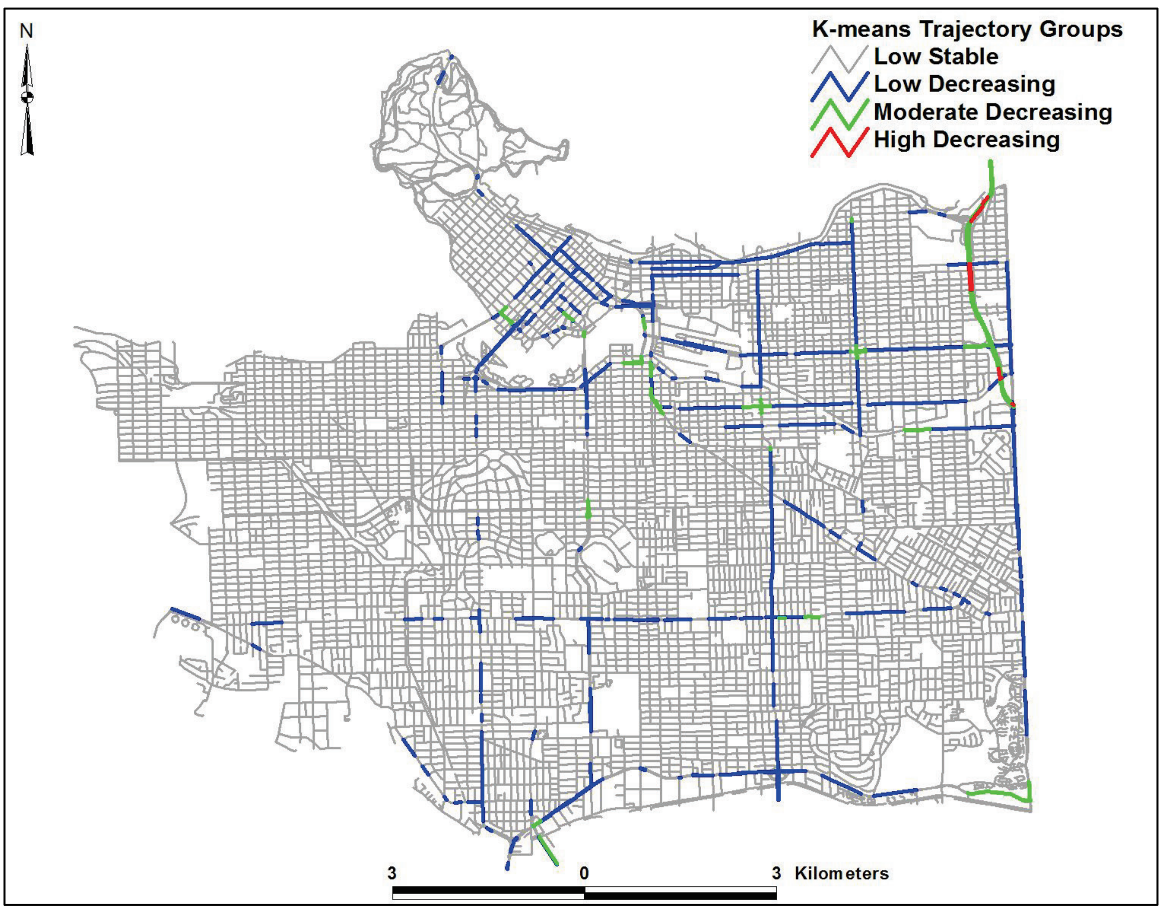
What is not known is the geographic distribution of these crime trajectories throughout Vancouver. Are the street blocks evidencing moderate and high levels of crime located uniformly throughout the city or clustered in specific areas? In order to shed light on these questions, two sets of geographic analyses were completed. First, as shown in both Weisburd et al. (2011) and Groff et al. (2010), visualization maps depicting the location of the trajectory classifications (i.e. stable and decreasing trajectories) were produced. Secondly, as completed in Weisburd et al. (2004), kernel density estimates were also conducted on each identified trajectory.

This section will summarize both sets of geographic results, beginning with the visualization maps, followed by the kernel density estimates. All spatial analyses were produced based on the k-means results only. This decision was made for two reasons. First, the GBTM in the SAS Proc Traj method, as noted previously, requires any case with a value above 50 to be truncated at 50. This affected trajectories 6 and 7 (high and extremely high crime) where 468 cases showing high levels of crime were cut off at 50. Although this does not affect the geographical display of these trajectories, it is argued that the alternate cluster analysis technique of k-means should be focussed on as it represents trajectories with raw counts and did not involve any truncation of data. Secondly, the GBTM method broke the lower crime trajectories into five separate clusters, constituting 93.36% of all street blocks in the city. However, the k-means method identified all the low crime blocks as one trajectory constituting 93.68% of all blocks in the city. It is argued for simplicity purposes that the k-means results are preferable when visualizing the geographic distribution of blocks that show low levels of crime versus those evidencing higher volumes.

Visualization Maps

Based on the k-means statistics, Figure 28 displays the location of each of the four trajectory groups throughout the city of Vancouver. The vast majority of areas are marked with streets that are low in criminal activity and remained low throughout the study period. These streets are marked by the grey, thin lines for the `low stable trajectory`. The significant presence of these blocks is not surprising as this trajectory constitutes 93.68% or 12,160 street segments.

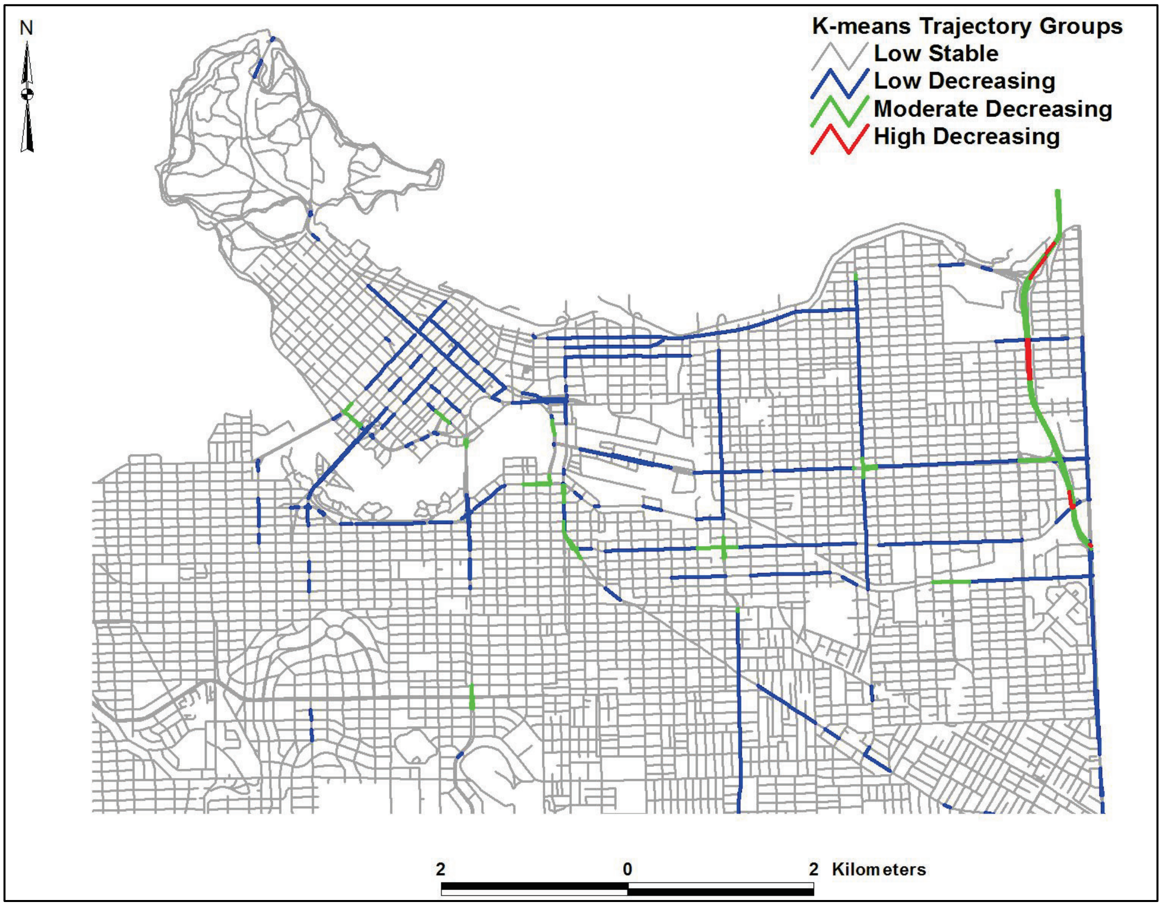
Figure 28. Spatial distribution of k-means trajectories



Upon close inspection, one can see that the low decreasing street blocks (as marked in blue) are largely located on arterial roads (i.e. those with higher speed limits and higher traffic volumes). This means that these busy streets did not evidence a large amount of criminal activity to begin with, but did show a notable decline over the study period. One possible reason for this may be the increased traffic volumes on all major roads in Vancouver in the last decade. The volume of road users has increased significantly and the presence of increased vehicles may have led to an increased guardianship effect in these areas where offenders are less anonymous and cannot carry out criminal activity with as much ease. It is also clear from Figure 28 that the western portion of the city, which is the most affluent, exhibits only the low stable trajectory streets. Conversely, it is only the eastern portions of the city, in particular the northeast part that harbors the higher crime street blocks.

Figure 29 focuses on the northeast part of Vancouver. This area shows the greatest heterogeneity in the City in terms of a mixed presence of crime volume trajectories at the street block level. The northeast area displaying the red lines representing the highest crime trajectory is known as `Hastings Sunrise`. This area has mixed land use between residential and industrial locations and is arguably less affluent than its neighboring areas to the west. In addition, this area also shows that all the high crime volume streets directly neighbor low stable blocks with low and moderate decreasing blocks interspersed in between. It is interesting to note that this area is marked with many arterial roads such as Hastings Street, Boundary Road, and McGill Street and an entrance onto the Trans-Canada highway, the major Highway 1 in British Columbia.

Figure 29. Spatial distribution of k-means trajectories in the Northeast portion of Vancouver.



This area also hosts the Pacific National Exhibition (PNE) each year. The PNE is a large-scale public event that includes a fair, concert events and amusement park rides. It runs each year throughout the summer and early fall and brings a significant volume of people to the Hastings Sunrise area. This may also be a reason why the higher crime street blocks are concentrated here.

Of great interest is the lack of high crime street blocks in the downtown eastside area of Vancouver, as shown in the northwest corner of Figure 29. The downtown area of Vancouver, particularly the eastside portion, is notoriously known for being riddled with drug problems and incivilities. The surprisingly low levels of crime volumes at the street block level may be due to the fact that the police primarily patrol this area to increase their presence and prevent criminal activity from getting out of hand. It may be the case that the drug charges may be higher in this area overall, but when compared to overall levels of criminal activity, this area may be less active in evidencing index crimes (as measured by this dissertation) and more active in behaviors not captured by the dataset, but specific to drug problems such as *prostitution* or *uttering threats*. The sizeable presence of the low decreasing street blocks in the downtown eastside area may also be a result of the specialized attention this area is given by the Vancouver Police Department over the years.

Figure 30 highlights the southwest portion of Vancouver. It is interesting to note that at the bottom right side of the map, the Oak Street Bridge is noted as including a moderate decreasing trajectory in its southbound lane, but a low decreasing trajectory in its northbound lane. This indicates that the bridge has seen an overall decline in criminal activity over the years, but exhibits varying levels of crime for each direction. This is a surprising result and one may speculate whether the moderate levels of criminal activity are driven by road rage incidents on the bridge stemming from heavy traffic volume. This would require further investigation to explore.

Figure 30. Spatial distribution of k-means trajectories in the Southwest portion of Vancouver.

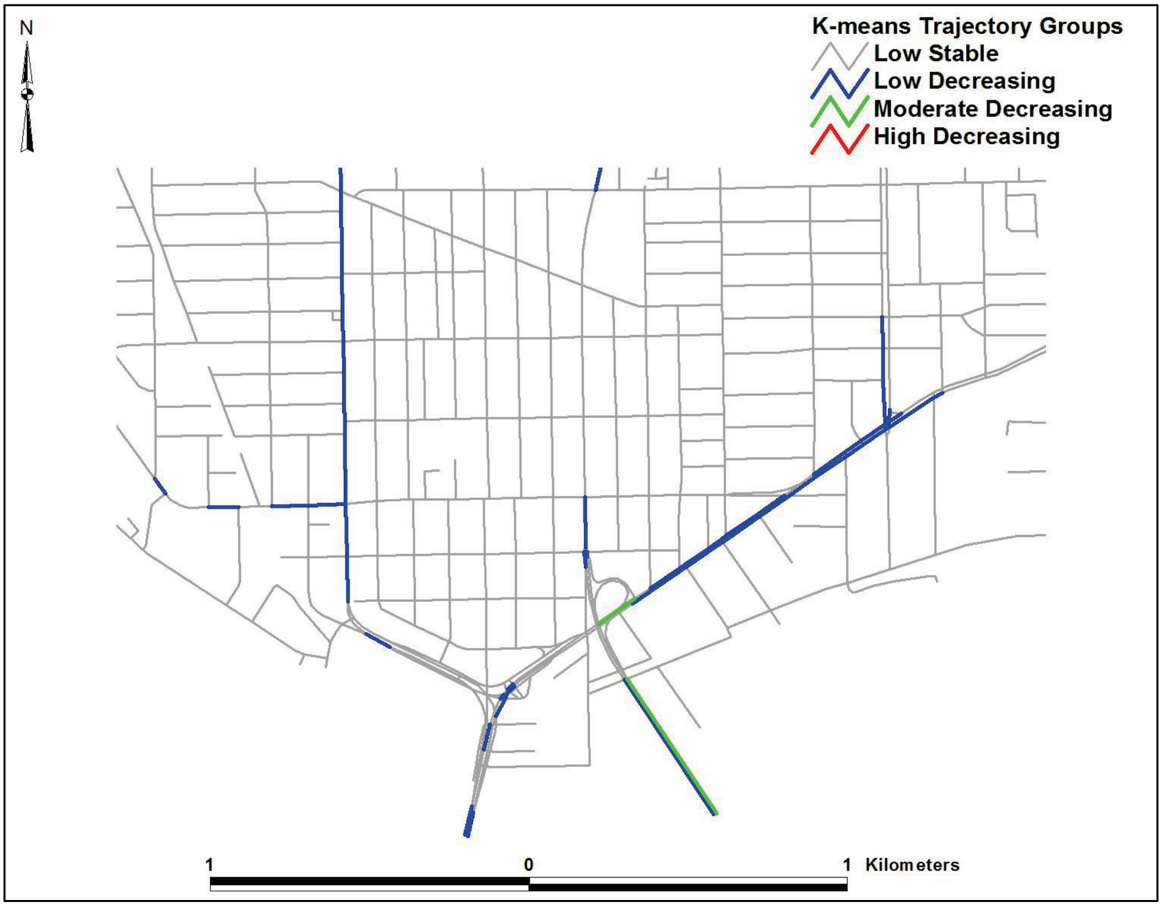


Figure 31 focuses on the southeast portion of Vancouver. What is notable here is the moderate crime trajectory identified at the bottom portion of the map (marked by the green line). This is located along Marine Way and is a stretch of road mostly marked with forest, but also industrial activity.

Figure 31. Spatial distribution of k-means trajectories in the Southeast portion of Vancouver.

These maps do offer a clear picture of both the heterogeneity and the homogeneity of crime patterns on street blocks. The street segments evidence a heterogeneous pattern in that varying crime volumes neighbor one another throughout the city. This is known as a steep crime gradient (Groff, Weisburd and Yang, 2010). Throughout the majority of Vancouver, one can see stable street blocks adjacent to various decreasing street segments. Conversely, the homogeneity of both the low stable and hi decreasing street blocks is evident. The former is clustered in the western portion of Vancouver, whereas the latter is entirely segregated within the northeast corner of the city. They underscore the importance of examining crime at micro places, as aggregate geographic analyses would have masked these more finite variations.

Kernel Density Results

In keeping with the replication of Weisburd et al. (2004), kernel density estimates were generated for all four trajectories identified by the k-means method and were performed in the software Crimestat (see Heraux, 2007). Kernel density estimation is a non-parametric way to estimate the concentration of a variable of interest and provides a visual interpretation of its density. The number of cases is represented by a circular shape with the increasing densities displayed by each circle, with the highest density located at the center. This technique was used to estimate the density of the stable and decreasing trajectories and equal bandwidths of 1km or 1000m was applied for each estimation with equal output cell sizes of $100m^2$.

Figure 32 shows the concentration of the low stable trajectory throughout Vancouver. It is evident that this trajectory is located throughout the entire city. Thus, the kernel density estimation is limited in its explanatory value with this particular trajectory. One can see concentrations of the low stable street blocks (as evidenced by the bright red circle) located throughout most portions of the city. However, the estimation does indicate the greatest density of low stable trajectories in the downtown and western portions of the city. This mirrors the findings from the visualization map which emphasized the presence of the low stable trajectory in the western part of Vancouver, also known to be the most affluent of areas.

__Figure 32. Kernel density estimation for the low stable trajectory.__

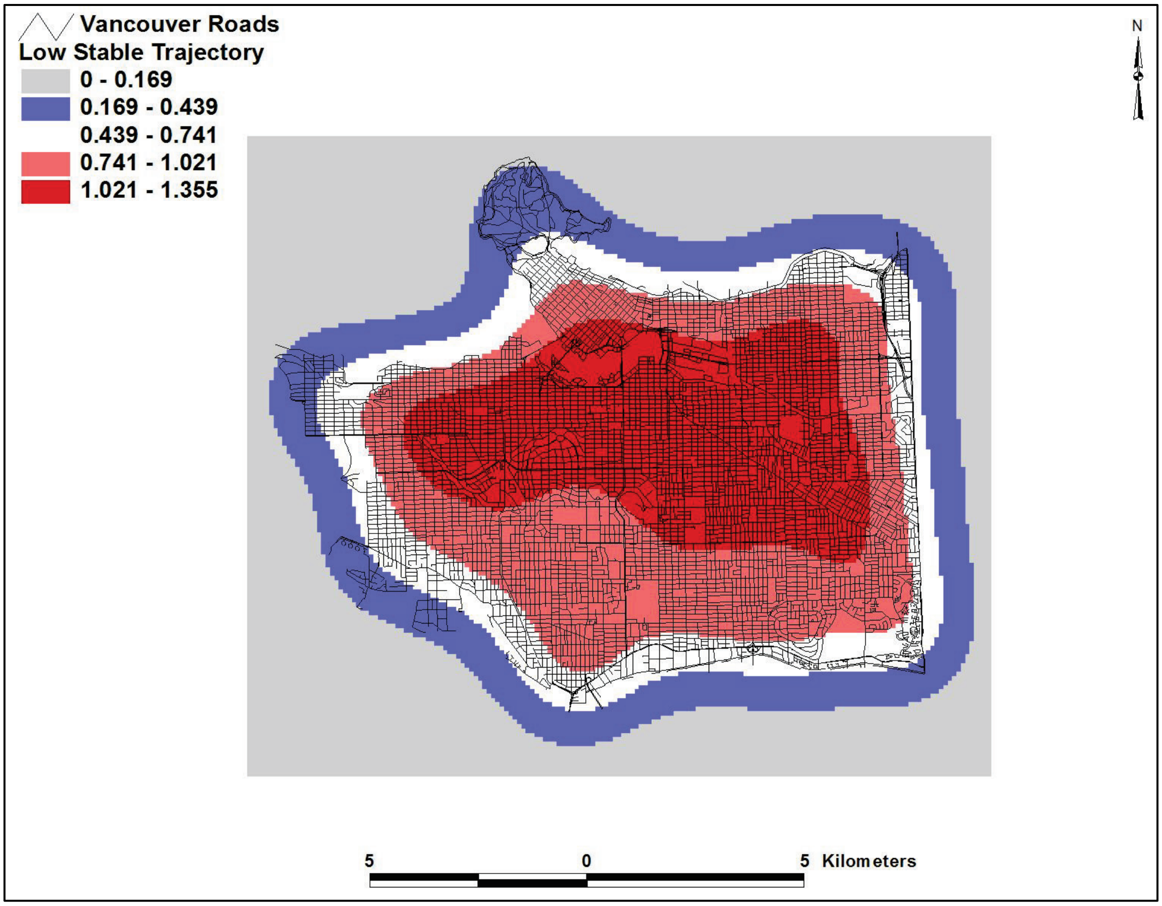


Figure 33 shows the kernel density estimate for the low decreasing trajectory. Once again, it is evident that these types of street blocks are dispersed throughout the city. However, the estimation indicates that the strongest concentration of lower crime volume streets with a decreasing trajectory is located in the downtown area, particularly the downtown eastside. This is interesting, as the visualization map certainly mirrors this finding. However, the visualization map also shows a strong presence of the low decreasing street blocks in the north eastern part of the city, which harbors a significant number of arterial roads. This is not reflected in the kernel density estimation. The southwest and southeast portions of Vancouver are also highlighted with particular emphasis on the area leading up to the Oak Street Bridge and Marine Drive.

Figure 33. Kernel density estimation of the low decreasing trajectory.

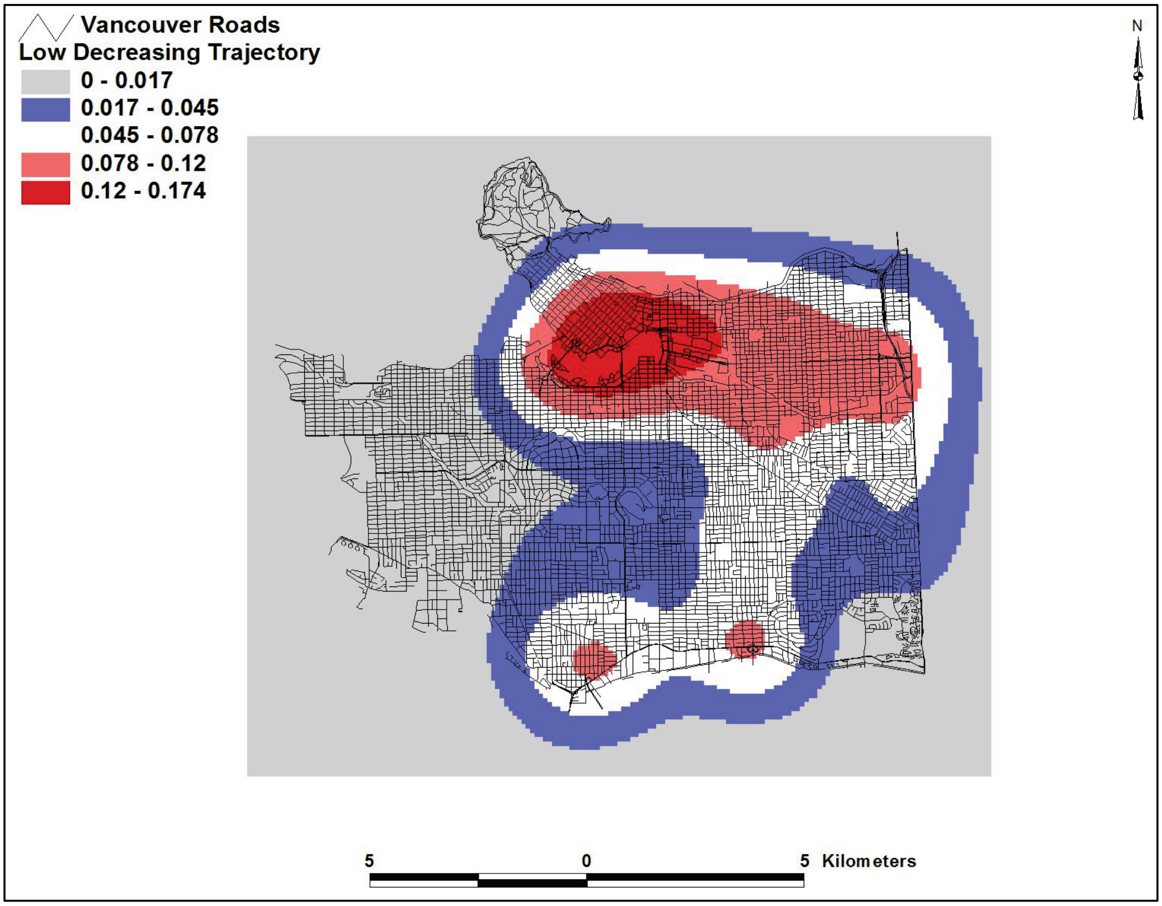


Figure 34 shows the kernel density estimate for the moderate decreasing trajectory. The results show no concentration of this trajectory in the most western portion of the city, with increasing density as one moves eastward. Specifically, the estimation indicates that the greatest concentration of moderate decreasing street blocks is located southeast of downtown, in areas surrounding West Broadway. Additionally, the results highlight the concentration of these street blocks in the Hastings Sunrise (northeast portion) area, which is evident from the visualization maps. Although the kernel density estimate highlights two areas of density for the moderate decreasing street blocks, it is difficult to interpret from the results, which one is of greater degree or whether their densities are statistically comparable.

Figure 34. Kernel density estimates of moderate decreasing trajectory.

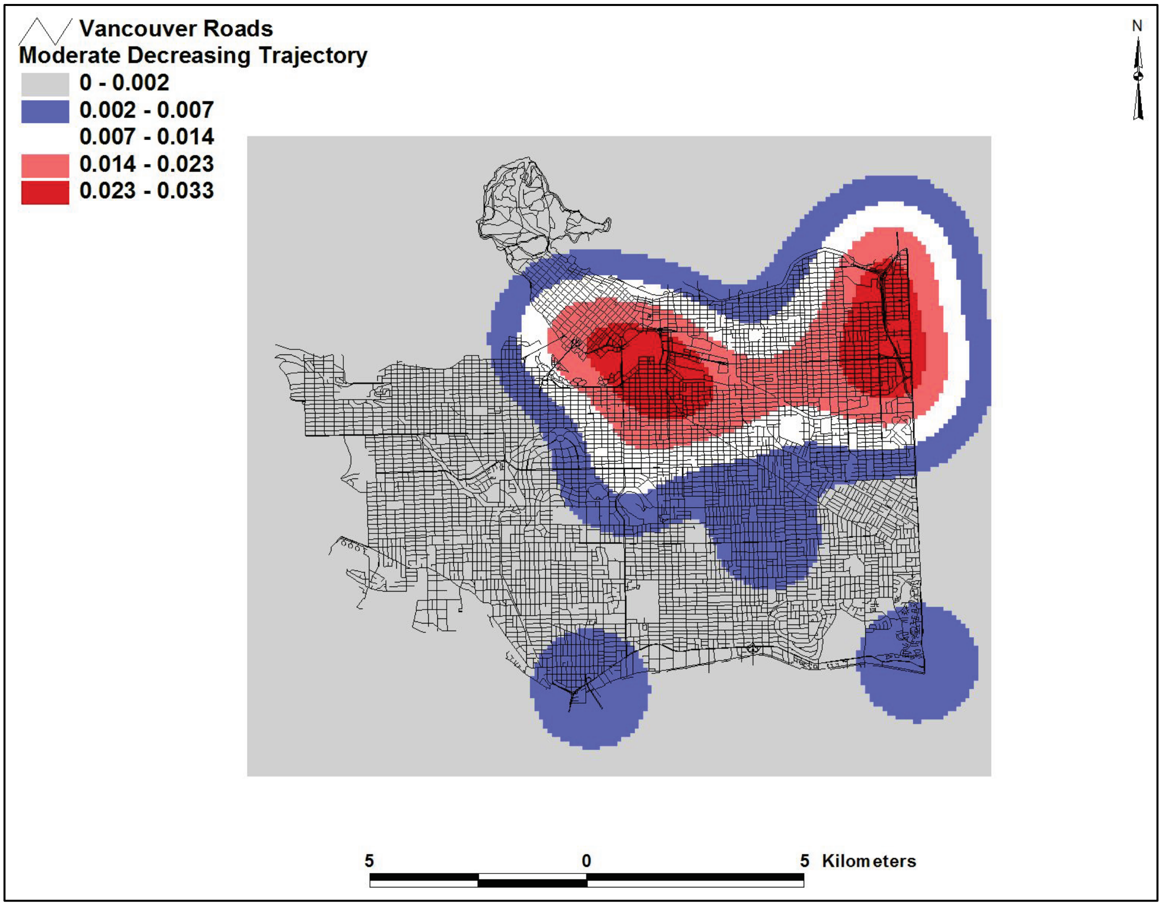
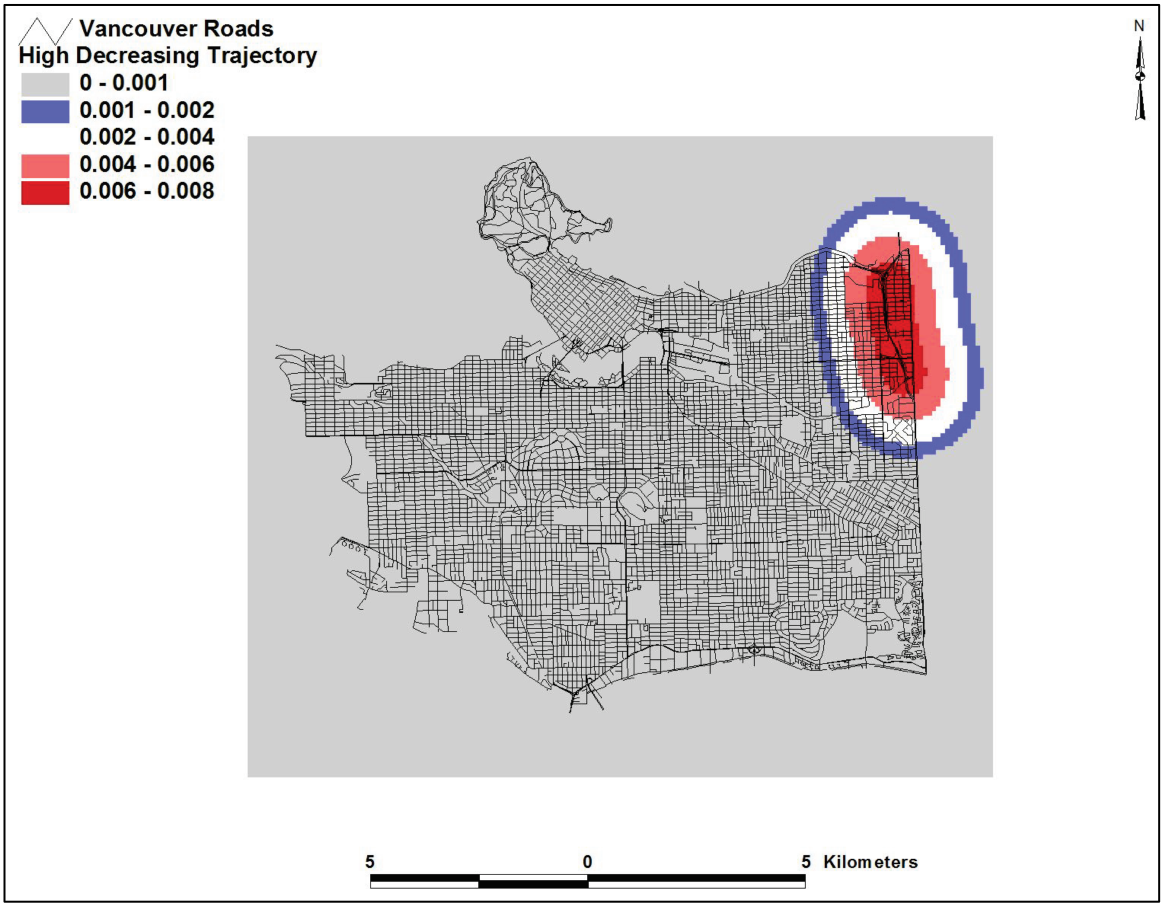


Figure 35 shows the kernel density estimate for the high decreasing trajectory. It is very clear that that only the northeast portion of the city shows a concentration of the highest crime street blocks. This mirrors the finding from the visualization map which shows the existence of these blocks solely in the Hastings Sunrise area. What is troublesome about this estimation is that it implies that the high crime street blocks have a presence throughout the entire area and in areas just outside of Hastings Sunrise, as evidenced by the orange circular shape which also represents a certain level of density for this trajectory. This may give a false impression as the maps clearly show that the high crime street blocks were only found in the northeast portion of Hastings Sunrise and only amongst 9 city blocks.

Figure 35. Kernel density estimation for the high decreasing trajectory.



One of the key limitations of the kernel density estimate is the potential for a false interpretation of the uniform density of crime levels in the identified hot areas. For example, Figure 35 shows a significant concentration of the high decreasing street blocks in the northeast portion of Vancouver. When looking at the kernel density estimate, it may appear that that entire area covered by the bright red circular shape is equally concentrated with high crime street blocks. This may misinform the viewer; the reality is that the geographical density of crime volume at the street block level is extremely variable. For example, Figure 35 shows although the high crime street blocks are concentrated in the Hastings Sunrise area, this area is comprised mainly of low stable street blocks with minimal criminal activity. This is not evident from the kernel density estimate, as the concentration of the high crime trajectory appears overstated.

These results must be viewed with caution so as not to overinflate the significance of the geographical concentrations shown by this statistic.

The following section concludes the dissertation with a discussion on the implications of the research findings, for both the enforcement community and towards future crime and place studies and the limitations inherent to an exploratory study.

CHAPTER FIVE: DISCUSSION

The field of Environmental Criminology has substantiated that crime is concentrated in its distribution throughout space, regardless of the geographic lens being viewed. However, most of this research solely emphasizes the non-uniform existence of crime, and has not attempted to confirm whether geographic patterns persist over time. It is argued that it may be time to advance this depth of knowledge towards focussing on the longevity of these hot spots and conversely, the crime free areas, and deciphering their characteristics. This is argued as essential to further progress the field of crime prevention and law enforcement strategy. As Weisburd, Bushway, Lum and Yang (2004) stress, “while the geographic concentration of crime at place has been well documented in recent years, the stability of crime at hot spots over time has received little research attention” (p. 286). Specifically, why should police and practitioners focus on hotspots if they move geographically? This dissertation has drawn on this question and sought to expand the knowledge surrounding the longevity of micro crime patterns by replicating the seminal research conducted by Weisburd et al. (2004) towards the city of Vancouver, B.C., Canada.

This research expands upon Weisburd’s in three main ways. First, the study spanned a 16 year period, which marks the largest dataset applied to the field of crime and place outside of Seattle, Washington, thus far. Second, the focus on the street block as the unit of analysis furthers Weisburd et al.’s (2004) efforts to highlight this particular unit of analysis as optimal when analyzing crime and place patterns. Lastly, by implementing the k-means technique, the research applied on an innovative technique to examine the developmental patterns of micro crime places over time. As such, this dissertation goes beyond replication and provides a useful comparison to the patterns evidenced in Seattle.

Overall, the research examines the stability of the concentration of crime at the street block level over time, the temporal patterns of those concentrations over time as well as examines the spatial distribution of crime throughout Vancouver. This chapter will briefly review the main results, as presented in Chapter Four. The results will be discussed in terms of the differences found between both trajectory techniques and between those found in Seattle, Washington by Weisburd et al. (2004) versus those exhibited in Vancouver, B.C. Next, various explanations will be offered regarding the developmental patterns uncovered, with a discussion on the limitations of the research. Lastly, considerable detail will be applied towards the discussion of future research in this field.

Crime Concentrations in Seattle, WA and Vancouver, BC

When comparing the two cities, the results show a strong concentration of criminal activity, or 'hotspots'. Vancouver's distribution of criminal activity at the street block level was comparable to that of Seattle's. Of particular interest is the fact that for both cities, 100% of the crime was located on only 50-60% of all street blocks. Also, half the criminal activity was evidenced on only 4.5-7.8% of street blocks. The street blocks with the highest levels of crime, defined as showing more than 50 incidents or calls for service through the study period encompassed only 1% of all possible streets in Seattle and only 3.6% of all streets in Vancouver. Table 14 displays these results.

Table 14. Descriptive Statistical Results of Crime Concentrations on Street Blocks

Category	Weisburd et al. (2004) and Seattle, WA*	Curman (2011) and Vancouver, BC
Included Years	1989-2002	1991-2006
Dataset Categories	All incident reports	Index Crimes
Most common crimes	50% property, 17% prostitution	41% property, 24.5% theft from auto
Mean # of crimes per block	3.6	5.25
Percent decline in crime	24%	40%
% of blocks with all crime	50%	60%
% of blocks with half the crime	4.5%	7.8%
% with more than 50 crimes	1%	3.6%
% of blocks with 1-4 crimes	34.5%	34%

*% of blocks with varying proportions of crime are represented as averages based on data presented in Weisburd et al. (2004)

Overall, both cities showed considerable concentrations of criminal activity over their respective study periods and the results for Vancouver's criminal activity at the street block level was both comparable to that of Seattle's and consistent with general Environmental Criminology research thus far. The results show that street blocks throughout Vancouver, B.C. evidence significant tendencies towards certain levels of criminal activity and that these proportions remain stable for long periods of time. What was not clear was whether it was the same street blocks evidencing the same proportions from one year to the next. In order to further examine the issue of stability of crime concentrations, the group-based trajectory model was conducted, as per Weisburd et al. (2004)'s methodology.

Group-Based Trajectory Model Results

A group-based trajectory model (GBTM) was conducted to examine the developmental patterns of criminal activity on Vancouver's street blocks from 1991 to

2006. The same methodology applied by Weisburd et al. (2004) was implemented using Vancouver Police Department calls-for-service data on 22 index crimes (see Chapter Three for description). Table 15 outlines the results compared to that of Weisburd's found in Seattle, WA. The following section will detail the similarities and differences between the two studies as found by the GBTM.

Table 15. Comparison of the GBTM Results

Category	Weisburd et al. (2004) and Seattle, WA	Curman (2011) and Vancouver, BC
Final Model	18 group solution	7 group solution
# of Stable Trajectories	8	3
-% of all street blocks	84%	70%
-range of y-intercepts	+0.03 to +7.5	+0.04 to +3.36
-range of slopes	+0.07 to +0.14	-0.1 to + 0.002
# of Decreasing Trajectories	7	4
-% of all street blocks	14%	30%
-range of y-intercepts	+4.3 to +96	+7.3 to +89.8
-range of slopes	-2.1 to -0.2	-2.0 to -0.23
# of Increasing Trajectories	3	NA
-% of all street blocks	2%	NA
-range of y-intercepts	-0.3 to +15.55	NA
-range of slopes	+0.3 to +2.3	NA

The GBTM found more than twice the number of distinct developmental trajectories of micro crime places in Seattle versus Vancouver. Vancouver, B.C. was shown to have seven crime trajectories at the street block level, whereas Seattle evidenced eighteen. This is arguably not a surprising finding considering the difference between the two datasets. Weisburd et al. (2004) analyzed all criminal activity reported in Seattle (n= 1.5 million reported crimes) versus 22 index property and violent offences analyzed for Vancouver (n=1.08 million reported crimes) and therefore included substantially more crimes overall. This may have led to the statistical program identifying a larger number of developmental trajectories throughout Seattle as more crime may have lent itself to greater variability and/or patterns at the street block level. What is more interesting though is that despite the large differences in the number of trajectories between the two studies, they both share marked similarity in the nature and type of trajectories identified. Both datasets identified the majority of trajectories as either stable or decreasing in nature, with Vancouver solely consisting of these two categories without any increasing street block trajectories. The stable trajectories accounted for the vast majority of street blocks throughout both cities. Seattle saw 84% of its street blocks classified as stable in nature and Vancouver had 70% of its streets labelled as stable. Additionally, both studies showed that their stable street segments could be categorized as low crime in nature. For example, the highest stable trajectory found in Seattle had an average crime incident count of 7.75 in 1989. Vancouver's highest average crime count in the stable classification was only 3.36 calls for service in 1991. The slopes for the stable trajectories throughout both studies were very close to zero. This means that for both Seattle and Vancouver, the majority of the city is categorized as having low levels of criminal activity that remain stable over time. This is not a surprising finding from an Environmental Criminology perspective. From decades of crime and place research, it has long been established that most areas throughout a geographic region evidence minimal levels of criminal activity, with only a select few areas harbouring the majority of either chronic crime levels or significantly changing crime levels.

Both cities have decreasing trajectories as their second largest group identified by the GBTM method; however, Vancouver has twice as many compared to Seattle. This may be due to the fact that Vancouver did not evidence any increasing trajectories. Seattle's decreasing trajectories included the street blocks with the highest crime counts, with the highest showing an average of 96 crimes for 1989. Vancouver's decreasing trajectories also involve the highest crime blocks, with one trajectory showing an average of 89 crimes for 1991. The decreasing trajectories show the largest overall range in criminal activity for both cities. For example, Seattle's decreasing trajectories range from an average incident count of 4.3 to 96 crimes per year and Vancouver's range from an average of 7.3 calls-for-service to almost 90 per year.

From 1989 to 2002, Seattle experienced a 24% decline in crime incidents. Weisburd et al. (2004) stress that it was the 14% of street segments identified as decreasing that were responsible for this decline. It was explained that the decrease in crime was not identifiable throughout the entire city, but was located only in those areas where the street blocks were shown to have statistically decreased in volume, through the GBTM method. In contrast, all but one of the seven trajectories identified within the Vancouver dataset showed negative slopes. Almost the entire city, even those street segments labelled as stable in nature, evidenced declines in calls-for-service. From 1991 to 2006 Vancouver saw a 40% decrease in the 22 index crimes measured within this dissertation. Unlike the findings from Seattle, it became clear that this decline in criminal activity was more widespread throughout Vancouver and almost all street blocks would have played a role in this change over time.

Weisburd et al. (2004) discussed the surprising homogeneity in crime patterns uncovered by the GBTM method. Specifically, it was highlighted that, "the main purpose of trajectory analysis is to identify the underlying heterogeneity in the population. What is most striking, however, is the tremendous stability of crime at places" (p. 298). Seattle's low crime trajectories remained low throughout the study period and the same trend was evident amongst the higher crime trajectories, regardless of their classification. For example, Weisburd et al. (2004) highlight that the highest rate trajectory begins at almost 95 incidents and only decreases to an average of 75 crimes by the end of the study period; as such, it remained the highest rate trajectory. The developmental patterns identified for Vancouver's street blocks are concordant with Weisburd's findings of overall homogeneity. The fitted slopes evidenced by the decreasing trajectories between the two cities are almost identical in their values and minimal range, showing that despite the classification of 'decreasing', these street blocks remained relatively stable over time. Vancouver's decreasing trajectories vary significantly in terms of their intercept values; however, these levels do not change dramatically over the study period, for each of the 4 decreasing patterns identified. For example, Vancouver’s highest crime volume group can be found in Trajectory 7 which had an average of 78 crimes and has at the end of the study declined to only an average of 55 crimes (although the GBTM method would have calculated any street blocks with counts greater than 50 at 50 itself due to the limitation of the Proc Traj application in SAS). Despite this decrease, this is still a higher rate than any other trajectory. Conversely, the lowest rate, found in Trajectory 3 begins at 0.04 crimes and by 2006, only changes to 0.05 crimes, which is still the lowest rate trajectory at the end of the study period.

The GBTM method clearly uncovered the significant stability of criminal activity at the street block level. The question as to whether hotspots persist over time was answered for each city- both Seattle and Vancouver evidenced high rate trajectories whose fitted slopes were statistically minimal, showing that these street blocks continued to evidence the lion’s share of criminal activity from one year to the next. This finding bodes well for crime prevention initiatives whose focus is on the places exhibiting particular crime problems; this research shows that the geographic focus of such programs is warranted. Overall, the group-based trajectory model proved useful towards examining micro crime patterns over time. However, the issue of truncation of all street blocks with crime counts greater than 50 must be discussed.

The limitation of the Proc Traj application in SAS to accommodate cases with counts greater than 50 affected 468 street blocks in the Vancouver dataset, or 3.6% of cases which was significantly higher than the cases affected by Weisburd et al.’s (2004) data. This meant that the highest rate street blocks were not represented in the group-based trajectory analysis. We do not know much about the developmental trajectories of these street blocks, as their crime counts were cut off at 50. The question that remains is whether these street segments would have evidenced minimal slopes or would they have showed great change over time? This dissertation has argued that it is imperative to answer that question and ensure that these streets were represented in a trajectory analysis of Vancouver’s street blocks to provide a valid representation of the developmental patterns of micro crime places. As such, an alternative trajectory analysis, k-means, was conducted to augment the GBTM method. The next section will compare the results of the two statistics.

GBTM versus k-means Results

Table 16 displays the results generated by the group-based trajectory model (GBTM versus that of the k-means statistic.   Both identified the majority of street blocks as evidencing stable crime patterns. The difference is that the GBTM identified three separate distinct subgroups of stable street segments, despite their highly comparable y-intercepts and slopes. These stable trajectories have slopes that range from only -0.1 to +0.002, thus it is questionable as to whether their separate identification is of practical use in discerning micro crime patterns. In contrast, the k-means method grouped all the street blocks showing stable tendencies into one trajectory, accounting for 94% of the city's segments. This is arguably more efficient as it more clearly informs the researcher that most of the city has low crime streets that remain stable over time.

Table 16. Comparison of GBTM versus k-means Results

Category	GBTM	K-means
Final Model	7 group solution	4 group solution
# of Stable Trajectories	3	1
-% of all street blocks	70%	94%
-range of y-intercepts	+0.04 to +3.36	+3.35
-range of slopes	-0.1 to + 0.002	-0.098
# of Decreasing Trajectories	4	3
-% of all street blocks	30%	6%
-range of y-intercepts	+7.3 to +89.8	+38.6 to +455
-range of slopes	-2.0 to -0.23	-12.74 to -1.03

The number of decreasing trajectories identified by both statistics is also comparable. GBTM identified four versus three decreasing trajectories for the k-means statistic. Both statistics also found that the decreasing trajectories evidenced the highest rate street segments. However, that is where the similarities end. The results from the k-means saw only 6% of Vancouver's street segments classified as decreasing in nature compared to 30% with GBTM. The range of intercept values is also significantly larger for the k-means statistic. The reason for this is clearly due to the statistic's ability to account for values greater than 50. The decreasing street blocks for the k-means range from 38.6 to 455, whereas the highest rate trajectory identified by the GBTM was 90, however, anything above 50 would not have been included as part of the calculations for the final model solution.

The notable differences observed in the statistical values between the two statistics underscores the importance of implementing an alternative trajectory analysis, such as k-means, when one's dataset includes cases above 50. The fitted linear slopes evidenced by the k-means technique also show an astoundingly larger range compared to the GBTM method. GBTM evidenced a range in slope values of -2.0 to -0.23 for all four decreasing trajectories, whereas the k-means statistic saw this range expanded from -12.74 to -1.03. And these slopes were applied to only 6% of street segments. Thus, the k-means statistic was extremely useful in not only accounting for the highest rate street segments and therefore including Vancouver's most interesting 'storyline', but also capturing the significant range of these high rate trajectories over time.

This is an extremely important finding. It may reflect a few possible realities for the City of Vancouver. It may be simply that the high rate trajectories evidenced a regression to the mean effect, and as such, decreased in their crime volumes. However, more likely, it may be a result of the Vancouver Police Department's concerted effort in targeting high crime areas. The decrease seen in the high rate street blocks may also have been a result of the gentrification or socio-demographic changes in those areas. Regardless, the k-means statistic allowed for the story to be told. The data showed that Trajectories 3 and 4 evidenced the highest crime rates of 118 and 352 respectively in 1991 and both combined were responsible for only 107 street blocks. Both showed considerable declines by the end of the study period to 83 and 267 respectively. Having said that they still remained the city's highest crime rate street blocks.

Regardless of the significant differences in the statistics produced between the GBTM method and k-means, it is important to underscore that both methods tell a very similar story pertaining to the overall developmental patterns of micro crime places. Both show that Vancouver's street blocks were, for the majority, either crime free or had low levels of criminal activity and that these patterns remained largely stable over time. Both statistics also show a minority of streets with high crime activity that decreased during the study period. Thus, despite the differences between the two cluster analysis techniques, both methods confirmed five main findings:

1. That Vancouver's crime scene is concentrated in nature
2. Vancouver is mainly comprised of street blocks with low crime levels that remain that way over time.
3. The chronic high crime streets exist on very few street blocks.
4. Vancouver's highest crime rate streets showed substantial declines over the study period.
5. All of Vancouver's street block trajectories evidenced declines in crime volume , meaning that the 40% decline in criminal activity experienced in the city from 1991 to 2006 is attributable to all streets, not simply those evidencing decreasing developmental patterns.

Both statistics strongly support the utility of crime prevention efforts focused on 'place based' initiatives. The next section will discuss the results shown by the spatial analyses conducted through the visualization maps and the kernel density estimates.

Spatial Analysis Discussion

Visualization Maps

All four trajectories identified by the k-means method were mapped onto a Vancouver street network in order to visualize where the stable and decreasing developmental patterns exist. From simple visualizations as displayed in Chapter Four, many interesting findings were uncovered. The following section will detail these and offer potential explanations for what may be occurring at the street block level in Vancouver, B.C.

First, Figure 28, from Chapter Four shows two interesting patterns worth further discussion. The first is that the western portion of Vancouver is entirely comprised of low stable street segments and through the k-means statistic; it was shown that these areas show stability of this trend throughout the study period. The western portion of Vancouver is particularly affluent encompassing areas high in residential land value, and also is home to the University of British Columbia and its surrounding endowment lands. Historically, this is not a high crime area, with the vast majority of streets harbouring strictly residential land use with older, character style homes that hold some of the greatest monetary value in the city. It may be argued that the low crime activity seen in these areas is due to the lack of criminal opportunity. There is very little industrial activity in this portion of Vancouver, and the neighbourhoods could be categorized as 'old' in nature, meaning that most residents know each other well and have resided there for quite some time. It is extremely likely that residents would notice anomalous behaviour, increasing the guardianship levels throughout the area.

Secondly, Figure 28 also shows that the low decreasing trajectories exist almost entirely on Vancouver's arterial roads, such as Boundary Road, Cambie Street and Granville Street. This trajectory (i.e. Trajectory 2) evidenced considerably higher crime levels than the low stable streets, however, was still relatively low compared with Trajectories 3 and 4. This is a particularly interesting finding. The question arises as to what characteristics of arterial roads engender a higher level of criminal activity? One noteworthy observation is that all the main arterial roads evidencing this trajectory are comprised of high levels of mixed land use (see Brantingham and Brantingham, 1993b). There are residences located on each of them; however, there is also an equal amount of industry located there in terms of restaurants, clothing stores, and larger chain department stores. The opportunity for criminal activity is arguably greater here with higher volumes of people and traffic marking these routes and their surrounding areas. As the low decreasing street segments are located throughout the entire city (with the exception of the most western portion of Vancouver), it is unlikely that varying socio-demographic levels of the areas hold explanatory value towards the higher crime levels seen. What is more plausible is that these streets and the parking lots located just off them are the locations of the high volume crimes such as theft from auto and that the residences on these major thoroughfares experienced higher levels of break and enter, which was the second largest crime category in the Vancouver Police Department dataset. The fact that the arterial roads and the businesses and residences on and near them are exposed to a high volume of people commuting there daily makes them more susceptible to criminal activity as they become part of an offender's awareness space (see Brantingham and Brantingham, 1984; 1993b). With the higher levels of anonymity offered by such high traffic areas, the opportunity for criminal activity may be prime along these routes.

Perhaps most interesting are the patterns evidenced by Figure 29 in Chapter Four. This map narrows in on the northeast portion of Vancouver, where the highest crime rate trajectory is located, as shown in red. There are three notable patterns evidenced in this area. Known as 'Hastings Sunrise', this area, as mentioned, evidences the highest rate crime trajectory, but also shows the greatest proportion of the second highest crime street blocks – the moderate decreasing trajectory. It also harbours the greatest proportion of different trajectories neighbouring one another. One can see that the high crime rate street blocks are adjacent to both moderate crime rate blocks as well as the low stable street segments. This visualization map underscores the importance of analyzing criminal activity at the micro crime level. If this particular northeast area were to have been aggregated to a census tract and subsequently analyzed, it may have led to the inaccurate conclusion that the entire northeast portion of Vancouver was a 'high crime' region and should be uniformly targeted by crime prevention and enforcement initiatives. However, it is clear from observing the street blocks, that the highest crime rate segments are not uniformly distributed throughout the entire area, but segregated to specific blocks that for the most part exist amongst a larger number of low stable streets. Examining the distribution of crime at the street block level allows one to accurately observe the micro level variation that underscores criminal activity within an area, unmasking the street by street differences that exist, which is imperative for enforcement purposes.

The Hastings Sunrise area is marked by lower socio-economic status, mixed land use, major arterial roads and perhaps most importantly, encompasses an entrance (and exit) onto the Trans-Canada Highway that is a major highway running through British Columbia. There are very few other areas in Vancouver that have entry-ways onto this major Highway. The high proportion of mixed land use, arterial roads and the presence of the highway may have created the strongest levels of criminal opportunity, as measured by the index crimes in this particular dataset (see Brantingham and Brantingham, 1999).

Equally interesting is the lack of the highest crime rate street segments in the notorious downtown eastside area of Vancouver. The downtown eastside portion of Vancouver is located just east of the downtown core of the city and is known for significant drug problems, homelessness, and incivilities and occupies the greatest proportion of the Vancouver Police Department's patrol resources. The fact that the highest crime rate streets are not located in this portion of Vancouver is surprising. However, this may be explained by the crime types assessed for this dissertation. Focusing on the 22 index crimes only, categories such as drug trafficking, prostitution, breach of probation, uttering threats and other incivilities were not captured and analyzed. It is likely that these types of calls-for-service, not included in the dataset, underscore a substantial amount of criminal activity occurring in the downtown eastside and this may be why the highest rate street segments were not identified as belonging to this notoriously 'high crime' area. Also, downtown Vancouver may be anomalous from many other urban centers in that it does not have a main freeway running through it. One cannot directly access the major Highway #1 from downtown Vancouver, without commuting outside of the core area first. The absence of a major freeway from this urban core may also explain the lower levels of criminal activity, compared to a city such as Seattle that does have a major freeway leading to its downtown core. The freeway access brings a significant amount of traffic, commuters and increases the visibility of an area substantially. It is notable that the Hastings Sunrise area does have direct access to the major freeway and incidentally is also the only portion of the city exhibiting the highest crime rate street blocks.

Additionally, as discussed in Chapter Four, the Hastings Sunrise area also hosts the Pacific National Exhibition (PNE) annually, including a popular amusement park. Combined, these events run throughout each summer period and bring large volumes of people and traffic to the area. The increased presence of car volume may have led to higher theft from auto rates, and the convergence of large crowds may have led to increased assaults and robberies. Thus, from an Environmental Criminology perspective, it is not surprising that the Hastings Sunrise area evidences the highest crime rate trajectory, with the presence of the highway, mixed land use, transient populations and large public events.

The strong presence of the moderate decreasing crime trajectory in the southeast portion of the city is displayed in Figure 30 in Chapter Four. This map shows that this second highest crime rate trajectory is located along a main arterial road in the area, Marine Way. The portion of this roadway that harbours the moderate decreasing trajectory passes through areas that are largely industrial in nature, with few residential units. It is likely that the criminal activity experienced along Marine Way is due to theft related crime along the roadway and amongst the numerous parking lots that mark it (see White, 1990). Additionally, for those few residential units on Marine Way, the likelihood of break and enters or thefts of businesses are also higher than average due to the large volume of people accessing this roadway and its surrounding areas, making it susceptible to those with criminal intentions (see Johnson and Bowers, 2010).

The prevalence of the higher crime rate trajectories throughout Vancouver that exist on arterial roads must be emphasized. This finding is likely reflective of the increased opportunities that such roadways and their surrounding streets experience. From a Routine Activities perspective, the convergence of motivated offenders with numerous targets underscores these streets. Also, with higher volumes of people and traffic, these areas offer higher levels of anonymity and decreased overall guardianship, with the large presence of commuters, transient populations and residents that may not be able to spot anomalous behaviour compared to those living in areas that are not on major roadways.

The implications of these findings for police and crime prevention are important. To decrease the likelihood of high crime levels in areas marked by main arterial roads, enforcement may want to consider increasing their presence to emphasize a level of guardianship in the area that does not exist naturally. This may be done through general patrol, but could also be accomplished through other types of enforcement such as traffic stops or roadblocks dedicating to impaired driving enforcement. Ensuring adequate lighting for night time hours along these stretches of roadway may also decrease crimes such as theft from automobiles or car theft itself. It may also be advantageous to ensure that a local community policing office exists in such areas and that volunteers combined with community police are a regular and visible presence, for the benefit of businesses and commuters alike. As motivated offenders are likely to use these arterial roads within their everyday routes as much as non-offenders (see Brantingham and Brantingham, 1993b), the regular presence of increased guardianship through the above noted suggestions, may decrease the extent to which these routes and their surrounding streets are viewed as prime criminal opportunities or exude crime generator characteristics.

Lastly, the utility of the street block as the optimal unit of analysis to examine micro crime places is illustrated by the visualization maps displayed in Chapter Four. One can see existence of hotspots at the street block level. The k-means statistic identified only nine street blocks within the entire city that harbour high rates of criminal activity, and these nine were classified into one trajectory. All nine streets were located within the exact same area and neighboured each other closely. Having said that, the maps also show that these high crime rate streets also neighboured the lowest crime blocks, as identified by the low stable trajectory. Thus this area was not ‘uniformly high’ in crime, that may have been an inaccurate conclusion reached with larger areal units of analysis such as census tracts. The street block is an ideal level of analysis for law enforcement purposes. Police are unlikely to target an address or point location to reduce crime and conversely, should not be misled into thinking that larger areal units evidencing crime concentrations should be uniformly targeted. The street block is a practical unit for resource allocation, both through patrol and crime prevention efforts. This dissertation not only shows that street blocks evidencing problematic crime levels are likely to remain that way over time, but that they are highly concentrated in nature and their existence may not necessarily be in regions of a city that are historically 'high crime areas'.

Kernel Density Estimates

Weisburd et al. (2004) conducted kernel density estimates to see whether the stable, increasing or decreasing trajectories are randomly distributed across space or if they exhibit some spatial dependence. The results showed that each of the three trajectory groups were present throughout the entire city of Seattle. Concentrations of the stable trajectories were found in the less densely populated areas in the North, with concentrations of the increasing and decreasing trajectories found in Seattle's urban city center. Kernel density estimates were also conducted for this dissertation and these results will be discussed throughout this section.

Similar to Weisburd et al. (2004), the low stable trajectory was located throughout the entire city, with notable concentrations in the more affluent part of Vancouver, the western portion of the city. Figure 32 displays the widespread nature of this trajectory and this is likely due to the fact that the k-means statistic identified this trajectory as encompassing 94% of all streets throughout Vancouver. The kernel density estimate also showed concentrations of the moderate decreasing trajectory in two areas of Vancouver- the downtown eastside, just east of the city center and in the Hastings Sunrise area in the northeast part of the city (see Figure 34 in Chapter Four). It is difficult to interpret from the spatial results which concentration is more statistically significant or which one is comprised of a greater number of street blocks of this category as the results do not lend themselves to this type of interpretation.

Lastly, Figure 35 in Chapter Four shows a concentration of the high decreasing trajectory in the northeast portion of the city- or Hastings Sunrise. When interpreting these results, it is interesting to note that the density estimate may give the impression that a large portion of this area exhibits the high decreasing street blocks, when in fact it is only 9 streets that mark this trajectory. This is arguably a significant limitation of the kernel density estimate. The technique may overstate how widespread the identified density is and in the case of numerous densities located, the visual results do not indicate whether one is more saturated than the other. It is argued that for both research and applied purposes, the visualization maps hold stronger information value than the kernel density estimations.

Further Observations

The results of this dissertation have supported the tenet that criminal activity is concentrated in space, and have also shown that street blocks evidence distinct developmental patterns over time. Even the street blocks classified as being part of a decreasing trajectory showed a stability of scale. Those with low, moderate or high decreasing streets, despite their decreases throughout the study period, remained low, moderate or high in their crime levels by 2006. Although the data do not allow for the examination of the underlying causes of these findings, potential theoretical explanations will be discussed. Based on well-established theory and research within Environmental Criminology as well as the work conducted by Weisburd, Groff and Yang (2011) attempting to explain the micro crime patterns observed in Seattle, various hypotheses will be offered. This will provide the basis for discussing future research in Vancouver, B.C. in order to develop a comprehensive model of crime and place.

This section will focus on five main points discovered regarding Vancouver's street blocks and crime patterns. First, approximately 40% of the city of Vancouver evidenced no crime at all throughout the 16 year study period from 1991 to 2006. One must ask what the characteristics of these places are that appear to have discouraged criminal activity. Second, the majority of Vancouver's street blocks evidenced very low levels of criminal activity and these remained stable over time. Third, the second highest set of street blocks showed only low or moderate levels of criminal activity. Fourth, a very small number of streets were identified as high crime rate blocks; these were also geographically concentrated. Fifth, there were no increasing street segments identified by either trajectory analysis. In fact, both sets of statistics identified only stable or decreasing street blocks with respect to the micro crime patterns throughout Vancouver. The following section will discuss the potential explanation of these findings.

As mentioned above, a sizeable number of street segments (approximately 5,000) did not experience any criminal activity throughout the 16 year period. It is argued that these streets may have been largely suburban side streets throughout more affluent areas of Vancouver. From a routine activities perspective, they may have exhibited few targets with primarily residential units with people who know each other well. These areas also were unlikely to be close to arterial roads or transit routes and farther away from public facilities that would generate large volumes of people who could be exposed to motivated offenders in the absence of guardians such as police or friends (Brantingham and Brantingham, 1993b; Cohen and Felson, 1979). In terms of social disorganization elements, it may be argued that these streets exhibit elements of social or economic stability whereby residents know one another and have formed a sense of community and social cohesiveness. For example, perhaps these streets have high rates of residential land use with low population turnover. As the data in this dissertation cannot confirm these hypotheses, further research will need to test these assumptions to accurately characterize the crime free street blocks throughout Vancouver.

The largest trajectory identified the low stable street blocks. Both statistical procedures identified these as encompassing the largest number of streets and the spatial analysis revealed their widespread distribution throughout the city. It is notable that even the stable trajectories evidenced negative slopes indicating these street blocks showed declines in criminal activity as well. In fact, Vancouver as a whole experienced a uniform decline in crime numbers at the street block level, however, the majority of these streets were statistically labelled as stable in nature due to the insignificance of the crime decrease. Weisburd et al. (2004) hypothesize that the stability of micro crime patterns at the street block level may be indicative of the fact that the elements conducive to criminal activity (albeit low levels for these particular streets) are unlikely to change significantly over the time period observed. It is argued that this explanation would be similar for the widespread existence of stable crime levels observed in this dissertation as well. The dataset spans 16 years and although this is a large time period, it is short in terms of the time it takes to observe large scale social change at the neighbourhood level. From a routine activities theory standpoint, it may be that the low stable streets exhibited characteristics leading to low levels of crime and that these factors did not change significantly throughout the study period. For example, the presence of targets, motivated offenders and levels of guardianship were not likely to have significantly changed for the duration of the 16 years observed. In tandem, these areas may also have evidenced a stability of socio-demographic characteristics that were conducive to low crime levels, as per social disorganization theory. Once again, in order to confirm these hypotheses, future research would have to test the significance of these types of variables amongst the low stable street blocks throughout Vancouver.

The second most prevalent trajectory included the low to moderate decreasing trajectories. Many of the low decreasing streets were located on arterial roads. It may be argued that the elements encouraging criminal activity were reduced, either through concerted efforts by the Vancouver Police Department, or through the minimization of characteristics conducive to criminal activity. For example, perhaps these street blocks experienced increased guardianship levels through police presence, or gentrification. Perhaps socio-demographic changes in these areas reduced the potential for criminal opportunity, limiting the presence of motivated offenders? The increased traffic volumes seen on Vancouver's arterial roads throughout the study period may have provided elevated guardianship levels with large-scale commuters. The visualization maps revealed that the low decreasing street blocks were located on major roads throughout the West Broadway area, for example. This area has undergone significant residential development (from approximately 2001 to 2006) with the introduction of new, highly priced housing units and the development of upscale grocery stores and restaurants. It may be argued that these types of gentrification may have led to decreased criminal activity, as measured by this dissertation. Having said that, it must be reiterated that all street blocks experienced a declining trend throughout the study period. Thus, perhaps to a certain degree, factors outside of social, demographic, or police presence changes occurred throughout the city that can account for this pattern. It may be that crime levels experienced a regression to the mean and declined to levels more indicative of the average. The majority of large urban centers in Canada also experienced declines in crime rates during similar periods of time (Ouimet, 2002; Levitt, 2004). The peak level of crime in the city occurred midway through the study period in 1996 with crime counts steadily declining afterwards until their lowest point in 2006.

The highest crime rate street segments were few in number and spatially clustered in the northeast portion of the city. Although small in number, these street segments evidenced an extremely large amount of criminal activity. From a theoretical standpoint, it is most interesting to discern why this is and whether such characteristics are changeable to further decrease the high levels of crime in these areas. Weisburd, Groff and Yang (2011) analyzed the characteristics of the high rate street segments throughout Seattle from both a routine activities and social disorganization perspective. The findings show that these streets evidenced high numbers of truant juveniles, businesses, public facilities, large residential populations, transit routes, arterial roads, vacant land, subsidized housing, physical disorder and a low percent of active voters. Considering the location of the high decreasing street blocks in the Hastings Sunrise area, it is clear that many of these characteristics also apply; however, this is strictly based on observation and not statistical analysis. For example, the Hastings Sunrise area embodies mixed land use with a high level of business and the presence of employees, which was a factor increasing the likelihood of a street segment being categorized in the high chronic trajectory for Weisburd et al.'s (2011) study. Additionally, this area has numerous public facilities from the Pacific National Exhibition, to public swimming pools and a library, to name a few. It also has a large residential population that is arguably of lower socio-economic status with lower land values, and has numerous arterial roads running through it, all of which are transit routes with bus stops. It would be highly valuable to systematically analyze these characteristics and their statistical significance towards the identification of a street block as being 'high crime' (see Newlands, 1983 for a discussion on break and enters in this area of Vancouver). One must also be cognizant that even though an 'area' such as Hastings Sunrise may encompass the characteristics described above, such factors many not explain crime levels on the exact street blocks evidencing the highest crime rates. One must be wary of inaccurately applying conclusions to micro crime places based on the elements present within a certain ‘area’. The research also highlighted that these street blocks were classified as decreasing in their developmental pattern, thus explanations towards why these particular high crime streets showed reductions in criminal activity are also necessary to represent a thorough story of the Hastings Sunrise area. Potential explanations for the decrease may be due to police attention or crime prevention programs. Additionally, it may be that socio-demographic changes in the area have increased the sense of community for residents in the Hastings Sunrise area, thus minimizing the opportunity or motivation to commit crime. Additionally, the decreases observed may be due to factors relating to gentrification processes, which during the study period was a significant phenomenon that occurred throughout Vancouver. It may be that with the development of new and higher priced residences in previously lower income areas, that certain types of criminal activity have been displaced to areas surrounding Vancouver’s central hubs. Once again, without systematic analysis of such hypotheses, this remains speculation.

Lastly, it is interesting that the trajectory analysis did not identify any increasing trajectories at the street block level. Although difficult to definitively explain, this may be due to the fact that most major cities throughout North America were experiencing declines in criminal activity throughout the late 1990’s and early 2000’s (Ouimet, 2002; Levitt, 2004). Thus, factors larger than those specific to Vancouver may be explicative of the lack of increasing trajectories; however, Weisburd et al. (2004) did uncover increasing levels of crime in Seattle, during a similar study period as that analyzed for this dissertation. Vancouver also has almost twice the population density of Seattle, and this only adds to the surprising finding with respect to the absence of any increasing street segments. Often, higher rates of population density are linked with increased crime levels within a region (Weisburd, Groff and Yang, 2011). Clearly, further research is needed to discern what factors may have led to the absence of any increasing developmental patterns at micro places throughout Vancouver.

Limitations

This section will discuss four primary limitations to this research that may affect either the results or the applicability of the findings. First, as noted throughout, a specific number of index crimes were included in this Vancouver dataset for analysis. Although they represent the main categories of both property and violent crimes, they do not include all calls-for-service and exclude many high volume crimes associated with motor vehicle incidents, traffic laws, drinking and driving, incivilities and disturbances. This also marks a difference between the research conducted in Seattle versus that of this dissertation. Weisburd et al. (2004) included all incident reports for analysis, compared to the subset of criminal activity examined for this dissertation. It is reasonable to conclude that the composition of crime categories analyzed may have affected both the trajectories identified and the spatial results. It would be useful to replicate this dissertation and include all recorded crimes for the same time period to assess whether either trajectory method would identify a different number and/or type of developmental crime pattern on Vancouver's street blocks. Perhaps the inclusion of all crimes would have resulted in the identification of an increasing trajectory within the city, or would have led to a more widespread distribution of the higher crime rate street blocks.

Second, although this dissertation encompassed the longest time series examining micro crime places outside of Seattle, WA, the period of 16 years is still short when considering the length of time it may take to see developmental patterns emerge or change at the street block level. For example, changes to the physical layout of a city, such as the development of new transit routes or streets, or changes to the land use of an area with the rise of gentrification, may eventually affect criminal opportunity and crime rates, however, this process is likely to occur over a longer period of time than that which was measured for this dissertation.

Third, as with any statistical analysis, the methodology employed only provides an interpretation or approximation of reality and should not be viewed as representing an absolute reality. The trajectories identified by both the group-based trajectory model and the k-means approach are solely estimations of the developmental patterns of criminal activity on the street blocks of Vancouver, B.C. Weisburd, Morris and Groff (2009) address this issue within the realm of trajectory analysis by stressing that the developmental patterns uncovered “are not inherently real or immutable over time” (pg. 453). No statistical process is without error and as with any study, the results of this dissertation were undoubtedly affected by the time-frame and quality of data analyzed.

Fourth, this study is based on reported (or police observed) criminal activity. It is a well-established fact that reported crime constitutes a proportion of actual criminal activity. Termed the dark figure of crime, criminologists acknowledge that there is a difference between how much crime occurs in society and how much is reported to or discovered by police (Griffiths and Hatch Cunningham, 2003; Linden, 2004). The current study attempted to minimize the effect of the dark figure of crime by focussing on 22 index crimes, which represent more serious property and violent offences such as break and enter, aggravated assault and homicide. It is argued that these crimes are more likely to be reported to police than other more non-serious offences. As such, it is argued that the potential influence of unreported crime on the trajectory results within the current study was likely minimized. Lastly, trajectory analysis is an exploratory tool. It provides an excellent starting point to assess whether micro crime places exhibit longitudinal patterns over time and whether these patterns are stable or significantly change. What it cannot do is explain the patterns that it uncovers. Thus, despite, for example, the semi-parametric nature of the group-based trajectory model, these statistics should be viewed as descriptive in nature, as they do not encompass the ability to infer explanation.

Future Research

This section will detail how future research can advance the findings generated from this dissertation and ensure their applicability to interested stakeholders. The majority of future research discussed in this section pertains to expanding the work from this dissertation towards generating an explanatory model for the observed trajectories in Vancouver that can benefit both the crime and place literature within Environmental Criminology and offer practical solutions for law enforcement. Nine main areas of further research will be offered.

Beginning with expanding the descriptive picture of Vancouver's micro crime patterns, it would be useful to conduct the same trajectory analyses with a more comprehensive dataset that included all calls-for-service. This could also include a separate analysis that compared the trajectories identified between property versus violent versus perhaps motor-vehicle or traffic related offences. It would be interesting to observe how the developmental patterns of Vancouver's street blocks vary as a function of whether property or violent crime is focused on. Additionally, it would be useful to expand the time period of the dataset as much as possible. In particular, the years from 2007 – 2010 saw even more changes to the downtown core and surrounding streets of Vancouver with significant residential development and further gentrification processes. Although it may be preliminary at this time to investigate whether these land use changes have affected criminal activity in the city, expanding the dataset to include the most recent years would allow police and researchers to see any short term changes in crime patterns on these particular streets.

Second, it may also be advantageous to geographically analyze the trajectory results stemming from the Proc Traj method. This group-based trajectory model identified seven separate trajectories of street segments throughout Vancouver, as opposed to four by the k-means procedure. Both statistics identified the vast majority of streets as being stable in nature over the 16 year study period; however the Proc Traj method identified a substantially higher number of decreasing trajectories. Specifically, the Proc Traj method found 30% of street blocks exhibited a decreasing tendency compared to only 6% according to the k-means approach. It would be interesting to compare the locations of both the stable and decreasing trajectories identified by both techniques. In particular, it would be interesting to observe whether the decreasing street segments identified by the Proc Traj method are also located on Vancouver's main arterial roads, as was observed by the k-means technique. If so, this would add to the interesting finding that many arterial roads in Vancouver were identified as having decreasing criminal trajectories. These streets saw the highest levels of crime (according to both techniques), which may be due to the fact that they represent border type blocks (see Brantingham and Brantingham, 1975b), however, it remains unclear as to why they would be identified as decreasing in nature. Should the Proc Traj method identify these streets as decreasing in nature as well, this would add to the importance of analyzing this finding further.

Third, in order to explain the observed patterns uncovered by the trajectory analysis performed in this dissertation, it is suggested that future research examine the characteristics inherent to the two identified trajectories- stable and decreasing. Such work has been conducted by Weisburd, Groff and Yang (2011) who tested the explanatory value of both routine activity theory and social disorganization characteristics as applied to the stable, decreasing and increasing trajectories identified throughout Seattle. The results allowed for the generation of a model wherein specific elements of both theories were offered as highly predictive of whether a street segment was likely to be classified as high chronic in nature. This was accomplished using a logistic regression technique and it is argued that the same or similar statistic should be applied to the Vancouver dataset to develop an explanatory model for the patterns observed. This would answer questions such as, what characteristics predict the inclusion of a street block within a high crime versus a low crime trajectory, or whether there are specific characteristics inherent to street blocks in Vancouver that are classified as stable versus those that are decreasing in nature? In particular, variables representing routine activities theory (i.e. presence of targets, likelihood of offender and victim intersection, presence of guardians), social disorganization theory (i.e. socio-demographic characteristics, land use and variables reflective of social cohesion or fragmentation) and pattern theory (i.e. development of transit routes, presence of arterial roads, extent of gentrification) should be included and systematically analyzed to develop a model that has explanatory value from an Environmental Criminology perspective.

Having said that, a discussion regarding the feasibility of analyzing such variables at the street block level is worth noting. In Canada, socio-economic and demographic data are collected every five years, as per the national census. The smallest unit of analysis in which this information is disseminated is the dissemination block. There are two primary challenges with accessing these data for future explanatory studies on crime and place at the street block level. The first is that dissemination block data are only available from 2001 onwards. As the current study includes calls-for-service on Vancouver street blocks from 1991, this would not be sufficient. Additionally, Statistics Canada defines a dissemination block as an area bounded on all sides by roads and or boundaries of standard geographic areas. This definition infers that a dissemination block does not equate to a street or city block and would actually include four street blocks per one dissemination block. Therefore, significant challenges arise should one attempt to apply Canadian census data to the street block level for analytic purposes. However, in considering the most recent analyses from Weisburd, Groff and Yang (2011), census-type data were not used in the generation of a model attempting to explain micro crime patterns observed on the streets of Seattle. For example, data from Seattle's Public School system were accessed for measures of racial heterogeneity, Seattle Housing Authority data were used to identify locations of public housing units and Seattle Planning Department data were used for information on residential property values. Albeit, collecting such information from a myriad of sources is time-consuming, it undoubtedly is the best way to access socio-economic data that can be applied to the street block level for theoretical analyses of micro crime places. It is suggested that such future research, as discussed in this section would include accessing similar types of agencies and public bodies throughout Vancouver, British Columbia.

Fourth, it must be reiterated that 40% of all street segments in Vancouver saw no criminal activity of the 22 index crimes measured over the period from 1991 to 2006. As important as it is to explore the reasons underlying geographic patterns of criminal activity, it is argued that spatially analyzing the street segments with no criminal activity may be advantageous as well. Where are these streets located throughout Vancouver? Are they clustered in one particular area? What are the characteristics of the street blocks absent of serious crime for 16 years? Perhaps by exploring the factors underlying street blocks absent of crime, one may gain insight into potential crime prevention initiatives for the problematic blocks/areas.

Fifth, not all explanations must come from inferential statistics or academia. It would be highly useful to liaise with the Vancouver Police Department (VPD) and engage in a dialogue discussing potential explanations for the observed micro crime patterns uncovered from this dissertation. The police represent those on the front lines who observe the criminal activity that academicians study regularly. Without the perspective of those who directly witness the crime patterns, the applied utility of such research is limited. It is suggested that the VPD's perspective on potential explanatory models be discussed and further to that, touch on whether the police have additional characteristics of street segments that should be included in an inferential analysis of the trajectory findings that could hold explanatory value.

Sixth, one of the key findings from the spatial analysis of this dissertation is the prevalence of the low to moderate decreasing crime trajectories situated on Vancouver's main arterial roads. It would be advantageous to explore this further. Specifically, it is suggested that these street blocks be segregated for analysis to examine what are the characteristics of these particular roads that have led to the higher rates of criminal activity? Also, it is questioned whether an explanation for the decreasing nature of these trajectories could be surmised? Overall, considering the magnitude of arterial roads towards the spatial distribution of crime trajectories in Vancouver, it is argued that further analysis attempt to discern statistically what the impact is of their presence within an area. This would be applicable to other scholars attempting to explain micro crime patterns, should the city in question exhibit similar patterns of crime trajectories on major thoroughfares.

Seventh, it is suggested that further research on the spatial distribution of street block trajectories in Vancouver is needed. It would be interesting and useful to analyze the spatial dependence of the differing street block trajectories. Are stable trajectories more or less likely to be adjacent to each other or neighbour decreasing trajectories? Conclusions reached from this type of research would add to the literature on the salience of micro crime places, as preliminary observations of the spatial distribution of Vancouver`s trajectories show high crime gradients in certain areas of the city. Such findings were tested in the city of Seattle by Groff, Weisburd and Yang (2010) who found `"significant variations in temporal trends from street segment to street segment which suggests that something is going on at the micro level that requires explanation`" (p. 26).

Conducting similar analyses on the Vancouver micro crime patterns would add to this body of emerging research.

Eighth, is the subject of linear adjacency. Like Weisburd, Groff and Yang (2011), this study revealed (at an observation level), a sort of spatial heterogeneity in the sense that street blocks of all different trajectories neighboured one another throughout all parts of Vancouver. The exception was the stable low trajectory, which evidenced a clustered pattern. However, this is far more likely due to the fact that this trajectory was comprised of 94% of streets in the city and thus these streets inevitably would neighbour one another due to their large number. This spatial heterogeneity, as translating into a lack of a clustered finding may also be looked at in a different way. If one looks at figures 29 and 30, one can see a linear pattern that may arguably infer a clustered phenomenon. Particularly from figure 30, it is clear that many of the low decreasing street blocks are connected to one another and that this trajectory evidences a strong linear adjacent pattern whereby one low decreasing street block is connected to another. Although they are the same street name, they are distinct units of analysis, as defined by the street block definition. This linear pattern may not meet a typical definition of a 'cluster' as detected by methods such as choropleth or grid cell analyses or spatial autocorrelation (Paulsen and Robinson, 2004). However, in the field of Criminology, this linear pattern certainly challenges this typical definition and raises a hypothetical question. If, for example, five street blocks of the same developmental crime trajectory are linear to one another, does that constitute a cluster? Even in the absence of such trajectories surrounding the linear pattern?

Focusing on the issue of linear adjacency is timely and important within spatial Criminology as the street block gains popularity and credibility as a useful unit of analysis to analyze micro crime trends. It may be advantageous to redirect the definition/consideration of a crime cluster when analyzing street blocks, from one that focuses on an 'area' to one that focuses on or includes linearity. It is argued that if this was the case, that Weisburd, Groff and Yang (2011) may have found support towards spatial homogeneity throughout Seattle. However, Weisburd et al. (2011) extensively discusses the degree to which the trajectories identified throughout Seattle evidence a spatial heterogeneous pattern. For example, it is noted that high rate trajectory segments are interspersed amongst low rate segments and other high decreasing, high increasing and chronic hot spot streets within an area. Seeing this observation underscored the importance of examining crime at a micro level where such finite differences in the spatial distribution of criminal activity are apparent.

Further, Weisburd et al. (2011) conducted various spatial statistics to test for clustering (using Ripley's *K*), spatial autocorrelation (using local indicators of spatial autocorrelation) and for spatial dependence (using cross-*K* analysis). None of these spatial statistics measure the significance of linear adjacency. Rather, the focus is on the nearest neighbour within a surrounding area. Using the Ripley's k statistic, the results showed a high degree of clustering amongst the highest rate trajectories, but not amongst the crime free, low stable or low increasing trajectories. The LISA statistic showed substantial amounts of negative spatial autocorrelation furthering Weisburd et al.'s (2011) conclusion that Seattle exhibited a great deal of spatial heterogeneity. Additionally, the cross-k analysis revealed significant levels of spatial attractiveness between different street segment trajectories. Despite the fact that these spatial statistics found spatial heterogeneity, it is still argued by this dissertation that linear clusters of street segments within the same trajectory are evident. For example, Weisburd et al. (2011) explain that the street segments within the crime free, low stable and low increasing trajectories were found to be spatially random. However, if one looks at the visualization maps depicting Northern Seattle, numerous streets within the crime free, low stable and also the moderately stable trajectory are linearly adjacent to one another. Additionally, the low stable and low decreasing trajectories evidence linear adjacency in Southern and Central Seattle and arguably the segments belonging to the high increasing trajectory are linearly adjacent in Southern Seattle with the high decreasing segments evidencing the same trend in Central Seattle.

There are two issues to note regarding this pattern. First, it is possible that the linear adjacency of street segments within the same trajectory seen in Seattle may be detected by techniques such as Ripley's *K*, and simply not register as being statistically significant in nature. Or secondly, street segments that are linearly adjacent may not be considered spatially clustered as per these types of commonly used statistics. Having said that, the fact that street segments of the same trajectory throughout both Seattle and Vancouver have shown to be linearly adjacent raises the question whether such patterns can be considered clustered in nature. In Vancouver, most of the moderate to high crime rate trajectories were located on arterial roads, and the observed concentrations did not expand outward in a circular fashion. Rather, they expanded along the street. It would be advantageous to test the density, spatial dependence and autocorrelation levels of the observed spatial concentration of these particular street blocks. However, it is the argument of this dissertation that traditional spatial tests such as Ripley's *K,* kernel density estimations or local indicators of spatial association such as Moran`s *I,* tend to detect the significance of spatial patterns that exist in a *circular* fashion. It is held that these spatial statistics may not be capable of analyzing the magnitude of linear spatial clustering that appears to be characteristic of crime patterns at the street block level. This implies that more progressive spatial statistics may need to be developed that effectively detect the existence of key spatial patterns such as complete spatial randomness or spatial autocorrelation that exist in a linear fashion, as opposed to those that function on the statistical assumption that spatial concentrations exist in a circular fashion.

Ninth, returning to the issue of the applied utility of this research, any explanatory models pursued should be used to inform police and other affected stakeholders about the characteristics predictive of high and low rate street block trajectories. Once an explanatory model is generated, the question remains as to whether any of the predictive characteristics of the high crime rate versus low crime rate trajectories are changeable and which ones are not. For example, the presence of elements that generate crime due to the intersection of targets and motivated offenders, such as public facilities, may not be changeable, but the level of security or police presence surrounding them is. The presence of bus stops may not be changeable, but the installation of surveillance mechanisms at these locations may be. Signs of physical disorder or vacant land are certainly changeable. Weisburd et al.'s (2011) research stressed that the presence of truant juveniles was highly predictive of whether a street segment was categorized within a high crime rate trajectory. This would be an example of a finding that both police and community practitioners would find useful and could lead to the development of more innovative programs targeting this demographic to decrease the likelihood of delinquency and to better occupy their time. It is incumbent on researchers in this field to ensure that the results of this type of analyses are made available to those on the front lines who are directly responsible for crime prevention and public safety. Overall, studies on micro crime places within Environmental Criminology have significant applied utility. Research and reality should amalgamate to ensure the most practical results for both academicians and practitioners.

Conclusion

The purpose of this dissertation was to expand the research of crime and place by replicating the seminal work of Weisburd et al. (2004) in a city outside of Seattle, WA. Over one million calls-for-service from the Vancouver Police Department from 1991 to 2006 were analyzed at the street segment level to determine whether micro crime places in Vancouver, B.C. evidence developmental trajectories over time. Using two separate statistical methods, a trajectory analysis was conducted that traditionally has been applied to only life course or developmental criminology studies. First, as per the methodology employed by Weisburd et al. (2004), a group-based trajectory model (GBTM) was conducted which identified seven distinct patterns of criminal activity throughout Vancouver's street segments over time. Specifically, three trajectories were identified as stable in nature, with the other four labelled as decreasing. The highest crime rate street blocks were categorized within a decreasing trajectory and no increasing developmental patterns were identified. A major limitation of the GBTM method was the inability of the software to process cases greater than 50. Thus, any street segments evidencing over 50 calls-for-service within any given year were truncated to 50 in order to allow the statistic to run smoothly. This affected 3.6% or 468 street segments in Vancouver throughout the study period. Due to this problem, a separate trajectory analysis, k-means, was also performed by which no truncation of data was necessary. The results identified four distinct micro crime patterns throughout Vancouver. One trajectory included almost 94% of street blocks and was classified as having low levels of stable criminal activity. The remaining three trajectories evidenced low to high crime rate patterns, and were all classified as decreasing in nature. Despite the differences in the number of trajectories identified between the two separate statistical analyses, the overall story was the same:

Crime on Vancouver's street blocks is highly concentrated.

The results showed that 100% of all criminal activity was located on only 60% of street blocks. The highest concentrations of criminal activity, defined as streets evidencing over 50 crimes on average per year, were found on only 2% of blocks.

These crime concentrations remained relatively stable over time.

The vast majority of street blocks were identified as having stable developmental trajectories over the study period. This means that the volume of criminal activity seen on street blocks throughout the majority of Vancouver did not change substantially from 1991 to 2006. Additionally, all of the street blocks labelled as stable evidenced minimal levels of crime. In sum, of the 60% of streets harbouring criminal activity, the majority showed low criminal activity and remained that way over 16 years. Vancouver did evidence hot spots of crime as well. A much smaller proportion of street blocks were categorized as high crime rate streets – all of which showed a decreasing trajectory over the study period. Thus, Vancouver's high crime streets were small in number and began to steadily decline over the study period. Having said that, the highest crime rate street blocks still remained the 'highest' by 2006, despite having been statistically classified as a decreasing trajectory. This lead to the conclusion that overall, Vancouver's street blocks showed great stability of scale.

Vancouver's street blocks show significant geographic variability.

The spatial distribution of street block trajectories throughout Vancouver strongly supports the tenet that micro crime places must be analyzed to both understand the variability of criminal activity and to further progress on crime prevention. The analysis for this dissertation showed that crime levels and the extent to which they are likely to remain stable versus change (i.e. decrease) varies substantially from one block to the next. Results showed blocks low in crime adjacent to blocks with the highest crime rates; results also showed street blocks with stable trajectories neighbouring those that decreased in nature. Thus, criminologists and practitioners cannot discount the spatial unpredictability of criminal activity evidenced at micro places. This finding is not only important but arguably fascinating as it negates the traditional point of view that cities have “bad areas” and that these “areas” ought to be avoided for fear of victimization. The research from this dissertation indicates that high levels of criminal activity vary from one street to the next. As such, there was no evidence found that would support the notion of a “bad area” – perhaps only, “bad streets”.

In the book titled, The Criminology of Place: Street Segments and Our Understanding of the Crime Problem”, Weisburd, Groff and Yang (2011) question whether their results regarding developmental crime patterns are generalizable outside of Seattle, WA. It is argued that this dissertation has shown that they are- with a few caveats. In general, the overall results are remarkably similar in terms of the three main findings as specified above. However, Vancouver did not evidence any increasing trajectories, whereas Seattle did. In fact, both sets of trajectory analyses conducted only yielded stable and decreasing developmental patterns throughout Vancouver’s street blocks.

Additionally, Vancouver’s overall declining crime rate throughout the study period appears to be attributable to all the street blocks evidencing crime (i.e. 60% of them). Although not all street blocks were classified as decreasing in nature, even those identified as stable evidenced negative slopes, meaning that they did show a decreasing tendency. In contrast, Weisburd et al. (2011) stress that Seattle’s crime decline is likely only attributable to those street segments identified as decreasing in their developmental patterns as the results also showed increasing trajectories. It is imperative to stress the significance that both trajectory analyses evidenced comparable developmental patterns of micro crime places in Vancouver, B.C. This bodes well for the internal validity of this dissertation. Genolini and Falissard (2010) stress how useful it can be for researchers to use the Proc Traj and the k-means technique in conjunction. Specifically, it is argued that “when the two algorithms yield similar results, it reinforces confidence in the results”

(p. 326). Thus, one can be highly confident that the overall developmental patterns uncovered in this dissertation depict a representative story of crime and place on Vancouver's streets, at an explanatory level.

In conclusion, this dissertation makes a strong argument for a renewed focus on micro places within Environmental Criminology. In particular, applied research aiming to assist police and practitioners in the field of crime prevention should pay close attention to two main trends, revealed by both the Seattle and Vancouver studies. One, both sets of research support 'place' based crime prevention initiatives. The results clearly indicate that hotspots of crime remain stable over time; thus, focusing public resources on targeting these streets is argued as a constructive endeavour towards public safety. Additionally, both studies show that criminal activity is not only spatially concentrated but that the locations of hotspots at the micro level can be rather unpredictable. Weisburd et al. (2004) stressed that the trajectory analysis revealed a surprising level of homogeneity in the developmental patterns of street blocks in Seattle, and this is true for Vancouver's patterns as well. However, when looked at from a spatial perspective, the results are far more heterogeneous. Both studies showed the existence of various trajectories throughout the entire city and both yielded unpredictable locations for the highest rate crime trajectories. Thus, decisions regarding where to focus crime prevention efforts or where to place new residential developments should be preceded by an examination of criminal activity at the street block level. Larger units of analysis may mask micro level variations that are essential towards the success of such projects.

Weisburd et al. (2011) implore other researchers to replicate their work in other jurisdictions to assess the generalizeability of the data stemming from Seattle, WA. It is argued that "this is essential if we are to build a science of the criminology of places" (p. 219). This dissertation has achieved the goal of systematic replication of the seminal work conducted in 2004 and hopes to generate enthusiasm for more scholars to assess the longitudinal patterns of micro crime places at the street block level using the same methodology. It is hoped that this expansion of research on micro crime places will lead to more Criminologists utilizing the methodology employed by Weisburd et al. (2004) and this dissertation to examine whether other cities evidence comparable patterns of criminal activity at the street block level. It is argued that the goal should be to see these statistical techniques welcomed by a broader scope of scholars within crime and place research.

Most important though, this dissertation has gone beyond the practice of replication and shown the advantage of an alternate statistical technique that allows for the inclusion and concomitant analysis of street blocks with crime counts above 50. For cities such as Vancouver, B.C. that evidenced a significant proportion of such high crime cases, the k-means statistic was extremely beneficial in exploring these hotspot street blocks. In the future, if scholars conduct longitudinal studies on micro crime places in cities with large crime counts, it is strongly suggested that the k-means technique be implemented to augment the group-based trajectory model. This is recommended for both comparative purposes and to ensure that the most interesting part of the ‘crime story’ on street blocks is revealed.

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