CONSTRUCTING BOUNDARIES FROM BUFFERS: A CRITICAL EXAMINATION OF THE IMPACT OF DRINKING ESTABLISHMENTS ON CRIME

by

Madeline Stenger

A dissertation submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Criminology

Summer 2022

CONSTRUCTING BOUNDARIES FROM BUFFERS:

A CRITICAL EXAMINATION OF THE IMPACT OF DRINKING

ESTABLISHMENTS ON CRIME

by

Madeline Stenger

Approved: _____

Eric Rise, Ph.D.
Interim Chair of the Department of Sociology and Criminal Justice

Approved: _____

John A. Pelesko, Ph.D.
Dean of the College of Arts and Sciences

Approved: _____

Louis F. Rossi, Ph.D.
Vice Provost for Graduate and Professional Education and
Dean of the Graduate College

I certify that I have read this dissertation and that in my opinion it meets the academic and professional standard required by the University as a dissertation for the degree of Doctor of Philosophy.

Signed: _____

Ronet Bachman, Ph.D.
Professor in charge of dissertation

I certify that I have read this dissertation and that in my opinion it meets the academic and professional standard required by the University as a dissertation for the degree of Doctor of Philosophy.

Signed: _____

Tammy Anderson, Ph.D.
Member of dissertation committee

I certify that I have read this dissertation and that in my opinion it meets the academic and professional standard required by the University as a dissertation for the degree of Doctor of Philosophy.

Signed: _____

Ellen Donnelly, Ph.D.
Member of dissertation committee

I certify that I have read this dissertation and that in my opinion it meets the academic and professional standard required by the University as a dissertation for the degree of Doctor of Philosophy.

Signed: _____

Brian Lockwood, Ph.D.
Member of dissertation committee

ACKNOWLEDGMENTS

To my family and friends: thank you for your encouragement, kindness, and support. I love you.

To my committee: thank you for your patience and guidance.

DEDICATION

This dissertation is completed in honor of someone who means the world to me: my sister Michelle who died after a long battle with mental illness.

Michelle: You are my inspiration. You are everything I strive to be: brave, intelligent, compassionate, beautiful, and strong. Words cannot describe how much it hurt to lose you. The privilege of earning this PhD does not compare to the privilege of knowing you and the honor of being your sister and friend.

Your story is not over. I will spend the rest of my life honoring you by working in whatever way I can to end stigma surrounding mental illness. Until we meet again, chasing each other in the stars and in the sea, I will always love you and fight for you; Always.

TABLE OF CONTENTS

LIST OF TABLES ix
LIST OF FIGURES xi
ABSTRACT xii

Chapter

1 INTRODUCTION 1

1.1 General Issues in Selecting the Appropriate Unit of Analysis 3
1.2 Study Aims 6
1.3 Study Contributions 9
1.4 Dissertation Outline 10

2 GUIDING THEORIES 12

2.1 Social Disorganization Theory 13
2.2 Opportunity Theories 20

2.2.1 The Routine Activity Approach 20
2.2.2 The Geometry of Crime and Crime Pattern Theory 26

2.3 The Concurrent Use of Social Disorganization and Opportunity Theories 34
2.4 Summary 38

3 EMPIRICAL INVESTIGATIONS 40

3.1 The Relationship between Alcohol Outlets and Crime: Traditional Geographic Units 43
3.2 The Spatial Extent of Alcohol Outlets: Bivariate Investigations 48
3.3 Census Enhanced GIS Spatial Units 52
3.4 The Current Study: Expanding Investigations of Merger Methods 54
3.5 A Brief Note on Other Innovative Methodologies for Creating New Geographic Units 58
3.6 Chapter Summary 59

4 EXPLORING THE SPATIAL EXTENT OF DRINKING ESTABLISHMENTS ON CRIME 61

4.1 Study Area 63
4.2 Data Sources for Examining the Spatial Extent 64
4.3 Data Preparation: Geocoding, Shapefile modification, Data Cleaning 64
4.4 Analytic Approach: Calculating the Spatial Extent of Facilities on Crime 68
4.5 Limitations of the Location Quotient 69
4.6 Location Quotient Results 71
4.7 Chapter Summary 75

5 OVERVIEW OF METHODOLOGICAL TECHNIQUES 77

5.1 Creating New Geographic Units in the Wilmington Metropolitan Area 80
5.2 Areal Weighted Interpolation 83
5.3 Data Sources and Variables 87

5.3.1 Outcome Variables 88
5.3.2 Explanatory Variables 88

6 RESULTS FROM NEGATIVE BINOMIAL MODELS 95

6.1 Descriptive Statistics 96
6.2 Negative Binomial Results: Population as Exposure Variable 103

6.2.1 Negative Binomial Results for Models 1 and 2: Property Offenses Per Capita 104
6.2.2 Negative Binomial Results for Models 3 and 4: Violent Offenses Per Capita 106

6.3 Negative Binomial Results: Area as Exposure Variable 109

6.3.1 Negative Binomial Results for Models 5 and 6: Property Offenses per Area 110
6.3.2 Negative Binomial Results for Models 7 and 8: Violent Offenses per Area 112

6.4 Summary 115

7 EXPLORING MODEL COMPARISONS 118

7.1 Model Comparisons: Union versus Update Units with Population as Exposure 119

7.2 Model Comparisons: Union versus Update Units with Area as Exposure 122
7.3 Comparison of Property Crime Models: Population versus Area as Exposure 125
7.4 Comparison of Violent Crime Models: Population versus Area as Exposure 128
7.5 Key Takeaways 131

8 DISCUSSION 134

8.1 The Impact of Being Part of a Drinking Establishment Buffer Zone 135
8.2 Examining the Impact of Geographic Creation Methods and Operationalization of Crime 137
8.3 Guidance on Selecting the Appropriate Model 141
8.4 Methodological Choices and Limitations 144
8.5 Directions for Future Research 147
8.6 Conclusion 150

REFERENCES 153

Appendix

VIF TABLES AND BIVARIATE CORRELATIONS 169

LIST OF TABLES

Table 1: Wilmington Metropolitan Descriptive Statistics for Crime by Year 72

Table 2: Location Quotients: Violent Crimes 73

Table 3: Location Quotients: Property Offenses 75

Table 4: Variables and Their Anticipated Impacted Based on Theoretical Expectations 91

Table 5: Overview of Negative Binomial Models 96

Table 6: Descriptive Statistics for Union Geographic Areas 97

Table 7: Descriptive Statistics for Update Geographic Areas 98

Table 8: Models Analyzing Property Offenses per Capita 105

Table 9: Models Analyzing Violent Offenses per Capita 107

Table 10: Models Analyzing Property Offenses per Square Kilometer 111

Table 11: Models Analyzing Violent Offenses per Square Kilometer 113

Table 12: Property Crime per Capita: Union versus Update 120

Table 13: Violent Crime per Capita: Union versus Update 121

Table 14: Property Offense/Sq. Km.: Union versus Update 123

Table 15: Violent Crime/Sq. Km.: Union versus Update 124

Table 16: Union Method-Property Offenses: Crime per Capita Vs. Crime/ Sq. Km. 126

Table 17: Update Method-Property Offenses: Crime per Capita Vs. Crime/ Sq. Km. 127

Table 18: Union Method- Violent Offenses: Crime per Capita Versus Crime per Sq. Km 129

Table 19: Update Method- Violent Offenses: Crime per Capita Versus Crime per Sq. Km 130

Table 20: Model Comparisons for Union and Update Units 131

Table 21: Variance Inflation Factors (VIF) for Per Square Kilometer Models 169

Table 22: Variance Inflation Factors (VIF) for Per Capita Models 169

Table 23: Bivariate Correlation Matrix: Union Units 170

Table 24: Bivariate Correlation Matrix: Update Units 171

LIST OF FIGURES

Figure 1: Social Disorganization Causal Model 19

Figure 2: Buffer Zones around A Treatment Facility 49

Figure 3: Street Distance (on left) versus Euclidean Buffers (on right) 67

Figure 4: Wilmington Metro Area Block Groups and Drinking Place Buffer Zones 80

Figure 5: Union and Update Approaches to Merging Areas 82

Figure 6: Comparison of Newly Created Units using the Update and Union Methods 83

Figure 7: Areal Interpolation and the Union Method 85

Figure 8: Areal Interpolation and the Update Method 86

Figure 9: Variable List for Analyses 93

ABSTRACT

OBJECTIVES: Advancements in technology have increased the capability of researchers to investigate the relationship between crime and place (Andresen & Malleson, 2013; Hunt, 2019). One area of scholarship that has received considerable attention concerns the relationship between crime patterns and alcohol related establishments (Groff & Lockwood, 2014; Wheeler, 2019). However, the majority of research in this area have relied on pre-existing census boundaries that do not align with the objectives of investigations analyzing the impact of facilities on crime. The purpose of this dissertation is to examine how different methods for creating new geographic units through merging buffer zones and census block groups can help enhance our understanding of the relationship between drinking establishments and crime.

METHODS: The primary data used for this project were Delaware police calls for service. Location quotient analyses revealed that property and violent crimes were more densely concentrated within 1600-foot buffer zones around drinking establishments relative to the crime density within the Wilmington Metropolitan area overall. Buffer zones and census block groups were merged using two approaches (i.e., the union and update methods) to determine if results from negative binomial

models varied depending on the unit type. As an additional check on the robustness of results, models varied in terms of the operationalization of the dependent variable.

RESULTS: Eight negative binomial models were examined to explore the impact of being part of a drinking establishment buffer zone on crime rates within the newly created geographic regions. Regardless of geographic unit type, operationalization of the dependent variable, and crime type analyzed, being part of a drinking establishment buffer zone was positively associated with crime rates. However, variation in models concerning other significant predictors demonstrate that the modifiable areal unit problem is an issue for this study.

CONCLUSION: While the results for variables such as buffer zone status and the level of crime counts in neighboring units appeared to be robust predictors across methods, the differences in terms of significance, magnitude, and direction between the coefficients of other socially relevant variables reinforce that there should be caution when deciding on the unit of analysis and operationalization of dependent variables.

Chapter 1

INTRODUCTION

Over the past several decades, advancements in geographic information systems (GIS) and statistical software packages have helped enhance our understanding of the connection between crime and place (Hunt, 2019). Within this field of geographic criminology, one area that has received significant attention concerns the relationship between crime and institutions (Groff & Lockwood, 2014; Wo, 2016). Studies relying on diverse analytical techniques have investigated the link between increased crime and a variety of establishments theorized to be "criminogenic" (e.g., Bernasco & Block, 2011; Bowers, 2014; Groff & Lockwood, 2014; McCord & Ratcliffe, 2007; Haberman & Ratcliffe, 2015; Kim & Hipp, 2021; Tillyer, Wilcox, & Walter, 2021). Such inquiries have generally focused on how the presence (i.e., number or density) of these facilities impacts crime within official geographic units from the census or on street segments (Inlow, 2021).

One establishment that has been at the center of many examinations of the crime-facility nexus is alcohol outlets (Groff & Lockwood, 2014). Empirical evidence linking alcohol outlets to higher crime rates has been obtained at various geographic levels including larger units such as census tracts (Peterson, Krivo, & Harris, 2000, Franklin et al. 2010) and smaller geographies such as street segments (Groff & Lockwood, 2014; Wheeler, 2019). This connection has been established when looking

at both the density of alcohol outlets (Pridemore & Grubesic, 2012; Grubesic et al. 2013) and the number of these facilities (White, Gainey & Triplett, 2015) as well as when examining violent (Franklin et al. 2010; Gruenewald, Freisthler, et al. 2006; Jennings et al., 2014) and nonviolent offenses (Toomey et al. 2012). Clearly, research investigating the relationship between alcohol outlets and crime is by no means underdeveloped.

Nonetheless, the relationship between alcohol-related facilities and crime has relied primarily on the use of official boundaries provided by the census bureau or street segments. What remains underexplored is how the use of geographies beyond these pre-defined units can enhance our understanding of the relationship between these facilities and crime. For instance, the technique of creating buffers (i.e., zones within pre-specified areas) around the facility can be used to gain a better sense of how crime is distributed within areas that fall within the nearby vicinity (Groff, 2011). Advances in technology have led to increased availability of software and statistical programs that allow for the creation of new geographic units through the merger of census geographies with these buffer zones (Rengert & Lockwood, 2009; McCord & Ratcliffe, 2007). Yet, few studies have systematically examined how the use of new geographic units created in this manner may shape our understanding of the crime-facility relationship (see McCord & Ratcliffe, 2007; Rengert, Ratcliffe, & Chakravorty, 2005 for exceptions).

Moreover, the different mechanisms of merging these data sources have not undergone critical examination in regard to their impact on results. For instance, some

scholars have relied on a union method for merging buffers around facilities with geographic units such as block groups (see McCord & Ratcliffe, 2007). This process produces new geographies based on the intersection of the census and buffer data. Essentially, the original census block group becomes divided into the portion that is part of a buffer zone around an establishment and a portion that is not associated with the buffer zones. However, another option for producing new units involves placing the buffer zones over the census geographies and creating new areas from the overlay, keeping the drinking establishment buffer intact. The resulting units of analysis tend to be larger based on this method relative to the union approach. In addition, the new unit may consist of an area extending across several of the original census units. To date, there does not appear to be a critical analysis of how these two different approaches can impact our understanding of the relationship between alcohol related facilities and crime. The current study helps fill this gap in the literature.

1.1 General Issues in Selecting the Appropriate Unit of Analysis

This dissertation contributes to the literature highlighting one of the most critical decisions that a researcher investigating the effects of criminogenic locations on crime can make: the choice in the appropriate unit of analysis (Weisburd, Bruinsma, & Bernasco, 2009). The significance of this decision is associated with an issue known as the modifiable areal unit problem (MAUP) (Openshaw, 1984). The modifiable areal unit problem is a statistical bias concerning how the size and shape of geographic units can impact spatial patterns and relationships therein. MAUP has two

fundamental components: the zonation effect and the scale or aggregation effect (Oberwittler & Wikstrom, 2009; Gerell, 2017). The zonation effect is linked to how boundaries are drawn and whether they reflect meaningful patterns of human behavior. On the other hand, the scale effect is related to determining what is the most appropriate size for the geographic unit in order to investigate associations (Oberwittler & Wikstrom, 2009). MAUP has important implications because spatial patterns can vary significantly depending on the shape and size of the geographic unit (Openshaw, 1984).

Recognition that the selection of the unit of analysis has important implications for identifying spatial patterns and subsequent results for crime related outcomes is nothing new. For instance, in the nineteenth century Glyde (1856) called attention to the potential of higher order geographies to hide lower-level variation by showing that larger geographic areas masked variation in crime rates that were evident when using smaller geographies (Weisburd, Bruinsma, & Bernasco, 2009). However, it is only relatively recently that the debate concerning the scale of research (i.e., whether to use macro or micro units) has gained wider acknowledgement and systematic attention within the field of criminology (Bruinsma,2017; Gerell, 2017; Hipp, 2007; Hipp & Williams, 2020; Weisburd, Bruinsma, & Bernasco, 2009). More specifically, one of the driving questions that has emerged in the extant literature concerns whether researchers should rely on larger units such as census tracts or smaller units such as street segments when trying to identify relevant associations (Weisburd, Bruinsma, Bernasco, 2009; Hipp & Williams, 2020). This line of inquiry has pushed many

scholars to advocate for smaller geographic units (Oberwittler & Wikstrom, 2009) especially since crime tends to be concentrated within very small units of geography (Weisburd, Groff, & Yang, 2012).

The move toward smaller units has both methodological and theoretical underpinnings. By focusing on these smaller units, scholars can uncover variability at the lower level that would be missed when higher order geographic units are used **(**Andresen & Malleson, 2013; Weisburd, Bruinsma, & Bernasco, 2009). Smaller units tend to be more homogenous (Oberwittler & Wikstrom, 2009), which can help scholars achieve the statistical goal of maximizing between- region variation while minimizing within- region variation (Rengert & Lockwood, 2009, p. 111). Moreover, the reliance on smaller areas tends to lead to more sampling units which increases statistical power (Oberwittler & Wikstrom, 2009). On a theoretical level, using lower-level geographic units to study crime patterns is logical since the environmental factors associated within an individual's setting which may (directly or indirectly) impact behavior is often confined by regions far smaller than commonly used geographies such as census tracts (Oberwittler & Wikstrom, 2009). Nonetheless, it is important to recognize that this move towards using exclusively smaller units is not free from its own limitations. More specifically, various scholars have cautioned that a reliance on smaller geographies can result in a failure to uncover broader level effects that are observable when larger units are incorporated into an analysis (Boessen & Hipp, 2015; Tita & Radil, 2010).

While important advancements have been made within the scale debate, the discussions and empirical tests examining the implications of the modifiable areal unit problem have largely centered around the use of officially defined boundaries from the census or street segments (see Gerell, 2017 for exception). However, as previously indicated, advancements in GIS and statistical software packages allow for the creation of new units that can provide a shifting focus to the crime-facility literature. Techniques merging drinking establishment buffers with census geographies can provide an important avenue for examining proximity-based influences of these establishments on crime (McCord & Ratcliffe, 2007). More specifically, by creating new geographic units that place a criminogenic facility at the center of the analysis and utilizing techniques that allow us to estimate the social makeup of these newly created areas, we can better assess how these establishments influence crime. Such techniques allow us to go beyond including measures of alcohol outlets as independent variables by infusing the facility into the geographic units under investigation.

1.2 Study Aims

A lack of empirical assessment on the use and comparison of methodological approaches for creating new geographic units for analyzing the facility-crime nexus provides important avenues of inquiry. The current study builds upon this nascent subset of research by exploring how different methods for creating new geographic units through the merger of buffer zones and census block groups can help enhance

our understanding of the relationship between drinking establishments and crime. This study addresses four research questions:

1) *Does the presence of drinking establishments affect the spatial distribution of violent crimes and property crimes in surrounding areas?*
2) *Does the relationship between drinking establishments and crime remain after controlling for the larger social environment in which these facilities operate*?
3) *How do different methodological techniques used to examine the relationship between criminogenic facilities and crime affect the results and shape our interpretations of the role of these facilities on crime?*
4) *Does the operationalization of the dependent variable (i.e., looking at crime density in terms of population versus area) impact which variables are significant predictors of crime within these newly created geographic units?*

To address the first question, buffer zones were drawn around drinking establishments in increments of 400 feet up to 1600 feet (i.e., 0-400, 400-800, 800-1200 and 1200-1600 feet). Location quotients were used to assess whether the distribution of crime around these facilities differed significantly from the distribution of crime within the study area as a whole. The exploratory assessment of crime distribution around the facility of interest is an important (but underutilized) first step of the process for establishing the link between facilities and crime. The second and third questions were explored using two different merger techniques: the union

process, which intersects census block groups with the buffer zones around drinking establishments, and the update process, which produces new units from the overlay, thus keeping the buffer intact. An areal weighted interpolation approach was used to estimate elements of the social makeup of these new units. Using a series of negative binomial regression models, crime rates for violent and property offenses were analyzed while controlling for a number of factors that are associated with the social and opportunity characteristics of the geographic unit of analysis. The results across these merger methods were compared in terms of coefficient significance, magnitude, and direction to determine if important differences existed across models. The final research question served as a check to assess whether results were a methodological artifact. The operationalization of the crime rate was examined as both a population-based measure and an area-based measure.

Data from this study were obtained from three sources. A more detailed discussion of these sources is provided in chapters 4 and 5. Data concerning criminal incidents were obtained from the Delaware Criminal Justice Information System (DELJIS). These data were originally obtained as part of the Delaware Opioid Metric Intelligence Project (DOMIP). DOMIP is a nationally funded projected conducted by Dr. Tammy Anderson (Principal Investigator), Dr. Dan O'Connell (Co-Investigator) and Dr. Ellen Donnelly (Co-Investigator) with the aim of reducing opioid related harms within the state of Delaware. Data concerning the location of businesses were obtained from ReferenceUSA while data on the social and demographic characteristics of block groups were obtained from the American Community Survey Census files.

1.3 Study Contributions

This study provides several methodological and theoretical contributions. First, this study draws attention to one of the basic methodological decisions a researcher must make: determining the units of analysis. While theory should ideally determine what unit is used, data restrictions and software limitations typically shape this decision as well. Research within the social sciences is often forced to rely on data that is collected for another purpose. For instance, the majority of studies within the crime and place literature relies on predefined boundaries from the census; geographic units which are created for purposes other than crime measurement. Few studies attempt to construct their own boundaries (Rengert & Lockwood, 2009). As such this study contributes to the literature through analyzing newly created geographic units. In addition, the current research explores how different methodological choices in the creation of these units and the operationalization of the dependent variable may shape results. By providing these comparisons on the same data, this investigation contributes detailed insight into how these methodological choices for constructing new units for analysis have the potential to shape results and subsequent interpretations. In other words, this study investigates the extent in which the modifiable areal unit problem is an issue in investigations using these merger techniques.

On a theoretical level, the current study contributes to the literature by using these new units to further investigate a facility that has been dubbed as criminogenic: drinking establishments. The positive correlation between drinking establishments and

crime has been established at various spatial aggregations including census tracts (Peterson, Krivo, & Harris, 2000, Franklin et al. 2010), block groups (Pridemore & Grubesic, 2013), blocks (Bernasco & Block, 2011; Murray & Roncek, 2008), zip codes (Gruenewald & Remer, 2006; Gruenewald, Freisthler, et al., 2006; Lipton & Gruenewald, 2002), and street block segments (Groff & Lockwood, 2014). However, few studies have attempted to investigate this relationship using different scales of geography, much less when relying on newly constructed geographic units that are created from buffer zones around the facility. In other words, previous explorations have labeled drinking establishments as criminogenic because a higher number or density of these facilities within predefined census or street segments have been associated with increased crime within those units. In order to determine if these facilities are truly crime generators, however, we have to place them at the center of analysis rather than include them as part of an index or within a series of controls.

1.4 Dissertation Outline

The remainder of this dissertation proceeds as follows: Chapter 2 consists of a theoretical overview of frameworks that have influenced this research: social disorganization theory and opportunity theories of crime. This chapter concludes with a discussion on recent research that has integrated these theoretical approaches. Chapter 3 provides an overview of relevant literature including findings concerning alcohol outlets and crime from inquires associated with official boundaries. This chapter also provides a broader discussion of the techniques from research that has

attempted to go beyond a reliance on census boundaries when examining the link between facilities and crime. Chapter 4 provides a descriptive assessment of the nature of the distribution of crime around drinking establishments using location quotients. This technique allows researchers to gain a better sense of how the density of crime around these facilities differs from the density of crime within the study area as a whole. Chapter 5 contains a technical discussion of the techniques for merging the drinking establishment buffer zones and census block groups for the larger analyses. The chapter also discusses the areal weighted interpolation approach which was used to estimate the social makeup of these areas. Chapter 6 highlights the results from the eight negative binomial models analyzed within this study. These models varied in terms of the unit of analysis, operationalization of the dependent variable and variation in crime type investigated. Chapter 7 focuses on the convergences and divergences between the models regarding the significance, magnitude, and direction of the coefficients. Finally, chapter 8 concludes with a discussion of the implications of these findings for future research.

Chapter 2

GUIDING THEORIES

Traditional approaches within the criminological literature have been concerned with criminality rather than criminal events. In other words, these theories are individual-centered approaches. Scholars relying on such frameworks may look at the role of peers (social learning theory), the strength of family and societal bonds (social bond theory), and/or the impact of parental guidance (self-control theory) on influencing whether an individual commits a crime (Snipes, Bernard, & Gerould, 2019). Such explanations center around "kinds of people", but other theoretical frameworks suggest that criminology would benefit from exploring "kinds of places" (Stark, 1987, Kubrin & Mioduszewski, 2019, Kubrin & Weitzer, 2003, p.374). Thus, environmental perspectives shift the focus to the criminal event itself (Wortley & Townsley, 2017). The situational context, both in terms of time and space, contribute to the non-random nature of crime patterns (Wortley & Townsley, 2017). Investigating where (and when) crimes occur has expanded our understanding of crime concentration and spatial variation (Weisburd, Groff, & Yang, 2012). The current study falls under the realm of environmental criminology as it is concerned with how the social, economic, and physical structures in which individuals (both potential offenders and targets) are situated, shape crime patterns (Brantingham & Brantingham, 1981; 1993;1995).

Several theoretical explanations of criminal events have helped illustrate the importance of exploring the impact of geography on crime, including social disorganization theory and opportunity theories of crime. These frameworks can help enhance our understanding of why certain facilities such as alcohol establishments may be correlated with increased levels of criminal activity. The following chapter outlines the historical development of these theories, their basic tenets, and limitations. It concludes with a discussion of empirical investigations that have attempted to link and/or integrate both social disorganization and opportunity theories into their analyses. While these theoretical frames inform this dissertation, it is important to emphasize that the current study does not directly test these theories. As will be made clear, limitations in data preclude direct testing of important theoretical tenets. Nonetheless, the analyses in this dissertation are significantly shaped by the following theoretical lines of thought. Although this dissertation is more methodologically oriented, the variables drawn upon are derived from previous work influenced by the frameworks of social disorganization and opportunity theories of crime.

2.1 Social Disorganization Theory

The theory of social disorganization arose in response to critics of individualistic theories that failed to account for the impact of rapid social and economic changes occurring in the United States in the early 1900s (Cullen, Agnew, & Wilcox, 2014). As industrialization and urbanization swept across the nation, the physical and built environment of individuals were altered in substantial ways. Areas

transformed from sparsely occupied rural communities characterized by homogeneity and stability into densely populated cities with diverse and transient residents (Cullen, Agnew, & Wilcox, 2014). The city of Chicago exemplified this rapid change, becoming a focal point of research for scholars from the University of Chicago who made significant contributions to sociology and criminology through their explorations linking spatial patterns of crime with other social ills (Wilcox, Cullen, Feldmeyer, 2018). As such, Chicago served as the birthplace for the theory of social disorganization.

Prior to introducing the core principles of social disorganization, it is important to acknowledge the work of Park and Burgess (1925) concerning the spatial organization of urban areas (Andresen, 2014). More specifically, the concentric zone theory of urban development had a significant impact on the growth of social disorganization theory by providing a framework for understanding how different societal processes (e.g., poverty, residential turnover) were more prominent in specific sections of the city. The theory outlined a process of radial expansion, starting from the center of the city and proceeding outward in a series of zones characterized by distinct features (Burgess, 1925; Mooney, 2019).

Drawing on concepts of plant and animal ecology, Burgess (1925) argued that the city changed and expanded through processes of competition, invasion, and succession. Essentially, concentric zone theory presented the city as consisting of five zones. The zone at the center was the central business district (i.e., downtown), which was the heart of human and business activities. This zone housed office and

department buildings, factories, warehouses, entertainment establishments (e.g., museums, theaters) and transportation hubs such as railroad stations (Burgess, 1925). Encircling the downtown area was the "zone of deterioration" or "zone of transition." The zone in transition often consisted of "submerged regions of poverty, degradation, and disease, and their underworlds of crime and vice" (Burgess, 1925, p. 55). Poorer individuals were forced to live in this zone because of financial restrictions that required being in close proximity to the downtown work centers and due to the cheaper rent. The zone of deterioration was surrounded by a residential zone for the working class. These individuals were able to escape the zone of transition but were unable to move farther from their work environment. The next zone consisted of the residences of the professional class who could afford to live farther away from the noisy and polluted environment of the downtown and surrounding areas. This zone, and the subsequent commuter zone, was home to wealthier individuals who had the means to avoid the downtown and surrounding areas that were less desirable.

To reiterate, the farther one moved from the center of the city, the greater the improvement in economic and social conditions (Andresen, 2014). The concentric zone theory demonstrates how urban organization segregated populations based on economic and social characteristics (e.g., newer immigrants to the United States were often forced to live in the impoverished zone of deterioration). Moreover, the zones were constantly in flux and competing for space as a result of industrialization and urbanization during that time period. For instance, as the downtown zone expanded in terms of manufacturing and business, more space was required which led to an

encroachment of this zone into the surrounding zone (i.e., the zone of transition). In turn, this increased the deterioration within the zone of transition. Subsequently, this forced zone 2 to further invade into zone 3, as residents attempted to escape the undesirable conditions exacerbated from the expansion of the central zones. As such, high population turnover within the inner zones, with people seeking to escape these undesirable areas, and segregation along social and economic conditions produced various levels of social organization throughout the city, with the inner regions being more socially disorganized.

Using this understanding of urban development, Shaw and McKay (1942) empirically examined the link between social disorganization and juvenile delinquency in Chicago. These scholars shifted the focus away from individuals and onto the neighborhoods to explore how sociological phenomenon within the regions shaped delinquency within these areas. Their findings indicated that neighborhood structure in terms of three factors- population turnover, poverty, and racial/ethnic heterogeneity- was strongly associated with delinquency patterns. Importantly, these findings showed that crime was strongly linked with other societal ills (Kubrin & Mioduszeskwi, 2019). Perhaps most significant, Shaw and McKay (1942) demonstrated that, over time, high delinquency rates in areas persisted even while the ethnic/racial compositions of the population residing in these areas changed. In other words, the characteristics of the place rather than the people living in these areas mattered when examining delinquency patterns (Andresen, 2014; Kubrin & Mioduszeskwi, 2019).

To be clear, Shaw and McKay (1942) never claimed that there was a direct relationship between crime and the societal characteristics of poverty, residential mobility, and heterogeneity. Rather, these factors operate indirectly by influencing the level of social organization within a community. A community or neighborhood is considered to suffer from social disorganization when individuals residing in that area are unable to come together to accomplish shared values or goals and lack the capacity to prevent undesirable social maladies such as crime (Kubrin & Weitzer, 2003). In other words, socially disorganized communities are characterized by weak social ties among residents that impede the ability of the community to implement measures of informal social control (i.e., community self-regulation through collective action) (Kornhauser, 1978; Kubrin & Wo, 2016). Examples of informal social control may include informing neighbors of their child's misbehavior or informally surveilling and interrogating a suspicious stranger (Kubrin & Mioduszewski, 2019; Kubrin & Wo, 2016; Sampson, 1987).

Thus, residential turnover inhibits unity among residents as individuals are committed to leaving undesirable areas rather than investing time and resources into the neighborhood. Similarly, racial/ethnic heterogeneity may prevent social ties due to cultural and in some cases language barriers among residents (Andresen, 2014). Such factors are not conducive to community self-regulation as these conditions keep individuals from coming together to realize and implement shared goals such as ensuring a crime-free neighborhood. Thus, neighborhood characteristics such as poverty weaken social ties and prevent residents from implementing measures of

informal social control, which in turn impacts crime rates. In other words, social (dis)organization mediates the relationship between neighborhood structure (e.g., poverty level, residential mobility, and heterogeneity) and crime (Kubrin & Mioduszeskwi, 2019).

The theory of social disorganization has been criticized in several important respects (e.g., see Bursik, 1988; Kubrin & Weitzer, 2003; Kubrin & Wo, 2016; Kubrin & Mioduszeskwi, 2019 for more extensive reviews). First, social disorganization has suffered from a lack of clarity and consistency in the conceptualization and operationalization of social disorganization. For instance, Bursik (1988) pointed out that Shaw and McKay often conflated the concept of social disorganization with the outcome it was seeking to explain (i.e., delinquency). Failure to clearly differentiate these two processes often led to confusion among scholars as delinquency was characterized as an example of disorganization as well as a contributing factor that caused disorganization within a neighborhood. Moreover, previous models often failed to account for spatial dependence (Kubrin & Weitzer, 2003). Modeling spatial dependence is important because areas that are near each other may exert influence on each other. In other words, areas that are close may have similar values on crime. To adjust for this clustering issue, which is known as spatial autocorrelation, research needs to incorporate spatially lagged variables that account for crime in neighboring regions (Kubrin & Weitzer, 2003).

Perhaps one of the most persistent challenges of social disorganization concerns the ability of researchers to empirically capture the full mechanism of social

disorganization (Kubrin & Wo, 2016). Few studies have incorporated the mediating variable of social disorganization into their models (Bursik, 1988; Andresen, 2014). As previously mentioned, poverty, racial/ethnic heterogeneity, and residential mobility do not directly cause crime according to social disorganization theory (Bursik, 1988; Kubrin & Mioduszeskwi, 2019). Rather, these neighborhood characteristics operate indirectly by influencing the level of social disorganization in a community. Figure 1 outlines the causal model for social disorganization. Unfortunately, few studies have been able to capture this full process due to data limitations (Kubrin & Mioduszeskwi, 2019).

Figure 1: Social Disorganization Causal Model

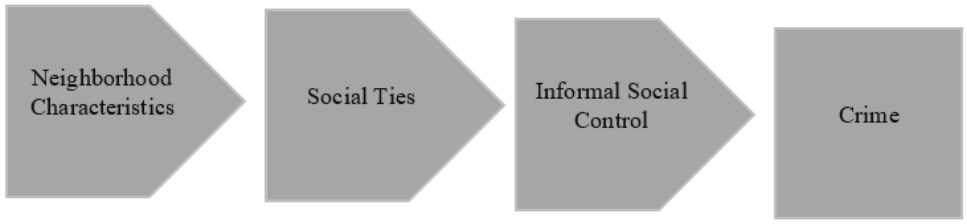


Figure Adapted from: Kubrin &Mioduszewski, 2019

Although several noteworthy studies have been able to use stronger datasets to capture these mechanisms (e.g. Sampson & Groves,1989; Lowenkamp, Cullen & Pratt, 2003), most research, including the current study, rely heavily on census data which does not contain measures suited to capture the underlying dimensions of social disorganization (e.g., measures of social ties and informal social control). Despite

these challenges, elements of social disorganization theory is a common staple in many studies analyzing geographic crime patterns (Kubrin & Mioduszeskwi, 2019).

2.2 Opportunity Theories

The next set of theories that inform this study center around the role of opportunity as a fundamental condition for the occurrence of criminal incidents. While this may seem like an obvious element, after all, without opportunity a crime could not possibly occur, prior theoretical approaches often took this condition for granted, failing to incorporate opportunity into their framework (Felson & Clarke, 1998). However, criminal opportunity is not ubiquitous and certain elements must converge in both space and time in order to create such opportunity (Felson, 2017). Empirical work building upon approaches such as the routine activity approach and crime pattern theory demonstrate the importance of exploring the impact of opportunity-based factors to enhance our understanding of the relationship between crime and place (e.g., Weisburd, Groff & Yang, 2012; 2014). As such, the following sections explore the routine activity approach and crime pattern theory in more detail.

2.2.1 The Routine Activity Approach

The routine activity approach emerged from a "sociological paradox" occurring during the post-World War II era: at a time when life for many Americans was improving economically and socially, violent crime rates had increased significantly (Cohen & Felson, 1979). In other words, even though conditions that other sociological theories purported to cause crime (e.g., unemployment, poverty)

were declining in metropolitan areas, the rates for both violent and non-violent offenses rose considerably. According to Cohen and Felson (1979), the key to understanding this paradox could be found in the changes to ordinary, everyday life that occurred during this time period. Rather than focusing solely on the illicit acts of individuals committing crimes, these scholars placed the lens on legitimate, routine activities which they defined as "recurrent and prevalent activities that provide for the basic population and individual needs, whether their biological or cultural origins" (p. 196). By looking at the flow of daily activities and the patterns of conventional behavior, criminologists could gain insight into how criminal opportunity emerged from the routine activities of citizens.

Between the 1960s to the 1970s, the United States experienced drastic changes in the social patterns of individuals (Cohen & Felson, 1979). For instance, there was an increase of young adults enrolling in college, more individuals were taking vacations and traveling, and an increasing number of women were entering the workforce. These shifts in activity patterns increasingly led individuals to spend more time away from their homes, a place that the routine activity approach characterized as simultaneously protective and in need of protection (Andresen, 2014; Felson, 2017). Moreover, technological advancements led to an influx of desirable good and services that caught the attention of potential offenders. Of particular importance were the changes in electronic and automotive items, which became more easily portable (i.e., lighter, and smaller) and were more widespread throughout the population (Andresen, 2014). For example, Cohen and Felson (1979) noted that television sets went from a

low of 38 pounds in 1960 to as light as 15 pounds in 1970 (p. 206). This decrease in weight clearly made such items more appealing for those seeking opportunities to acquire such goods by illegal means.

The routine activity approach built upon concepts from Hawley's (1950) theory of human ecology, which focused on the interdependencies between individuals and the temporal and spatial organization of their physical environment (Cohen & Felson, 1979). In particular, temporal components of rhythm, tempo, and timing were useful for understanding the connection between illegal and legal activities. Rhythm indicates the regularity of an event while tempo refers to the number of events per a specific unit of time (Hawley, 1950, p. 289). Meanwhile timing concerns the overlap or coordination of various symbiotic activities. Cohen and Felson (1979) argued that these temporal elements are important in criminal incidents, as the syncing of the daily rhythms of offenders and their targets are necessary for a crime to take place. In other words, the structure (both spatially and temporally) of habitual routines links the ordinary behavior patterns of both targets and offenders, increasing the likelihood that criminal opportunity may be present.

Thus, unlike mainstream approaches that placed the offender at the center of the analysis, the routine activity approach shifted the focus toward the criminal event itself. Moreover, Cohen and Felson did not concentrate on the source of an offender's motivation; rather the circumstances surrounding the event were central to understanding a criminal occurrence (Andresen, 2014). The offender was just one component in the crime equation. While a necessary element, the presence of an

offender in and of itself is not enough to result in the occurrence of a criminal event. According to the routine activity approach, in addition to a motivated offender, at least two other elements are required to create the opportunity for a criminal event to take place: a suitable target and the lack of capable guardians (Cohen & Felson, 1979). The routine activity approach argues that if any of these three elements are missing in a situation, it is typically enough to thwart criminal opportunity (Cohen & Felson, 1979; Felson, 2017).

The elements of a suitable target and capable guardianship deserve more attention. For instance, what makes a target, which can be a person or object, desirable? The attractiveness of a target can be linked to four elements (Andresen, 2014). First, the target must be valuable. In other words, the offender must determine that the target is/has something that is worth acquiring. Visibility is another important component in target attractiveness. More specifically, the offender needs to be aware that the target is present. For instance, if a iPad or iPhone is lying on the seat in your car and is visible to those passing by, the offender will be more aware of that item than if it were in a more concealed location such as under the seat or in the trunk (Andresen, 2014). Concerning accessibility, the target gains suitability if it is simple to acquire (e.g., if the target is in an unlocked car or house). Finally, the inertia of the target is important. Inertia concerns how easily the target can be overcome if the target is an individual or moved if it is an object (Cohen & Felson, 1979). For example, an elderly individual may be seen as more suitable for theft if the offender is younger and more powerful than the victim while the offender may be more hesitant to target

someone who appears to be in peak physical shape. As discussed previously, technological advancements led to an increase in objects that were more appealing in terms of inertia as newer electronic appliances were sleeker and more easily transportable.

In addition to the presence of a motivated offender and suitable targets, the final (minimum) element necessary for the presence of criminal opportunity to emerge concerned the absence of other individuals (or technology) capable of preventing the crime from occurring. While many scholars thought of guardianship in terms of police officers and other law enforcement or security officials, this is not what Cohen and Felson had in mind when they developed the concept of capable guardians. Rather, it was the role or presence of other individuals routinely in the would-be target's life that mattered. More specifically, neighbors, co-workers, friends, and family members were essential to preventing the occurrence of a crime. These average citizens provided social guardianship through watching the property of others in their social networks as well as providing a protective factor for the person themselves (Madero-Hernandez & Fisher, 2013). In addition, target hardening techniques (e.g., security alarms and cameras) were also an important form of guardianship to help limit the emergence of criminal opportunities (Madero-Hernandez & Fisher, 2013).

To reiterate, the routine activity approach outlined the synergy between legitimate behaviors that form daily life patterns and the illegal activities of offenders. More specifically, crime thrives on legal behavior (Cohen & Felson, 1979). This symbiotic and predatory relationship ensnares conventional, ordinary activities within

the web of criminal behavior. Rather than being aberrant or abnormal, crime can be seen as a logical (yet ironic) outcome of social and technological evolution (Cohen & Felson, 1979; Madero-Hernandez & Fisher, 2013). The tools and technologies meant to increase the quality of life for average citizens such as electronic devices, power tools, and automobiles, could be adapted for darker purposes, facilitating an offender's ability to capitalize on criminal opportunities. These items could serve as instruments of protection for an individual or could be harnessed to cause harm against them or their property. As Cohen and Felson (1979) so aptly concluded:

> "Rather than assuming that predatory crime is simply an indicator of social breakdown, one might take it as a byproduct of freedom and prosperity as they manifest themselves in the routine activities of everyday life." (p. 216)

Thus, to understand crime, criminologists needed to explore the natural rhythms of ordinary life: e.g., the habitual patterns associated with individual's work, social and recreational routines. The overlap of offender-target routines in the absence of guardianship capable of preventing unlawful activity produce the conditions conducive for crime to take place. As society progressed and citizens took advantage of technological improvements, more and more time was spent away from the home, increasing the likelihood that these three necessary elements would converge in space and time.

Clearly, ordinary individuals may have certain locations or activity patterns that increase their likelihood of experiencing a situation in which these necessary components converge. The concentration of these factors within an area (e.g., the percentage of the population that may be more criminally oriented) produces greater

opportunity for the occurrence of criminal events within that area. For instance, some locations may be more conducive to criminal activity because they draw in motivated offenders and suitable targets while potentially lacking the guardianship necessary to inhibit criminal conduct. This theoretical line of inquiry was developed further through the work of Brantingham and Brantingham (1981; 1993;1995) who focused on how specific facilities could serve as generators of crime. The next section expounds upon their work further.

2.2.2 The Geometry of Crime and Crime Pattern Theory

The work of Brantingham and Brantingham (1981; 1993) situated criminal opportunity more explicitly within the social and built environments in which potential offenders and targets may operate. At the center of this theoretical framework are a series of relatively simple rules which coalesce and interact in various ways to produce complex crime patterns (Brantingham, Brantingham, & Andresen, 2017). The following section briefly outlines these rules, but a more extensive discussion can be found in the work of Brantingham, Brantingham, and Andresen, 2017. First, all activity, regardless of legality, is situated in a specific context containing a particular social system and physical environment (rule 1) (Brantingham, Brantingham, & Andresen, 2017). In other words, human activities and choices are shaped and constrained within the social, physical, political, and economic structures in which individuals are located.

Moreover, the patterns of individuals tend to encompass routine activities that are associated with consistent nodes and paths (rule 2). Nodes are places that the individual frequently encounters such as work, home, and recreational or entertainment facilities while paths are the transportation networks that connect these nodes (e.g., streets, walking paths) (Brantingham and Brantingham, 1993). Because humans are creatures of habit, many people follow the same route to these locations and tend to operate with general temporal regularity for many of these activities. As such, travel to and from various nodes typically follows a repetitive pattern, barring non-routine elements that may cause an individual to alter their movements (e.g., an accident that prevents an individual from taking the normal route to work). These routine movements make up the activity and awareness spaces of individuals. While the activity space refers to locations that individuals have direct experience with, the individual is often aware of other locations surrounding activity nodes and the paths on which they are located.

Another rule for the geometry of crime is that individuals who commit crimes spend the majority of their time pursuing non-criminal endeavors (rule 3). Similar to everyone else, people who become involved in criminal conduct have activity and awareness spaces that are constrained by the social and physical structures of their environments and shape their movements (Brantingham, Brantingham, & Andresen, 2017). Most individuals have habits and processes that provide a sense of stability or consistency. As such, offenders are more likely to commit crimes in areas that are known to them and in which they feel comfortable (Brantingham, Brantingham &

Andresen, 2017). In addition, cognitive templates develop for the repeated decisions associated with routine activities including crime (rule 4). Applying this "crime template", potential offenders will use cues or signals from the environment to assess if a target is "suitable" (Brantingham & Brantingham, 1993, p.12). It is important to note that since many individuals do not exist in a world devoid of connections, the activity spaces and routine patterns of their social networks (e.g., friends, family members) also inform behavior patterns and decisions, including those associated with crime templates (rule 5).

These elements all come together to shape criminal opportunity when the awareness spaces of potential offenders and targets overlap spatially and temporally (rule 6). To be clear, the overlap in and of itself is not sufficient to produce criminal opportunity. Recall that the potential offender and target are constrained by their physical and social environments (rule 1). However, the overlapping of activity spaces at certain places can make the realization of a criminal opportunity more likely when the offender is sufficiently motivated, the target fits the definition of "suitable" according to the crime template and movements are uninhibited by guardianship in the form of people or technology (Brantingham, Brantingham & Andresen, 2017).

Some locations are more conducive to creating conditions optimal for criminal opportunity. Basic elements of the "urban backcloth" (e.g., road networks, land use zoning policies) influence the location of "nodal activity points" where crime concentration is likely to be higher (rule 7) (Brantingham, Brantingham & Andresen, 2017, p. 106). This rule is particularly important to the context of the present study as

it concerns the link between facilities and crime. More specifically, certain establishments have an increased potential to serve as a spot for the spatio-temporal overlap of the activity spaces of potential offenders and targets. Such locations fall under the concepts of crime generators and crime attractors (Brantingham & Brantingham, 1995). Both crime generators and crime attractors are nonresidential locations that have the potential to create conditions conducive to criminal opportunity. For instance, crime generators draw in large numbers of individuals for purposes of noncriminal, daily activities. Some of the individuals drawn to these places will be more inclined toward criminal endeavors if the opportunity presents itself. While not necessarily going to the facility with the intention of committing a crime, a (potential) motivated offender may find an environment rich in illicit opportunities because of the large number of potential victims and other targets that converge at the facility in question. Examples of crime generators may include entertainment and shopping districts (Brantingham & Brantingham, 1995; Brantingham, Brantingham, & Andresen, 2017). In comparison, crime attractors are places that have a reputation for criminal behavior. Motivated offenders are attracted to these locations *because* of the well-known opportunities these establishments possess for illegal behavior. Facilities having the potential to be crime attractors include bars, large shopping malls, and drug markets (Brantingham & Brantingham, 1995; Brantingham, Brantingham, & Andresen, 2017).

A large body of research has explored the facility-crime nexus, demonstrating a positive association between crime rates and certain establishments such as alcohol

related outlets (Bernasco & Block, 2011; Pridemore & Grubesic, 2011; Groff & Lockwood, 2014; Tillyer, Wilcox, & Walter, 2021), gas stations/convenience stores (Bernasco & Block, 2011; Boehme, Malhotra, & Mulrooney, 2022; Snowden, 2019; Tillyer, Wilcox, & Walter, 2021), banks (Tillyer, Wilcox, & Walter, 2021), hotels/motels (Tillyer, Wilcox, & Walter, 2021), check-cashing facilities and pawn shops (Bernasco & Block, 2011; McCord & Ratcliffe, 2007) among other locations. However, innovative studies suggest that the relationship between crime and establishments may be more nuanced (Tillyer, Wilcox, & Walter, 2021). For instance, Groff and Lockwood (2014) explored the impact of the exposure of street segments to five different facility types (bars, schools, subway stops, drug treatment centers and halfway houses) which were inversely weighted by distance at three different street network thresholds (i.e., 400, 800 and 1200 feet from the street centroid). Results demonstrated varying patterns by facility type, offense, and distance threshold. For instance, bars and subway stations were positively associated with all three crime types examined (violent, property and disorder) at all three thresholds. However, schools were only positively associated with disorder crimes at the various thresholds examined while halfway houses appeared to have a diminishing impact on violent crime at the 1200-foot threshold and a diminishing impact on property crime at the smaller thresholds.

While crime attractors and generators focus on locations that may increase crime, more recent research has attempted to understand how certain establishments may diminish or inhibit criminal opportunities (e.g., Jones & Pridemore, 2019; Tillyer,

Wilcox, & Walter, 2021). Although this area of research on local guardianship is relatively underdeveloped compared to the crime generator/attractor investigations, empirical evidence shows the importance of investigating these protective facilities in place-based analyses (Jones & Pridemore, 2019; Wagner, 2020). For instance, Jones and Pridemore (2019) included a 'local guardianship index' within their model which included facilities and technology that could increase the level of capable guardians within an area. This measure included police stations, fire stations, security alarms and CCTV locations. Results demonstrated a significant negative association between the local guardianship index and property and violent crime in a multi-level analysis accounting for other factors associated with opportunity (e.g., crime generators) and local and neighborhood characteristics.

It is important to recognize that the link between some facilities and reduced crime rests on the theoretical roots of social disorganization rather than opportunity theories per se. For instance, scholars have speculated that religious and civic organizations may be linked to lower levels of crime due to the capacity of these organizations to strength ties in a community which increases the ability to implement informal mechanisms of social control including guardianship of property and persons (Slocum et al. 2013). Unfortunately, empirical evidence linking such facilities and crime is limited and inconclusive (Wo, 2016). For example, using a measure of employees within social and civic organizations, Wo (2016) did not find a significant association for violent or property crimes at the census tract level. Concerning religious organizations, there also appears to be mixed evidence as Beyerlein and Hipp

(2005) found that the impact depends on the type of congregation and crime being analyzed while Slocum et al. (2013) found some evidence that the crime reducing impact of places of worship may extend beyond the focal block group into neighboring areas. Thus, similar to crime producing facilities, further research on crime reducing facilities is needed as the current body of literature utilizes a wide range of operationalizations of these organizations, relies on diverse units of analysis and employs a plethora of statistical techniques.

Before moving onto the limitations associated with opportunity theories of crime, it is important to acknowledge that facilities do not always operate exclusively as crime generators/attractors or local guardians (Brantingham, Brantingham, & Andresen, 2017). Similar to how individuals drift in and out of crime, facilities may drift in their influence on crime depending on the context. For instance, a facility may become a crime generator but later implement managerial or technical changes that inhibit crime at that location (e.g., increasing the number of employees and/or security personnel; change protocols for handling conflict) (Madensen & Eck, 2008; Weisburd & Eck, 2017). Moreover, the extent to which a facility is potentially criminogenic may depend on a number of factors including the crime-type and temporal context (e.g., night versus day) (Brantingham, Brantingham, & Andresen, 2017). In other words, just because a facility-type is considered a crime attractor at a certain point in time, that does not mean it is forever doomed to that status.

While opportunity theories have found support within the criminological literature on spatial crime, there are several limitations that must be acknowledged.

Madero-Hernandez and Fisher (2013) highlight three important issues that geographical criminologists contend with: the reliance on proxy measures often resulting in the codependence on concepts and indicators that are shared with other theoretical frameworks, the ability to provide diverse conceptualizes depending on results for certain indicators, and the failure to incorporate crime-specific measures (p.522). For instance, some scholars have used "unemployment" as a measure to capture the potential motivated offender population within an area, but this same measure has also been conceptualized as an indicator of social disorganization (Madero-Hernandez & Fisher, 2013). Moreover, another issue is linked to "theoretical indeterminacy" as some indicators can be conceptualized and/or rationalized as representing diverse causal mechanisms (Meier & Miethe, 1993, p. 485). For instance, Madero-Hernandez and Fisher demonstrate that family income can be conceptualized as two ends of a spectrum: both as a protective factor and as an element increasing risk. On the one hand, increased family income can increase the ability of guardianship through the power to buy services and technology that could guard against victimization. At the same time, however, this indicator could serve to identify increased risk because those with higher family income may be more desirable targets. Thus, regardless of whether family income increases or decreases crime, scholars using this concept could provide theoretical justification under the routine activity approach. As such, there is a need for more specific measures that cannot be re-conceptualized based on results (Madero-Hernandez & Fisher, 2013). Finally, research on opportunity theories such the routine activity approach has typically relied on broad

measures rather than crime-specific indicators that could help provide a more nuanced understanding of criminal events. For instance, what may serve as a protective factor for crimes against strangers may not serve as protective factors within intimate relationships (Madero-Hernandez & Fisher, 2013). The home as a source of protection does not apply to all. Nonetheless, despite these limitations, scholars have found opportunity theories to be useful perspectives for understanding the link between crime and place.

2.3 The Concurrent Use of Social Disorganization and Opportunity Theories

In general, both social disorganization and opportunity theories of crime have received considerable empirical support within criminological research (Jones & Pridemore, 2019; Shen & Andresen, 2021). In fact, in a meta-analysis of 214 empirical macro-level studies, Pratt and Cullen (2005) found moderate support for predictors associated with routine activity theory and strong support for social disorganization predictors, especially family disruption, racial heterogeneity and poverty which were among the most stable predictors examined. As such, these two theoretical frameworks have a solid basis for informing spatial research on crime. Both theories can play a vital role in shaping our understanding of the connection between crime and place. Over the past few decades, theoretical and empirical explorations have demonstrated the utility of simultaneously incorporating elements of these perspectives into criminological research (Jones & Pridemore, 2019; Miethe & Meier, 1990; Shen & Andresen, 2021; Smith, Frazee &Davidson, 2000; Tillyer. Wilcox, &

Walter, 2021; Weisburd, Groff, & Yang, 2012). In particular, research explorations have shown that the inclusion of indicators from both frameworks improve the predictive power of models by explaining more variance (Rice & Smith, 2002) and help provide a stronger contextualization of the nature of certain relationships (Jones & Pridemore, 2019; Tillyer. Wilcox, & Walter, 2021).

Over the last several decades, empirical research has provided strong support demonstrating the utility of incorporating variables related to both these perspectives into spatial models of crime. In one comprehensive study, Weisburd, Groff and Yang (2012) analyzed crime in Seattle over a sixteen-year period at the street segment level. Using a multinomial regression model to predict membership in crime-based trajectories, these scholars found that variables linked to opportunity (e.g., presence of high-risk juveniles, number of employees in the area, the presence of nearby public facilities) and social disorganization (e.g., measures of higher housing assistance; lower property values; physical disorder) increased the risk for membership in being a chronic crime trajectory relative to a crime-free trajectory. Weisburd, Groff and Yang (2012, 2014) argue that the importance of significant indicators concerning both theoretical perspectives demonstrate the necessity of reducing crime opportunity in areas (e.g., through hot spot policing) as well as the need for social interventions to improve conditions in these high crime areas. As such, models incorporating both theoretical perspectives can provide stronger insight into potential policy implications or solutions that may be overlooked when only one framework is relied upon.

In another important study, Shen and Andresen (2021) examined spatial regression models using indicators associated with social disorganization and routine activities to see how these variables impacted five types of property crime in Vancouver, Canada. Overall, their results proved favorable for simultaneously including relevant variables from both theoretical frameworks to examine spatial patterns of property offenses. In addition, while variables that were statistically significant generally behaved as anticipated in terms of theoretical expectations across models, several variables had mixed impact including the percentage of the households occupied by renters. Interestingly, the percent of households with renters was positively associated with three crimes (i.e., theft, theft from vehicle, and theft of vehicle) but negatively associated with residential burglary. The positive associations matched theoretical predictions based on social disorganization (i.e., population turnover) as well as the routine activities perspective due to lowered guardianship. Shen and Andresen theorized that individuals renting may spend more time away from their households doing other routine activities and rentals tend to be in areas of higher population change. Concerning the negative relationship between the percent of households with renters and burglary, the authors argued that this could still be viewed as an outcome of increased guardianship in the form of security technology associated with (newer) apartment units (see also Hodgkinson & Andresen, 2019 for similar discussion). Attention is drawn to this finding as it demonstrates a more nuanced relationship between these variables that may be crime contingent for some components but not necessarily others.

Attempts to integrate these theoretical perspectives demonstrate the importance of including measures for both structural factors and opportunity characteristics in shaping the spatial distribution of crime (Tillyer, Wilcox, & Walter, 2021). While most models have relied on single-level analysis in examining the concurrent and/or interactive effects of structure and opportunity, recent research highlights the importance of exploring the effect of the larger social environment on local levels of crime (Jones & Pridemore, 2019; Tillyer, Wilcox, & Walter, 2021). For instance, Jones and Pridemore (2019) found that crime generators at the street level had a weaker impact on both property and violent crimes when street segments were nested within census tracts that had higher levels of concentrated disadvantage. While this was counter to their original hypothesis, they argue that these results may reflect the fact that businesses located in socially disorganized neighborhoods may provide fewer opportunities for crime because they may attract fewer customers and possess fewer suitable targets. On the other hand, in their analysis of crime in blocks nested within block groups, Tillyer, Wilcox, and Walter (2021) found that the positive relationship between block-level crime and crime generators was enhanced in block groups with more concentrated disadvantage and increased traffic activity. As such, more research is needed to clarify this relationship. Nonetheless, studies in this area demonstrate the importance of both structure and opportunity on spatial patterns of crime.

2.4 Summary

As evidenced within this chapter, two theoretical frameworks are central to understanding spatial patterns of crime: social disorganization theory and opportunity theories (i.e., the routine activity perspective and crime pattern theory). The theoretical and empirical scholarship discussed above provide a strong foundation for examining models that control for both the structural and opportunity characteristics of an area. As such, the current study incorporated a number of theoretically relevant variables from both perspectives into the final models examining the impact of drinking establishments on crime. These variables will be discussed in more detail in chapter 5.

Before discussing the methods utilized in this dissertation, it is important to get a sense of the work that has been done concerning the relationship between alcohol-related facilities and crime. While this relationship has been researched extensively, few studies have gone beyond the use of pre-defined census boundaries to explore how treating the area surrounding the facility as the unit of analysis may enhance our understanding of this relationship. By using methodological techniques to create new units of analysis, this study explores whether there is variation in the significance of theoretically relevant predictors based on the geographic unit, operationalization of the dependent variable, and crime type examined.

Exploring the current scholarship concerning what is known about drinking-establishments and crime using traditional boundaries can help inform our expectations and provide a basis for the methodological approach. As such, the next chapter can be divided into three sections based on the unit of analysis. It begins with

an exploration of research relying on traditional census boundaries as the unit of analysis. Next, it explores research exploring the spatial extent of alcohol-related facilities on crime in surrounding areas. The studies in this section tend to be descriptive in nature but are important for understanding the spatial distribution of crime within the vicinity of these establishments. The chapter concludes with an extensive look at the few studies that have gone beyond pre-defined census geographies, using buffer zones to create new geographic units for exploration.

Chapter 3

EMPIRICAL INVESTIGATIONS

The general association between alcohol and crime has been central to many investigations within criminological literature (Martin, 2001; Parker & McCaffree, 2013). While many individuals may choose to drink within the confines of their home, a large number of people frequent social establishments for alcohol consumption and leisure activities (Parker, 2004). The social and contextual factors linking alcohol and crime, especially violent crime, within these social environments are connected in ways that are times difficult to disentangle (Bromley & Nelson, 2002). Nonetheless, scholars often point to a number of processes that link alcohol and crime including the "disinhibiting" effects of alcohol consumption (Parker, 2004; Snowden, Stucky & Pridemore, 2017). According to the disinhibition perspective, if the right circumstances collide, alcohol consumption may lead individuals to behave in ways that deviate from the socially constrained reactions associated with conventional norms (Parker, 2004). In other words, if the "right" conditions are present, individuals may view violence as a viable option for resolving conflict due to the impact of alcohol on cerebral functioning and thought processing (Parker, 2004, p. 159). In addition, alcohol consumption at drinking establishments often occurs in an environment conducive to crime: in the context of night when guardians are either

unavailable (i.e., empty streets) or are themselves indisposed due to alcohol (Parker, 2004). In summation, drinking establishments have the potential to become attractive locations for criminal activities because such establishments provide an environment conducive to criminal endeavors (Snowden, Stucky & Pridemore, 2017).

Opportunity theories provide a strong basis for theoretical expectations concerning why certain facilities may be positively associated with crime. Within this framework, alcohol establishments are nodes for overlapping activity spaces of potential offenders and targets. Opportunities for criminal endeavors may emerge from the convergence of these individuals (and/or objects) within proximate time and space combined with conditions of lowered guardianship that may accompany the disinhibiting effects of alcohol (Snowden, Stucky & Pridemore, 2017). Moreover, the social disorganization perspective posits that facilities exist in environments with different structural characteristics that may enhance or inhibit criminal opportunities. Together, these perspectives provide a foundation for understanding why certain establishments may be linked with higher crime in surrounding areas. The remainder of this chapter will highlight findings from the empirical literature that has tested the theories opportunity and social disorganization theories within the crime and place literature.

A significant body of empirical research confirms the association between crime and the facility that is at the center of this dissertation: alcohol establishments (e.g., Bernasco & Block, 2011; Parker, McCaffree, & Skiles, 2011; Wheeler, 2019). However, nearly all studies exploring the facility-crime connection rely on predefined

areas that were constructed for reasons that fall outside the purview of identifying relationships between crime and place. Although recognized, the disconnect between research goals and the purpose of geographic units is often accepted as an inevitable limitation within this body of research (McCord & Ratcliffe, 2007; Rengert & Lockwood, 2009). As will be made apparent throughout this dissertation, issues associated with different methodological techniques and choices of units of analysis provide valid justification for continued investigations of this relationship.

The current study thus provides a subtle shift in focus. The over-reliance on census boundaries created for administrative purposes could lead scholars to overlook nuanced aspects of the facility-crime nexus (Rengert & Lockwood, 2009). Consequently, there is a need to go beyond the use of traditional boundaries and rely on techniques that align with a facility-centric approach. In other words, rather than asking how alcohol establishments may impact a predefined area, the establishment itself can become the origin for the units of analysis with the vicinity surrounding these institutions serving as new sources for boundary creation. The alcohol establishment moves from being used as point-based data and becomes the centroid for a polygon/areal unit. Such geographic entities align more with inquiries concerning how alcohol related establishments may impact crime in surrounding areas because the facility itself is central. Although new developments within geographic information systems make methods for geographic unit creation more accessible to a wider audience of scholars, few studies have incorporated these approaches into investigations of the facility-crime nexus.

Before providing technical aspects on how to conduct a multivariate analysis that is facility-centric, it is important to understand how scholars have currently explored the relationship between crime and institutions serving alcohol. As such, this review begins with an overview of research that has explored this relationship using traditional geographic units such as census tracts, blocks, and street segments. Next, there is a brief discussion of research looking at the spatial extent of alcohol outlets on crime within the nearby vicinity using bivariate techniques such as location quotients. The review concludes with an examination of research that has gone beyond census boundaries and relies on an innovative method for creating new geographies to examine the relationships between crime and place: *census enhanced GIS spatial units*. Because of the limited research utilizing this technique, the discussion of this method will go beyond a focus on the relationship between drinking establishments and crime.

3.1 The Relationship between Alcohol Outlets and Crime: Traditional Geographic Units

Within ecological studies, alcohol outlets have received the most attention among potentially criminogenic facilities (Groff & Lockwood, 2014). A vast amount of evidence concerning a positive relationship exists among research relying on various spatial aggregations including census tracts (Peterson, Krivo, & Harris, 2000, Franklin et al. 2010), block groups (Pridemore & Grubesic, 2011), blocks (Bernasco & Block, 2011; Murray & Roncek, 2008), zip codes (Gruenewald & Remer, 2006;

Gruenewald, Freisthler, et al., 2006; Lipton & Gruenewald, 2002), and street segments (Groff & Lockwood, 2014; Wheeler, 2019). Moreover, there is evidence of an association between alcohol establishments and increased crime for both violent offenses (Jennings et al. 2014) and nonviolent offenses (Toomey et al. 2012; Snowden, Stucky & Pridemore, 2017).

The relationship between establishments serving alcohol and criminal activity has been investigated from several different angles within the realm of environmental criminology using traditional units of analysis. One of the most common approaches involves examining the impact of this facility type on neighborhood crime through a count measure (Trangenstein et al. 2019). Research in this area typically involves either creating a variable containing the number of alcohol establishments within an area (Demeau & Parent, 2018; Taniguchi, Rengert, & McCord, 2009; Jennings et al. 2014) or including drinking places as part of a larger 'crime generator' index along with other facilities to see if the number of these establishments impacts the crime in a region (Jones & Pridemore, 2019; Tillyer, Wilcox, & Walter, 2021). Such research typically finds an association between higher numbers of alcohol related outlets in an area and higher crime rates within that region (Jennings et al. 2014; Peterson, Krivo, & Harris; Roncek & Maier, 1991; Wheeler, 2019).

Moreover, some evidence suggests that the impact of alcohol related establishments such as bars may extend beyond the focal region into neighboring areas (Bernasco & Block, 2011; Wheeler, 2019). For instance, in an examination of street midpoints and intersections within the Washington, DC area, Wheeler (2019) found a

diffusion effect for both on-premise and off-premise alcohol outlets. More specifically, the impact of these institutions on neighboring street units was greater than the impact on the street unit on which the facility was located. These findings of extended influence reinforce the importance of selecting the appropriate unit of analysis for investigating the crime-facility nexus. Areal units based on census geographies that use institutions as aggregated point data may miss more nuanced relationships because the way in which data are aggregated can significantly alter results (Andresen & Malleson, 2013). This bias, known as the modifiable areal unit problem, is discussed in more detail at the end of this chapter.

A second line of research has examined how alcohol accessibility influences crime rates, with many studies identifying a positive association between alcohol outlet density and violence (Grubesic & Pridemore, 2011; Pridemore & Grubesic, 2013; Snowden & Freiburger, 2015). For example, Parker, McCaffree and Skiles (2011) conducted an analysis of violent crime within block groups in San Bernardino, California. Findings indicated that both alcohol outlet density (per 1000 population) as well as the average percentage of shelf space devoted to single serve beverages was positively associated with violent crime after accounting for several relevant structural factors. However, density-based investigations are also vulnerable to edge effects similar to count-based approaches in which the impact of a facility that is near the boundary of census geographies may have little influence on the unit it falls within and may have a greater impact on a neighboring region.

Despite many studies demonstrating a positive association between alcohol related establishments and crime, some inconsistencies exist and there is debate concerning what is the best approach for measuring this relationship (Trangenstein et al. 2019) For example, some evidence suggests that the relationship may be contingent on the type of crime and alcohol outlet analyzed (e.g., Costanza, Bankston & Shihadeh, 2001; Pridemore & Grubesic, 2013). Research has explored the impact of both on-premise (i.e., establishments where alcohol is meant to be consumed on site such as bars or restaurants) and off-premise (i.e., places which sell alcohol meant for consumption elsewhere) outlets with mixed results. Some research suggests that the impact of these diverse establishments is similar in magnitude (Wheeler, 2019) while other inquires indicate the type of outlet matters (Costanza, Bankston & Shihadeh, 2001). In an analysis of simple and aggravated assault density at the block group level, Pridemore and Grubesic (2013) found that off-premise outlets had a stronger association compared to bars and restaurants for both simple and aggravated assaults. Meanwhile, looking at hospital discharges for violent assaults at the zip code level, Gruenewald, Freisthler, Remer, LaScala and Treno (2006) also found a positive relationship between off-premise establishments and rates of violence but the finding did not hold for bars. Rather, the impact of bars was contingent upon structural and population characteristics of the zip code. On the other hand, Wheeler (2019) found similar effects for both on-premise and off-premise establishments when examining crime on street units. These dissimilar findings may stem from divergent choices in unit of analysis (e.g., block group, zip code and street units), methodological

approaches (e.g., negative binomial versus other spatial regression models), and data sources (e.g., hospital discharge data versus police data).

Although many of these studies control for elements related to social disorganization, several attempts have been made to determine if neighborhood context moderates the relationship between alcohol density and violence (e.g., Pridemore & Grubesic, 2012; Snowden, Stucky & Pridemore, 2017; Snowden & Freiburger, 2015). Results in this area have been mixed. Pridemore and Grubesic (2012) found the positive relationship between alcohol outlets and assaults was moderated by the level of social organization for block groups in Cincinnati, Ohio. More specifically, the impact of alcohol outlets on assault was stronger in neighborhoods with higher levels of social disorganization. Conversely, in an analysis using block groups from Milwaukee, WI, Snowden, Stucky and Pridemore (2017) found the moderating influence of social disorganization was in the oppositive direction: higher levels of social disorganization weakened the association between alcohol outlets and vandalism. Moreover, Snowden and Freiburger (2015) failed to find moderating effects of neighborhood characteristics on the outlet-crime association when examining robberies. These studies suggest that the moderating impact of social disorganization may vary depending on type of crime.

The studies within this section provide substantial evidence concerning the link between crime and alcohol related outlets. However, the focus is on how these establishments impact specific pre-defined units such as census geographies or street segments. A limitation of this approach is that boundaries used within these studies are

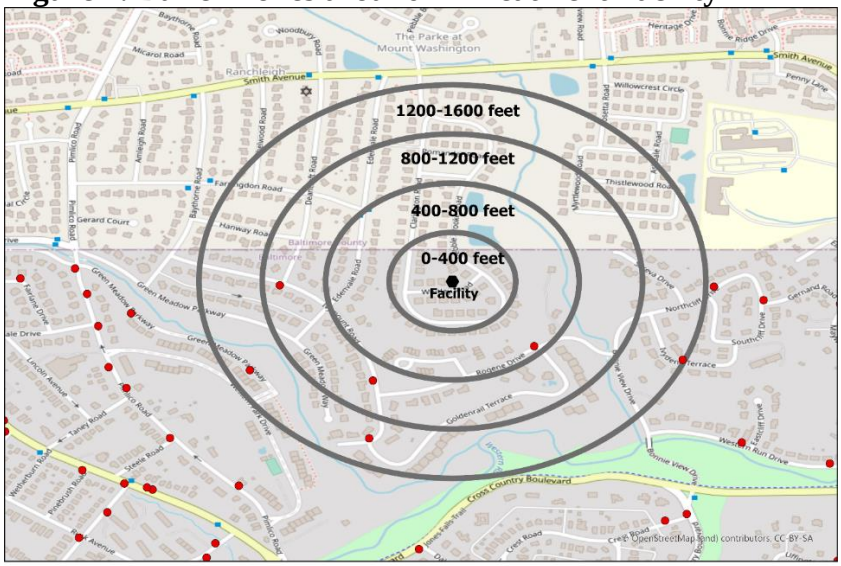
conducted for administrative purposes and thus often fail to align with specific research goals (McCord & Ratcliffe, 2007; Rengert & Lockwood, 2009; Weisburd et al. 2009). In addition, count measurements contained within these predefined areas may miss the potential spatial extent of facilities that fall near boundary edges (McCord & Ratcliffe, 2007). Thus, while evidence of investigations focused on census geographies provide an understanding of the impact of these facilities on crime within officially outlined entities, a more nuanced understanding of the spatial extent of alcohol related establishments could be gained by placing the facility itself at the center of analysis. The next section briefly highlights point-based analysis that explores the spatial extent of institutions through the use of location quotients. These bivariate investigations are an important first step in uncovering the relationship between establishments and crime. More specifically, explorations of the spatial extent of facilities on crime can help inform techniques for creating new units of analysis for investigating the facility-crime relationship.

3.2 The Spatial Extent of Alcohol Outlets: Bivariate Investigations

Importantly, asking whether the number or density of facilities in an area is associated with higher crime rates is different than understanding *how* crimes may cluster near these facilities. In other words, understanding the spatial influence (i.e., the extent at which crimes occur near the facility) is an important avenue of exploration (Groff, 2011). As such, a second body of research places the facility (as a point-based object) at the center of analysis and examines the facility's spatial

influence on crime in nearby regions. More specifically, these studies seek to answer the question 'How close is near'? (Groff, 2011; Ratcliffe 2012a, b). Empirical research within this latter area often relies on some form of buffer analysis to determine the extent of the establishment's influence on crime in nearby areas (Groff, 2011; Ratcliffe, 2012a, b). A buffer is a zone drawn around the facility at specified distances (e.g., 0-400 feet, 400-800 feet). Figure 2 provides an illustrative example of circular (Euclidean) buffer zones. Criminal incidents are aggregated within each range and, depending on the technique employed, these summed measures are examined in a model to see if the number of crimes within the range is different than what one would expect based on a random distribution or compared to crime clustering in other areas (e.g., the entire city).

Figure 2: Buffer Zones around A Treatment Facility



To reiterate, these studies differ from the aforementioned research in that the facility is the unit of analysis with the goal of determining if crime clusters around the facility in a fashion that differs from the larger region under investigation (e.g., a city). Within this body of literature, researchers have employed a variety of techniques for measuring clustering including location quotients (Rengert et al. 2005; McCord & Ratcliffe, 2007; Groff, 2011), change point regression (Ratcliffe, 2012a, 2012b) and negative binomial regression (Furr-Holden et al. 2016). Not surprisingly given the variety of techniques used, the extant literature has shown wide variation in the spatial extent of alcohol related establishments. While some research suggests a larger bandwidth of influence for alcohol related establishments (e.g., McCord & Ratcliffe, 2007; Rengert et al 2005), other evidence suggests that the influence of this facility type on crime only extends to a shorter distance (Ratcliffe, 2012 a.,b.). However, many of the studies within this area vary in terms of analytic technique, crime type, study location, and type of alcohol establishment investigated (e.g., on-premise versus off). These inconsistent methodological and operational practices make it difficult to compare results across studies.

There does not appear to be a consensus regarding which technique or buffer size or type (e.g., Euclidean vs Street distance) is most appropriate (Groff, 2011). In an attempt to clarify some of these issues, Groff (2011) compared two types of methods for measuring the distance of buffers: Euclidean and street distance techniques. She also compared these two techniques for different buffer width increments: street block intervals and quarter-mile intervals. The use of bandwidths approximating the size of

street blocks (0-400 feet/0-122 meters) is common in the literature, yet previous research has failed to establish a systematic assessment for the utility of using this approach. Groff's results demonstrated that the best approach for analyzing the spatial extent of drinking establishments on crime occurred when using street distance buffers with the finer 0-400 bandwidth size. More specifically, the 0-400-foot bandwidths using street distance buffers revealed more nuanced findings and showed higher crime densities that extended an additional block farther than the Euclidean distances. For instance, street distance buffers around the drinking establishments demonstrated higher densities of crime clustering at the 800-1200 buffer (LQ=2.74) compared to a smaller indication of clustering when using the Euclidean buffer at that range (LQ=1.48).

While these inquiries provide important indications of the spatial extent of alcohol related establishments on crime, location quotient investigations are bivariate and thus do not account for the surrounding environment in which these facilities are located. Thus, while understanding crime distribution around these facilities is an important first step, the characteristics of these locations in terms of opportunity and social organization must be accounted. The next section of this review focuses on the limited research that uses a technique for merging buffer zones with official census geographies to create new units of analysis known as census enhanced GIS spatial units. Although few studies have relied on this approach, the sparse research in this area provides promising evidence that such investigations can provide a more nuanced understanding of crime when multivariate approaches are facility- centric.

3.3 Census Enhanced GIS Spatial Units

Although the above research provides strong evidence supporting the relationship between crime and alcohol related facilities, these investigations are often reliant on the boundaries of census data that is created for administrative purposes (Rengert & Lockwood, 2009). Some scholars have advocated for the exploration of how geographic units beyond the official census boundaries can help shape our understanding of the relationship between crime and facilities (McCord & Ratcliffe, 2007; Rengert & Lockwood, 2009). One method, known as census enhanced GIS spatial units, can be used to place facilities such as alcohol establishments at the center of the analysis (Rengert & Lockwood, 2009). This approach aligns more closely with the goal of investigating the proximity impact of drinking establishments on crime in nearby areas (McCord & Ratcliffe, 2007).

While a more technical discussion of creating census enhanced GIS spatial units is provided in later chapters, a short introduction is necessary before examining the results from the few studies that have incorporated this method. Essentially, the creation of these geographic units involves a merger of buffer zones around the establishment (or establishments) under investigation with the desired census geography (e.g., block groups). This merger is followed by an areal weighted method for deriving the social characteristics of these newly created units based on census data from the source geographic entity. For instance, when merging buffer zones with census block groups, data from the unaltered census block groups may be used to estimate the population within the new unit based on the proportion of coverage this

new unit has relative to the block group (or groups) it is generated from (Rengert & Lockwood, 2009).

Only a few studies have relied on this method of geographic creation for investigating the crime-facility nexus. More specifically, a literature search of both criminological and sociological data bases can find only two studies that have relied on this technique to analyze drug related offenses: studies in Wilmington, Delaware (Rengert, Ratcliffe & Chakravorty ,2005) and Philadelphia, Pennsylvania (McCord & Ratcliffe, 2007). Both studies start by calculating location quotients, a measure of crime density, around a number of potentially criminogenic facilities. Next, buffer zones around facilities with high location quotients were merged with census block groups using the union process in which new geographic units are created from the intersection between the buffers and block groups. For instance, McCord and Ratcliffe (2007) produced new geographic units through the union of block groups with buffers around eight facility types including beer establishments and state liquor stores. Findings from a zero-inflated Poisson analysis revealed no significant relationship regarding proximity to any of the potentially criminogenic facilities and the existence of a drug market, which was characterized as areas containing drug arrests. However, some facilities did impact the size of drug markets (i.e., the number of drug arrests) in areas that such markets could be sustained. For instance, when accounting for other opportunity and social disorganization variables within the model, beer establishments were significant and positive predictors in the size of drug market, while liquor stores were negatively associated with the size of these markets.

3.4 The Current Study: Expanding Investigations of Merger Methods

The current study differs from the limited research investigating the relationships between facilities and crime through the above merger processes in several ways. First, while the previous studies merged buffers from several different facility types, the current project is limited to buffers around one facility type: drinking establishments. This methodological decision was made in order to clarify/simplify the proximity impact of this establishment on crime. The presence of other potentially criminogenic facilities is controlled for using a crime generator index which will be discussed in more detail in Chapter 5. Moreover, the model in this research accounts for the presence of facilities that are considered to be local guardians (e.g., police departments, fire stations). Second, the current study uses street distance buffers rather than Euclidean buffers, as street distance buffers more accurately capture human patterns of behavior. Third, while the previous research examined drug offenses, this study investigates two different crime types: violent and property offenses. The exploration of different crime types provides a broader understanding of the relationships under examination. Fourth, while the previous studies looked within cities, the present investigation utilizes a metropolitan area. Metropolitan statistical areas consist of a central urban focal point (e.g., Wilmington), connected to neighboring communities that are heavily enmeshed with the social and economic operations within that principal region (US Census Bureau, n.d.). This decision is important as Rengert and Lockwood (2009) point out the issues with politically bounded space. More specifically, they argue that metropolitan areas tend

to be more similar to each other than cities tend to be to each other. Finally, this exploration goes beyond the union method of merger utilized in the previous research. The union method intersects the buffer zones and census geography to create units that essentially divide the original census unit into areas within the proximity of a facility (or facilities) compared to areas that are not. However, a different technique, known as the update method, overlays the buffer zones onto the census geography and leaves these zones intact. In other words, the buffer zone becomes a new unit that is not subdivided into smaller pieces; a unit that can incorporate the area within several different block groups. This dissertation is the first study to examine how these different methodologies may influence the results.

The importance of comparing these two methods of geographic unit creation stems from the modifiable areal unit problem (MAUP). All geographic research faces the potential threat of the MAUP, which is a form of aggregation bias (Openshaw, 1984). This issue occurs when aggregating data to different geographic constructs produces disparate spatial patterns, thus influencing subsequent results and conclusions (Openshaw, 1984). Andresen and Malleson (2013) outline the three divergent outcomes associated with MAUP. First, there may be no effect in that results are consistent, or differences exhibit statistical insignificance across geographic levels. A second possibility is that substantive results remain the same despite quantitative differences. In this case, the direction of impact and significance remains consistent across geographic units although the strength of the relationship may vary. Finally, there may be significant differences in terms of the magnitude, direction, and

significance of relationships examined. This variation in results across geographic levels is problematic because different conclusions concerning which processes matter for the outcome of interest are reached depending on what unit of analysis is employed. Clearly, this potential outcome is the troublesome for researchers investigating spatial relationships.

The recognition of issues associated with MAUP encompass a significant historical extent (e.g., Gehlke & Biehl, 1934; Fotheringham & Wong, 1991; Openshaw, 1984). In the early twentieth century, scholars noted the positive association between coefficient size and the area of contiguously grouped geographic units: larger geographic groupings were associated with greater correlation coefficients while smaller geographic units corresponded with smaller correlation coefficients (Gehlke & Biehl, 1934). Openshaw (1984) provided more insight into the mechanisms in which MAUP infiltrates studies based on scale (i.e., size) and zonation (i.e., the shape or drawing of boundaries) of geographic units. While early investigations relied on univariate and bivariate explorations, Fotheringham and Wong (1991) examined the implications of MAUP within a multivariate context. More specifically, the authors analyzed the influence of changes in scale and zoning sensitivity in which contiguous units were randomly aggregated in different forms. Two dependent variables were assessed: mean family income and proportion of owner-occupied households. Results varied drastically depending on the scale and zoning scheme utilized. For instance, the difference concerning the impact of the proportion of the population that was elderly on mean family income was clearly

impacted by the modifiable areal unit problem. The impact was nearly nine times greater when analyzing the larger geographic aggregation of 20 areal units compared to a scale and zoning scheme that aggregated data to 800 units. Their findings led them to issue a warning concerning the reliability or stability of findings emerging from areal data, advocating for the exploration of results across different units of analysis.

Despite the potential implications of MAUP, few studies in criminological research relying on spatial analysis have systematically investigated how MAUP impacts results (Andresen & Malleson, 2013; Gerell, 2017; Ouimet, 2000). In addition, findings within studies that have heeded the call for uncovering MAUP's impact have produced divergent conclusions concerning the seriousness of aggregation bias (Gerell, 2017). The extent of MAUP's influence within these studies fall along the spectrum outlined by Andresen and Malleson (2013), with some exhibiting null effects (Wooldredge, 2002) and others outlining the continued need for evaluation of MAUP on criminological research (Ouimet, 2000; Gerell, 2017). For instance, in a comparison of crime on street segments and blocks, Kim (2018) found that opportunity related variables (e.g., number of employees within certain facilities) were robust predictors. However, the impact of racial/ethnic heterogeneity on property crime resulted in substantially different conclusions depending on the unit of analysis. For block-level analysis, the association between racial/ethnic heterogeneity was positive but for street-level analysis, increased racial heterogeneity was associated with decreased crime. Kim demonstrated that such findings point to the importance of

testing associations across different levels of analysis as MAUP may have serious implications for understanding how certain processes are related to crime. As such, the current study provides a significant contribution to the current literature by investigating how MAUP influences the results emerging from analyses using census enhanced GIS spatial units.

3.5 A Brief Note on Other Innovative Methodologies for Creating New Geographic Units

While the current study relies on a specific type of geographic unit creation (i.e., the use of census enhanced GIS spatial units with two different merger methods), it is important to acknowledge that the method utilized in the current project is not the only option for creating new geographic units. For instance, one technique of geographic creation that has been used in several studies within the crime and place literature is known as Voronoi diagrams or Thiessen polygons (Melo, Frank, & Brantingham, 2017; Ratcliffe &Taniguchi, 2008; Taniguchi, Ratcliffe & Taylor, 2011). Voronoi diagrams have been used for a range of purposes including examining crime concentration (Melo, Frank, & Brantingham, 2017), exploring equitable resource allocation among police beats (Verma et al. 2010), constructing spatial weights (Wheeler, 2019), examining the relationship between bike-sharing stations and robbery (Haberman, Clutter, &Henderson, 2018), and investigating open-air drug markets and gang "set space" (Taniguchi, Ratcliffe & Taylor, 2011). Thiessen polygons produce unique, statistically independent areal units stemming from a

generator point (e.g., street corner, facility, street centroid) (Taniguchi et al. 2011; Wheeler, 2019). Thiessen polygons emerge so that the space within the polygon is closest to the centroid of that unit than it is to any other centroid (Taniguchi et al. 2011). For instance, if police departments are used as the generator for Thiessen polygons, then each polygon created would only include the space that is closest to the police unit that forms the centroid of that Thiessen polygon. While such techniques provide an important lens upon which to investigate the facility-crime nexus, the current research uses census enhanced GIS spatial units because this technique allows for a better investigation about the proximity impact of drinking establishments on crime in nearby areas.

3.6 Chapter Summary

The current chapter highlighted research examining the relationship between alcohol related facilities and crime from a number of different perspectives. While studies relying on traditional geographies from the census and street segments provide strong evidence of an association between these facilities and crime, methods of new geographic creation may provide more insight into the proximity impact of these establishments. More specifically, the present research builds upon the limited literature utilizing census enhanced GIS spatial units. By comparing two approaches (i.e., the union and update methods), this work hopes to provide more insight into the strengths and weaknesses associated with going beyond a reliance on official geographic boundaries. The next chapter focuses on the use of location quotients for

establishing the spatial extent of drinking establishments on violent and property offenses within the Wilmington metropolitan area.

Chapter 4

EXPLORING THE SPATIAL EXTENT OF DRINKING ESTABLISHMENTS ON CRIME

Examining how crime is spatially distributed around a facility of interest is an important first step for exploring the relationship between crime and potentially criminogenic facilities. The process of exploring the spatial extent of facilities can be viewed as more descriptive in nature, highlighting bivariate rather than multivariate associations. Nonetheless, understanding the spatial distribution of criminal activity has important implications not only for policing efforts and city planning, but also for future research (Groff, 2011). More specifically, research often conceptualizes specific facility types as crime generators, adding these places to an index in an attempt to capture an element of criminal opportunity (Jones & Pridemore, 2019; Tillyer, Wilcox, & Walter, 2021; Wagner, 2020). However, few studies take the concrete step to illustrate that the crime around these establishments is in fact more dense than other areas of the geographic location under investigation. If these facilities do not have significant crime clusters nearby, this could mean that characterizing them as crime generators is insufficient. To phrase it bluntly: if crime does not cluster significantly around a facility, why is it labeled a crime generator? In other words, the more facilities-more crime finding may have more to do with the general ambient

population flows associated with busy locations (i.e., census tracts with more facilities and traffic) than the actual type of facility examined (Tillyer & Walter, 2019).

As such, an important initial step in clarifying if a relationship exists between facilities and crime is going back to the basics and examining the spatial distribution of criminal events within the vicinity of potentially criminogenic establishments. After identifying if there is significant clustering, researchers can move onto the next part of the process (i.e., a more complex multivariate model) and examine whether the environmental features of these locations could impact crime patterns in the area. As such, the first research question of this study is exploratory in nature and seeks to understand the spatial distribution of crime around a facility type that has been framed as a potential crime generator within past research: drinking establishments. More specifically, location quotients are used to investigate the following inquiry:

1. *Does the presence of drinking establishments affect the spatial distribution of violent crimes and property crimes in surrounding areas?*

This chapter provides an overview of the study area and data sources for the current project. Next, the chapter provides a detailed discussion of the strengths and weaknesses of location quotients. Following this conversation, results from location quotient analyses are provided and reflected upon. The chapter concludes with an overview of how results from the location quotients inform the next part of this research process: the creation of new geographic units. By starting with this descriptive approach to gain a better understanding of the extent of drinking

establishments on certain crime types, the current study provided a stronger justification for investigating this relationship further.

4.1 Study Area

The Wilmington, Delaware metropolitan area was chosen to explore the above question for several reasons. First, although Delaware is a small state in size, it is densely populated. More specifically, while Delaware is ranked 49th in size, it is 6th in population density (Statista, 2021). As part of the larger Philadelphia-Camden-Wilmington metropolitan area, this location is easily accessible to larger urban regions and populations. Not only has the central Wilmington area experienced higher rates of drug and gun violence over the past several years (City of Wilmington Delaware, 2021), but both Camden and Philadelphia have also experienced high levels of violence in the past (May, 2015; Ratcliffe & Rengert, 2008; Ratcliffe, Taniguchi, Groff & Wood, 2011). In addition, Wilmington is characterized by significant economic inequality. A report on the racial disparity within Wilmington found that African American/Black and Latinx households had a median income of about half that of white households ($30,034 and $32,976 compared to $60,772 respectively) (Prosperity Now, 2019). As such the Wilmington metropolitan area serves as a unique microcosm for exploring the spatial relationship between crime and potentially criminogenic establishments. As explained in the previous chapter, looking at the wider metropolitan area rather than a single city is beneficial as metropolitan areas

tend to be more similar and thus provide a stronger position for future comparisons with other metropolitan areas (Rengert & Lockwood, 2009).

4.2 Data Sources for Examining the Spatial Extent

Data for examining the spatial extent of drinking establishments were obtained from two sources. First, data concerning criminal incidents were obtained from the Delaware Criminal Justice Information System (DELJIS). DELJIS is a centralized, statewide system in which local and state police departments enter information concerning a criminal event (e.g., location, type of offense, time/date). Next, geographic location data for drinking establishments were gathered from the U.S. Business database provided by Data Axle Reference Solutions (formerly ReferenceUSA). This data source included company name, business type (based on the North American Industry Classification System (NAICS) code), and business address. Only verified businesses were included in analyses for this project.

4.3 Data Preparation: Geocoding, Shapefile modification, Data Cleaning

Various data manipulation procedures were used to prepare the data for analyses. While important for all types of analyses, data cleaning and processing is fundamental for accurate estimates in geospatial models. The following section offers a brief overview of these important steps to provide transparency and ensure that replication of this research can be easily implemented. These processes were carried out using ArcGIS Pro 2.8, Stata, and R statistical programming software.

To begin with, Topologically Integrated Geographic Encoding and Referencing (Tiger) shapefiles for Delaware block groups and metropolitan areas were obtained from the Census Bureau. These files were imported into ArcGIS Pro and projected into the 1983 North American Datum (NAD): Delaware High Accuracy Reference Network (Coordinate Reference System: 2880). Files were clipped to the Wilmington Metropolitan area. This process resulted in 353 block groups[1].

As the data obtained from Data Axle Reference Solutions did not have geographic coordinates, the next part of the process involved geocoding the business location data. Geocoding is a process of converting address data to geographic (latitude and longitude) coordinates**.** Geocoding of facilities was completed using the "tidygeocoder" package in R. To increase the number of geocoded items, the "geo_combine" function was utilized. This method combines geocoding queries from both the Census geocoding services and Open Street Map (OSM) (Nominatim) geocoding services. More specifically, if a match was not found within the Census data (single or batch inquiries), the query was subsequently conducted within the OSM services to see if a match could be located. Using this dual procedure check for geocoding helped increase the "hit rate" (i.e., percent of successfully geocoded data) well beyond the 85 percent recommended by Ratcliffe (2004). Data were examined for duplicates and insufficient/incomplete addresses. In total, 133 drinking establishments

[1] In total, Delaware has 574 block groups. The shapefiles used for this study were from 2010 as they were the most recent files available at the start of this project.

were identified from this data cleaning process. Data obtained from DELJIS were already geocoded.

After this cleaning process, the geocoded facility data were imported into ArcGIS Pro. The ArcGIS Network Analyst extension was used to create street distance buffers around the drinking establishments. While the use of street distance buffers has grown over the last few decades, the majority of previous research has relied on the Euclidean method, which is also known as the "as the crow flies" or straight-line method (Xu & Griffiths, 2017, p.251). Scholars have pointed to the limitations of using the Euclidean buffers as human behavior and facility locations are bounded or constrained by street networks and the shortest path between two points within a study is rarely captured by a straight line (Groff, 2011; Xu & Griffiths, 2017). For instance, Euclidean buffers may include physical features of the landscape that serve as natural barriers to travel (e.g., a river or lake). The probability of a crime occurring in such areas is limited.

The street distance method is an alternate approach that attempts to overcome limitations associated with the Euclidean method. Street distance buffers incorporate information about transportation networks and potential natural or environmental barriers to determine the shortest path between places (Groff, 2011). Information on street networks and features that inhibit movement (e.g. rivers, lakes) is used to create the buffer zone, allowing this method to capture the constrained nature of human activity. Figure 3 illustrates the effects of these two divergent approaches on the estimation of buffer zones. The figure demonstrates the same location using the two

different buffer types. The image on the left shows an example of a street distance buffer technique while the image on the right demonstrates the Euclidean buffer technique. Relative to the street distance buffers, the Euclidean buffers tend to include a greater degree of environmental space in which crime cannot occur (e.g., waterways). As can be seen, street distance buffers tend to be more compact (Groff, 2011).

As previously discussed, while scholars recognize the utility of using street distance buffers, there is relatively limited research relying on this buffer type, with the majority of studies instead utilizing the more traditional Euclidean buffer type (see Groff, 2011; Groff & Lockwood, 2014; and Xu & Griffiths, 2017 for exceptions). The relative lack of research using street distance buffers may be linked to limitations in accessibility of GIS software in creating these types of buffers. However, increases in open-source data platforms may soon lead to a shift in the choice of buffer types incorporated in studies exploring the impact of facilities on crime.

Figure 3: Street Distance (on left) versus Euclidean Buffers (on right)

For each facility, four network buffers were created using the thresholds of: 0-400 feet, 400-800 feet, 800-1200 feet, and 1200-1600 feet. The "ring" option was selected to ensure that each buffer distance consisted of a separate entity (e.g., the 800-foot buffer did not include the area under the 400-foot buffer) (ESRI, n.d.). In addition, the dissolve option was used to merge overlapping polygons produced from the street network output. Subsequently, the area for each street distance buffer was calculated using the "Calculate geometry feature" in ArcGIS Pro. The spatial join function was then used to calculate the number of crimes located within each buffer.

4.4 Analytic Approach: Calculating the Spatial Extent of Facilities on Crime

To reiterate, the first research question in this project attempted to enhance the understanding of the spatial parameters of crime clustering around (potentially) criminogenic places. More specifically, the following question was explored:

1. *Does the presence of drinking establishments affect the spatial distribution of violent crimes and property crimes in surrounding areas?*

To address this question, an analytic technique known as the location quotient was used to measure the density of crime within a region. The location quotient was calculated as follows:

$$LQ= \frac{C_i/a_i}{C_R/a_R}$$

Where:
C_i is the reported number of crimes within sub-region *i*
a_i is the area of sub-region *i*
C_R is the reported number of crimes within the whole study region
a_R is the area of the whole study region

In a place-focused analysis, the location quotient represents the density of criminal incidents around a certain establishment (e.g., drinking establishments) compared to the density of criminal incidents in the whole study area (e.g., the metropolitan area). In the current analysis, the sub-regions under investigation are the buffer zones around drinking establishments within the wider study region of the Wilmington metropolitan area. As such, the proportion of crimes within buffer areas around drinking establishments served as the numerator of this equation, while the proportion of crimes within the Wilmington metropolitan area as a whole served as the denominator.

A location quotient of one means that the density of criminal incidents within a sub-region is proportional to the density of criminal incidents within the whole study region. A location quotient above one means that the density in the sub-region is disproportionately greater than the whole region under investigation and a location quotient under one indicates that the density in the sub-region is less than the density within the whole region. To put this into context, if the 400-foot buffer zone around a drinking establishment is two, this would mean that the clustering of criminal incidents within this region is twice as dense as the clustering of crime throughout the entire study area (Groff, 2011, Ratcliffe, 2012).

4.5 Limitations of the Location Quotient

While the location quotient appears to be a simple calculation of proportional density, several limitations may impact its ability to accurately depict crime

concentration. Issues linked to the measurement of the area for both the buffer zones around facilities and the larger region under investigation can skew results when using the location quotient (McCord & Ratcliffe, 2007). The selection of the "appropriate" bandwidth for a buffer is often subjective or arbitrary in nature. While many scholars rely on 400-foot intervals, which approximate the size of a city block, there are no axiomatic guidelines for making this decision (McCord & Ratcliffe, 2007, Groff, 2011). Clearly, the choice of a radius size can significantly impact the results by either failing to capture events within a facility's influence if the bandwidth is too small or through incorporating incidents that fall outside of the establishment's purview when the radius is too large (McCord & Ratcliffe, 2009).

Moreover, a common practice when using location quotients is to use the entire area of the region under investigation. However, these environments may include locations in which there is limited opportunity and crime is unlikely to occur such as rivers and wetlands. Including these areas within the analyses can distort the denominator of the equation and bias results (Ratcliffe, 2012a, b). In other words, the amount of crime throughout the metropolitan area may seem less concentrated than it actually is when the areas of such features are not removed.

The current study incorporated several steps to minimize the impact of these limitations. First, as outlined above, street distance buffers were used rather than Euclidean buffers. Street distance buffers account for the constrained movement in which human beings operate, following the road network instead of the unconstrained, straight-line approach of circular buffers. The result is a tighter buffer that accounts

for barriers to movement. Second, this investigation used a "masked" approach (Chainey & Ratcliffe, 2005). This approach involved removing areas from the analysis in which there is a low probability of crime. In this case, block groups that had no crimes were removed from the analysis. Furthermore, this study adjusted for the areas of lakes and water features within the larger study area. This process involved several steps. First, the "calculate geometry" feature was used to calculate the overall area. Next, data within the Census shapefile were used to calculate the proportion of the area that was water. Finally, the proportion of water area was multiplied by the overall calculated area and removed to get an accurate land area estimate. These adjustments allowed for a more accurate density calculation by excluding areas in which crime is unlikely to take place.

4.6 Location Quotient Results

To reiterate, the determination of location quotients was used to get a general sense of how crime may cluster around drinking establishments. This descriptive examination was an important first step in critically assessing the role of drinking establishments on crime because it provides an indication of how crime around such establishments compares to crime in the area under investigation in general. To be clear, this is an exploratory measure and should not be taken as conclusive evidence that the facility is in fact a crime generator. Rather, the location quotient demonstrates the spatial extent (e.g., how far away from the facility) crime may be elevated relative to other areas.

Before discussing the results of location quotients calculated within this study area, Table 1 provides an overview of the property and violent offenses that occurred within the Wilmington Metropolitan area during the three-year study period for which data were obtained (2015-2017). Violent offenses include assaults and robbery incidents[2]. Property crimes include burglary, larceny/theft, and vandalism. During the three-year period under investigation, the Wilmington metropolitan area had 12,929 assaults, 5,528 robberies, 6,027 burglaries, 26,067 larceny/theft incidents and 9,726 vandalism offenses. This resulted in a total of 18,457 violent and 41,820 property offenses in the study area over the three- year study period with an average of 6,152 violent crimes and 13,940 property crimes per year.

Table 1: Wilmington Metropolitan Descriptive Statistics for Crime by Year

Crime-Type	**2015**	**2016**	**2017**	**Total 2015-2017**	**Average 2015-2017**
Violent	**6,647**	**6,458**	**5,352**	**18,457**	**6,152**
Assault	4,575	4,458	3,896	12,929	4,310
Robbery	2,072	2,000	1,456	5,528	1,843
Property	**13,467**	**14,558**	**13,795**	**41,820**	**13,940**
Burglary	1,779	1,987	2,261	6,027	2,009
Larceny/theft	8,525	9,320	8,222	26,067	8,689
Vandalism	3,163	3,251	3,312	9,726	3,242

[2] Following previous research, sexual assault and rape excluded from the analyses because these crimes is severely underreported (Kubrin, Branic & Hipp, 2021). Incidents concerning homicide/murder were also excluded because of the rarity of these crimes and the difficulty in detecting spatial patterns for this offense at small spatial scales (Kim & Hipp, 2021).

If a facility is potentially impacting crime in the surrounding area, we would expect to see the greatest impact in the first buffer zone, with decreasing impact as we move farther away from the facility. When examining the location quotients for violent offenses, this appears to be the case (see Table 2). The location quotients for the first buffer (0-400 feet) had the largest location quotient across all violent offenses, with decreasing location quotients within each subsequent buffer. For instance, when looking at the combined measure of violent offenses, the location quotient in the first buffer suggested that crime in this region, on average, was over 5 times higher than the study region as a whole. Importantly, with the exception of robbery, the average location quotient in even the farthest buffer (1200-1600 feet) suggested that crime within these zones were at least twice as dense as crime within the Wilmington Metropolitan area in general.

Table 2: Location Quotients: Violent Crimes

	2015	2016	2017	Average
Violent Combined				
0-400 feet	6.31	5.77	4.83	5.64
400-800 feet	4.43	4.04	4.04	4.17
800-1200 feet	2.69	2.94	3.22	2.95
1200-1600 feet	2.48	2.65	2.68	2.60
Assault				
0-400 feet	5.41	5.22	4.13	4.92
400-800 feet	3.76	4.07	3.82	3.88
800-1200 feet	2.37	2.78	3.03	2.73
1200-1600 feet	2.35	2.70	2.49	2.51
Robbery				
0-400 feet	5.16	4.39	3.38	4.31
400-800 feet	3.66	2.43	2.31	2.80
800-1200 feet	2.09	2.06	1.85	2.00
1200-1600 feet	1.69	1.55	1.60	1.61

Table 3 provides results from location quotients associated with property offenses. When examining the location quotients for property offenses, a slightly different pattern emerges. Location quotients were generated for an aggregate measure of property offenses as well as disaggregated estimates for burglary, larceny, and vandalism. For the crime of vandalism, we see the expected pattern of the location quotient being highest in the first buffer and subsequently decreasing when moving outward. Even at the farthest buffer (1200-1600 feet), vandalism on average is approximately twice as dense as the clustering of crime throughout the entire metropolitan area. For the crimes of burglary and larceny, the location quotients are still highest in the first buffer. For example, larceny/theft incidents are significantly greater in the 0-400 foot buffer with these incidents being 7 times as dense as the clustering of crime throughout the study area. However, while the location quotient decreases in the subsequent buffers as expected, the location quotient is slightly elevated in the fourth buffer (LQ=3.90) relative to the third (LQ=3.33). While we do not see the consistent decrease that is expected as we move away from the facility, the difference between these buffer zones does not appear to be significantly vast and could thus be due to random fluctuation. Moreover, the crime density within this last buffer is still, on average, nearly 4 times greater for larceny relative to the study area as a whole (average LQ=3.90).

Table 3: Location Quotients: Property Offenses

	2015	2016	2017	Average
Property Combined				
0-400 feet	6.90	6.86	7.09	6.95
400-800 feet	4.19	3.83	3.53	3.85
800-1200 feet	3.32	3.03	3.01	3.12
1200-1600 feet	3.46	3.97	2.79	3.41
Burglary				
0-400 feet	3.57	3.29	3.60	3.49
400-800 feet	2.75	2.34	1.74	2.28
800-1200 feet	1.94	1.89	1.72	1.85
1200-1600 feet	2.00	1.80	2.13	1.98
Larceny/theft				
0-400 feet	7.75	7.96	7.52	7.74
400-800 feet	4.27	4.01	4.08	4.12
800-1200 feet	3.52	3.15	3.32	3.33
1200-1600 feet	4.05	4.78	2.88	3.90
Vandalism				
0-400 feet	5.22	4.67	6.77	5.55
400-800 feet	3.92	3.39	2.63	3.31
800-1200 feet	2.90	2.73	2.43	2.69
1200-1600 feet	2.09	2.31	2.31	2.24

4.7 Chapter Summary

The first research question of this dissertation concerned whether drinking establishments affect the spatial distribution of crime within surrounding areas. The location quotients discussed above provided some indication that crime density may be significantly elevated in the areas surrounding drinking establishments. On average, location quotients for the combined violent and property offenses indicated that crime density was at least twice as great within the 1600-foot buffer regions relative to the Wilmington metropolitan area as a whole (LQ= 2.60 and 3.41 respectively). However, location quotients fail to provide the reason this may be the case. To be clear, these

estimates are not definitive proof that the facilities in themselves are criminogenic. Rather, these approximations are an important initial stage of the exploratory process in determining if it is the facility itself or some other factor within the vicinity impacting the crime in the surrounding areas.

For the purposes of this study, the above location quotients suggest that, on average, the density of property offenses and violent incidents surrounding the vicinities of drinking establishments is relatively greater than the density of crimes within the whole Metropolitan area- at least within the vicinity of the 1600-foot buffer. The next step in the process is to determine if drinking establishments are in fact crime generators or if other factors characterizing these buffer zones are the primary predictors of crime net of the presence of drinking establishments. Chapter 5 outlines an approach for estimating the social and environmental characteristics of these buffer zones in order to conduct a more traditional model for examining the impact of drinking establishments on crime patterns. More specifically, this approach involved merging the 1600-foot buffer zones with census block groups to create new geographic units that are known as census enhanced GIS spatial units (Rengert & Lockwood, 2009). The following chapter provides a technical overview of this process.

Chapter 5

OVERVIEW OF METHODOLOGICAL TECHNIQUES

While the descriptive analysis in the previous chapter offers preliminary evidence of clustering around the drinking establishments under investigation, it does not consider the wider social and economic context in which these facilities exist. As demonstrated in the previous chapters, factors associated with social disorganization (e.g., economic disadvantage, residential mobility) as well as criminal opportunity (e.g., presence of local guardians) can impact the crime patterns in an area (e.g., see Jones & Pridemore, 2019, Tillyer, Wilcox, & Walter, 2021, Weisburd, 2012, Weisburd, Groff & Yang, 2012). Moreover, different types of potentially criminogenic facilities tend to cluster in space. This clustering contributes to a busy context of increased human activity and can inhibit the researcher's ability to assess the unique impact that each type of facility may independently exert on crime in an area (Wilcox & Eck, 2011). As such, it is important to disentangle the crime clustering around these drinking establishments from the effects of the social and economic contexts of the locations in which these facilities operate.

To assess the impact that a specific type of establishment may have on crime, researchers must move beyond a reliance on pre-defined census units and explore how the make-up of the areas surrounding these alleged criminogenic establishments shape crime patterns. The present research further investigates the relationship between

crime and drinking establishments using spatial models to explore the following research question:

2) *Does the relationship between drinking establishments and crime remain after controlling for the larger social environment in which these facilities operate?*

To explore this question, the areas in which these facilities are located must be central to the analysis. Methods for constructing new geographic areas are rarely utilized within the literature investigating the relationship between crime and place (Rengert & Lockwood, 2009). Rather, most research relies on census geography boundaries and other pre-constructed units (for exceptions see Rengert, Ratcliffe, Chakravorty, 2005; McCord & Ratcliffe, 2007; Rengert & Lockwood, 2009). However, the creation of new geographic entities incorporating the areas surrounding potentially criminogenic facilities can be used to gain a better understanding of the relationship between facilities, crime, and the social context in which these establishments are located. For instance, the drinking establishment buffer zones which were created in the previous chapter can be merged with the block groups to create new units of analysis. Subsequently, methods such as areal interpolation can be used to estimate the social and economic characteristics of these newly created areas. In addition, the process or method in which these new units are combined needs to be considered carefully as this methodological choice can significantly impact outcomes as it influences the size and shape of the new geographic units. This leads to the third research question that this study attempts to address:

3) *How do different methodological techniques used to create the new units of analysis affect the results and shape our interpretations of the impact that these facilities have on crime?*

This study attempts to investigate this question through the creation of new geographic units relying on estimations from an areal weighted interpolation approach. In addition to assessing how the surrounding environment of the areas around drinking establishments may shape crime patterns, this research also provides a methodological contribution by considering how the technique for creating these new units of analysis is fundamental to these types of investigations. Moreover, in order to ensure that results are not a methodological artifact, the current study incorporates an additional element of variation by examining two different ways of operationalizing the dependent crime variables: as rates per capita and rates per square kilometer. Thus, the final research question within this study is:

4) *Does the operationalization of the dependent variable (i.e., looking at crime density in terms of population versus area) impact which variables are significant predictors of crime within these newly created geographic units?*

The remaining sections of this chapter provide the framework for exploring the impact of the social and environmental factors on crime within these geographic units. A detailed discussion of the creation methods of these new units and the process of estimating their social and economic characteristics through areal weighted interpolation is provided below.

5.1 Creating New Geographic Units in the Wilmington Metropolitan Area

The Wilmington metropolitan area consists of 353 block groups and 62 buffer zone locations around drinking establishments.[3] The left image of Figure 4 provides an illustration of the block groups in this study area while the image on the right shows the buffer zones around the drinking establishments.

Figure 4: Wilmington Metro Area Block Groups and Drinking Place Buffer Zones

Two different procedures are used to combine the generated buffer areas with the block groups to make new geographic units. First, using the union geoprocessing

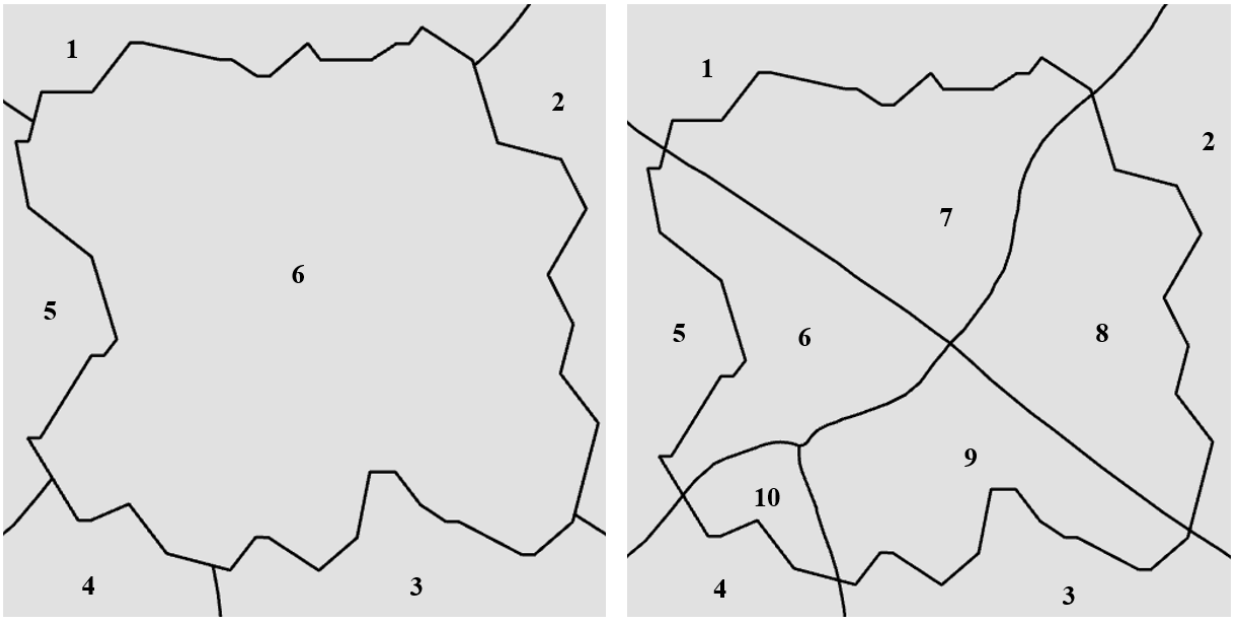
[3] There were 133 drinking establishments overall. Clustering of these locations led to the merger of several overlapping buffer zone areas.

tool for overlay analysis in ArcGIS Pro, buffer zones were merged with the block group shapefile. This type of union process results in geographic units split into finer pieces at the locations in which the buffer zones and block groups intersect. This approach is illustrated in the left portion of Figure 5. Areas in dark black represent the location of drinking establishment buffer zones while areas in red represent the areas affected from the merger. A second process for combining the buffer zones and block groups into new geographic areas involved using the update analysis tool in ArcGIS Pro. Rather than dissecting the block groups and buffer zones at points of intersection, the update tool essentially overlays the buffer zone onto the block groups, keeping the buffer intact as a new unit. In this way, the block groups are updated with new areas carved out based on the overlay of the buffer zones. The image on the right of Figure 5 illustrates the update method for the study area locations.

Figure 5: Union and Update Approaches to Merging Areas

The union method in which buffer zones and block groups are intersected creates finer units than the update method in which the buffer zones are overlaid on top of the block groups. For a better illustration, Figure 6 zooms in on a specific area to demonstrate these differences more clearly. Both images represent the same area. However, the picture on the left highlights the creation of new units based on the update method and the figure on the right demonstrates unit creation based on the union method. While the update method results in six geographic areas from the merger, the union process results in ten geographic units.

Figure 6: Comparison of Newly Created Units using the Update and Union Methods



The decision concerning what merger process to use (i.e., union versus update) can have implications for the subsequent analyses because each method results in geographic units that differ in terms of size and shape. However, since research has yet to compare results across these merger methods, a better understanding concerning how these methodological decisions influence results is needed. By comparing spatial models for two different crime types (e.g., property and violent) across these two procedures for creating new geographic units, the present study will provide additional insight on the importance of this decision.

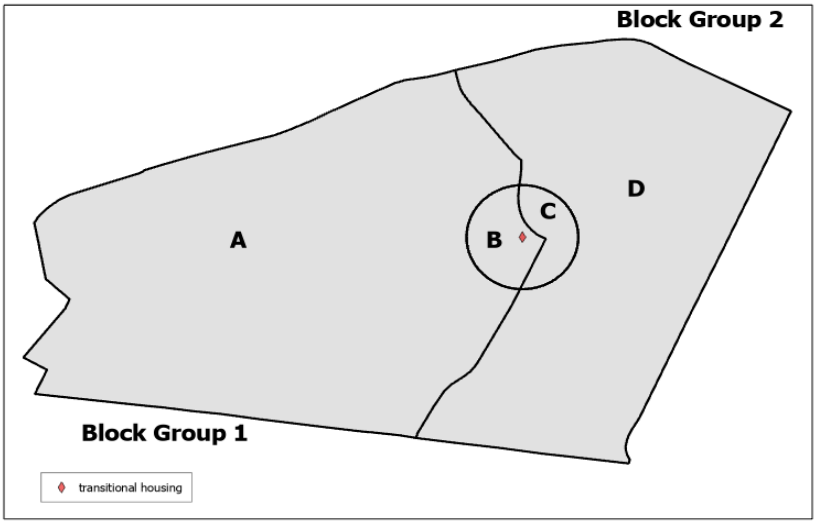
5.2 Areal Weighted Interpolation

Once the new geographic areas are created, researchers must find a way to estimate the different social and economic characteristics of that area. One method that

can be used to accomplish this is areal weighted interpolation. Areal interpolation is the process of using data from one set of polygons (the source data) to estimate values for a set of target polygons. In the current study, data from the census geographies are disaggregated to the newly defined geographic areas created by the union and update methods outlined above. Areal weighted interpolation was carried out using the 'areal' package in R statistical software (Prener & Revord, 2019).

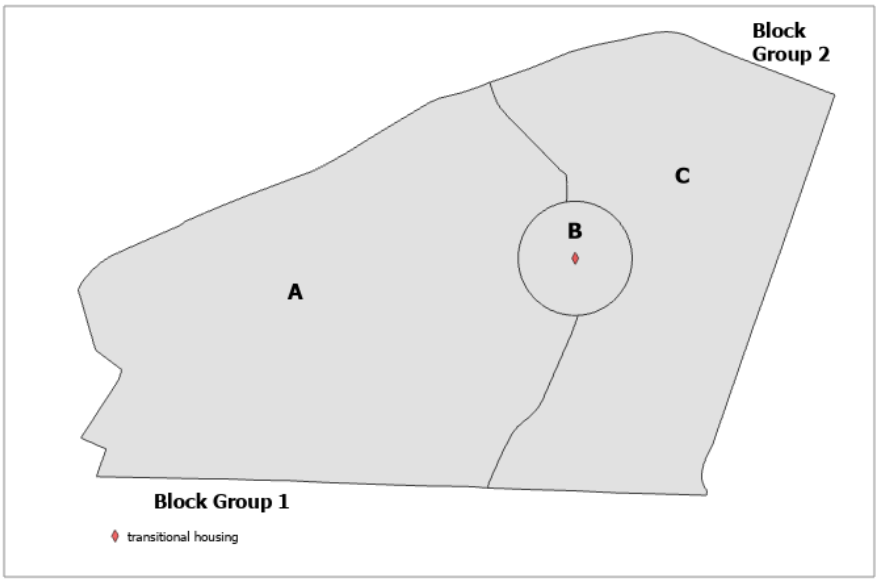
To illustrate how this interpolation process works, a simplified example is demonstrated below. Figure 7 shows the creation of four new geographic units (A, B, C and D) from the union of a buffer surrounding a facility and two block groups. In this hypothetical example, we can interpolate the population estimate using the proportion of the original block group that each new geographic unit covers. For instance, if block group 1 has a population of 1,000 individuals and unit A is proportionally 95% of the area of block group 1, we would estimate that unit A has a population of 950 individuals (1,000* 0.95). Similarly, we would estimate that unit B, which is 5% of the area of block group 1, would have a population of 50 individuals (1,000 * 0.05).

Figure 7: Areal Interpolation and the Union Method



Now, using this same example to demonstrate the areal weighted interpolation process using the update merger method, we see that the merger of the same region results in three geographic units: A, B, and C. Using the interpolation method based on the proportion of a block group in which the newly created unit lies, unit A would still have an estimated population of 950 individuals (1,000* 0.95). The estimate of unit B depends on its proportional coverage of both block group 1 and block group 2. Thus, if block group 2 also has a population of 1,000 individuals and unit B covers 5% of the area of block group 2 as well as 5% of the area of block group 1, we would estimate that unit B has a population of 100 individuals (5% of block group 1 and 5% block group 2).

Figure 8: Areal Interpolation and the Update Method



These examples illustrate one of the major limitations of using an areal weighted approach: the assumption that the population is evenly distributed throughout the geographic unit of analysis. This assumption is problematic because it is more likely that certain contextual factors (e.g., population, poverty) may be concentrated within specific parts of the geographic unit rather than evenly spread out. Thus, while the calculations for the current study are based on a proportional procedure that assumes even distribution of populations throughout the source unit (i.e., the census block group), this assumption potentially creates estimates that either under-estimate or over-estimate the population characteristics because knowledge of the true distribution patterns remain unknown. However, it is important to note that this is a limitation for the majority of geographic research that relies on census

polygons. Therefore, the risk of estimation error in the current study is generally consistent with the risk of error in other studies relying on areal units.

5.3 Data Sources and Variables

As indicated in the previous chapter, data concerning criminal incidents are obtained from the Delaware Criminal Justice Information System (DELJIS). The present study also incorporates several facilities that the literature identifies as potentially criminogenic as well as several establishments that may provide a protective factor within areas. Geographic location data for potential crime generators/attractors and protectors are gathered from the U.S. Business database provided by Data Axle Reference Solutions (formerly ReferenceUSA). More specifically, this source was used to obtain information on the potentially criminogenic facilities of gas stations, convenience stores, banks, check cashing facilities, off-premise liquor stores, and pawnshops as well as the potential local guardianship facilities such as churches, fire stations and police stations. This data source includes company name, business type (based on the North American Industry Classification System (NAICS) code), and business address. Only verified businesses are included in analyses for this project.

Finally, data concerning socio-demographic information were obtained from the Census Bureau. More specifically, American Community Survey 5-year estimates (2013-2017) were pulled for block groups. The American Community Survey is conducted every year from a sample of over 3.5 million households across the United

States (US Census Bureau, 2017). The Census Bureau uses information collected from this survey to produce data profiles concerning the social, economic, and demographic makeup of a location. Currently, the smallest geographic unit for which these data are produced is the census block group.

5.3.1 Outcome Variables

The outcome variables of interest are property and violent offenses aggregated to the geographic units produced from the intersection/overlay of buffer zones generated around drinking establishments and census blocks between 2015 and 2017. Following previous research, the average of this 3-year period is used to account for any temporal variation in arrest patterns over the time period (see Donnelly et al. 2021). Violent offenses included assaults and robbery incidents. Property crimes included burglary, larceny/theft, and vandalism. As will be discussed in more detail in the next chapter, these offense counts were transformed into rates. Moreover, rates were operationalized in this study in two ways: as a population-based measure (i.e., rates per capita) and as an area measure (i.e., rates per square kilometer).

5.3.2 Explanatory Variables

This study looks further into the relationship between crime and drinking establishments by creating new geographic units based on distance from the establishment itself. To do this, the census geography was broken up into areas that fall within a specified distance from the facility and areas that were outside that distance. This specified distance was determined from the location quotients

calculated in Chapter 4 which suggested that crime density up to the 1600-foot buffer was relatively greater than crime clustering within the Wilmington metropolitan area in general. The 1600-foot buffers around the drinking establishments were used to create new geographic units for analysis.

The primary explanatory variable for this set of analyses was whether the geographic unit lies within the 1600-foot buffer range of a drinking establishment or if it lies beyond this range. A categorical variable was used to establish this relationship, with geographic units that were part of these buffers coded as 1 and geographic areas falling outside of the drinking establishment buffers coded as 0. Essentially, this process helped determine if the facilities of interest were affecting the distribution of crime net of the other explanatory variables.

Rather than looking at the establishment as the unit of analysis, as does the first research question, the focus here shifted to an ecological approach with the newly constructed geographic units (e.g., the buffer zones around drinking establishments) placed at the center of inquiry. However, because these areas were generated for a specific purpose and are not part of a pre-defined Census geography, data concerning the social and environmental make up of these new units were not readily available. Instead, these characteristics were estimated from the Census data that does exist. More specifically, the technique of areal weighted interpolation, which was outlined in detail above, was used to estimate the social and demographic characteristics of the resulting enumeration units. Thus, the process of areal weighted interpolation was

carried out for each new unit types (union and update) to estimate a number of ecological factors that could be contributing to crime within these new locations.

As outlined in the theory section, factors related to the structure/organization and opportunity within a region can impact crime rates in those areas. Table 4 outlines the variables included in this dissertation along with their expected direction of influence based on theoretical guidelines. To reiterate, this study does not test any theory directly; rather it draws on proxy measures related to the frameworks of structural and opportunity perspectives. First, several measures were included that could potentially impact the level of social disorganization within the geographic unit. Two measures were incorporated to capture the relative residential instability within a geographic area including the percentage of households occupied by renters and the percentage of the population that moved in the past calendar year. Following previous research, regression-based factor scores were used to construct an economic disadvantage index (Donnelly, Wagner, Anderson, & O'Connell, 2022; Donnelly et al, 2021). This index consisted of four items: 1) percentage of the population living below the poverty line, 2) percentage of residents receiving food stamps, 3) percentage of households headed by a single female with dependent children under eighteen, and 4) percentage of the workforce between 18 and 65 years old that is unemployed. Finally, a variable was included to capture the percentage of the population who identify as white, non-Hispanic. Except for the percentage of the population who identified as white, the variables link to the structure or organization of a geographic entity were expected to have a positive association with crime. Thus, increased economic

disadvantage, a higher percentage of the population that moved, and greater percentage of households occupied by renters in an area had expected associations of higher crime rates in an area. The percentage of the population that was white was expected to have a negative impact. As such, areas with higher percentage of the population that identified as white were expected to be associated with decreased crime rates.

Table 4: Variables and Their Anticipated Impacted Based on Theoretical Expectations

Theoretical Framework	**Independent Variable**	**Expected Direction**
Social Disorganization		
	Economic Disadvantage Index	Positive
	Percent White	Negative
	Percent Renter	Positive
	Percent Moved	Positive
Opportunity Theories		
	Buffer Zone Area	Positive
	Percent Male 15-24	Positive
	Drug Incidents	Positive
	Local Guardian Index	Negative
	Crime Generator Index	Positive
Other Controls		
	Spatial Weight	Positive
	Area/Population	Positive

In addition to the proxy measures of residential stability and economic deprivation, several opportunity focused variables were controlled for in the analyses. Since prior research demonstrates that certain facilities may influence the level of

crime within the focal geographic unit, an index was created for facilities that may increase crime within an area while a separate index included facilities that may have a diminishing impact on crime. These indices are labeled the crime generator index and local guardianship index respectively[4]. While the crime generator index is expected to have a positive association with crime rates, the local guardianship index is expected to have a negative association. Variables controlling for the percentage of the population who are males between the ages of 15 and 24 and the number of drug incidents were added to account for the potential offender/victim populations and the presence of illegal markets in a region respectively.

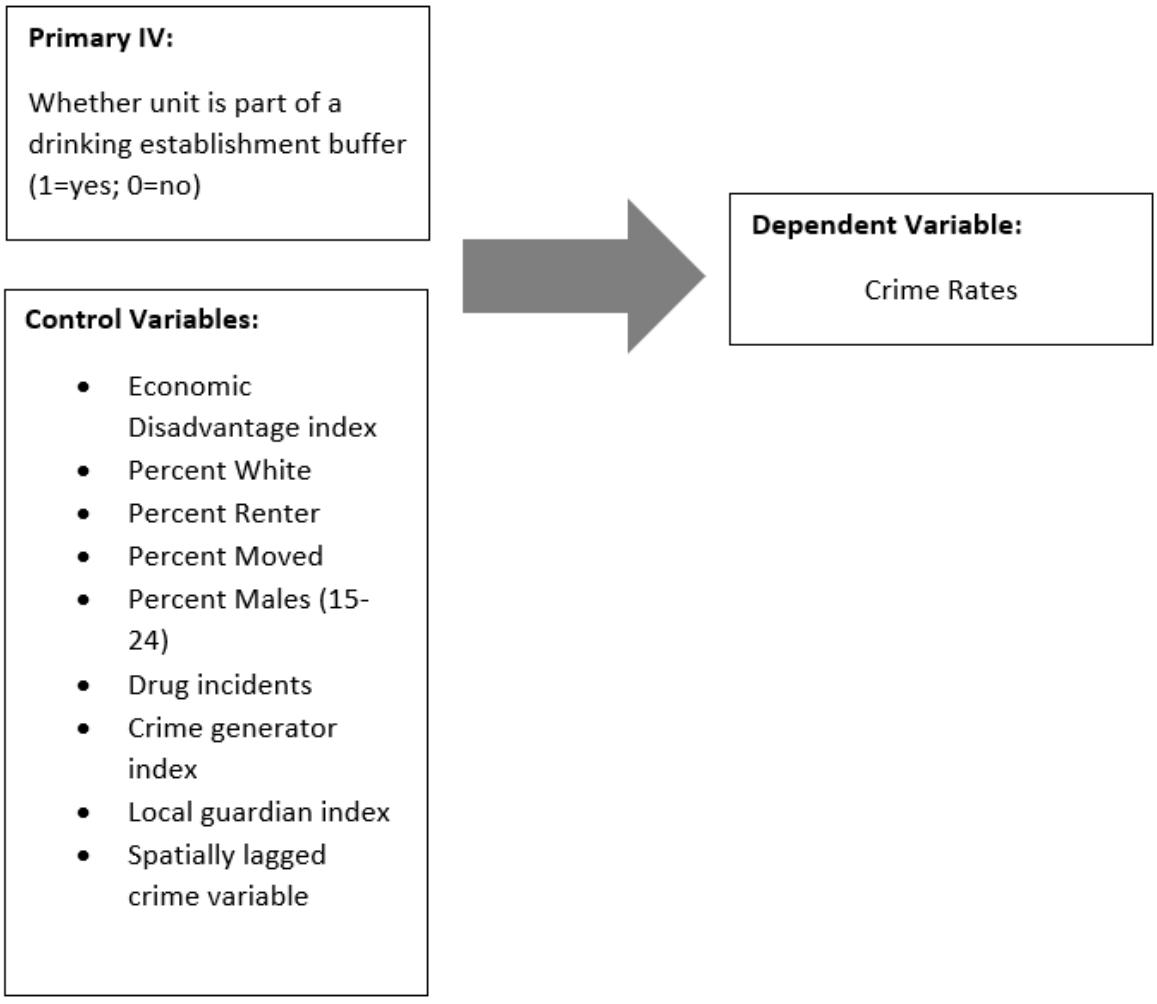
Finally, as discussed in the previous chapter, spatial autocorrelation is often an issue with geographic research. To account for this issue, a spatially lagged variable for crime counts in neighboring regions was constructed using an inverse-weighted distance approach. For the violent crime models, this spatial weight was calculated based on the count violent crime in surrounding areas. Similarly, for the property crime models, this spatial weight was based on the number of property crimes in

---

[4] The facilities included within these indices have been used in previous research using similar indices. It is important to note that these variables do not provide an exhaustive account of all facilities that have been labeled "crime generators" or "local guardianship" facilities. As such, it is possible that these variables may underestimate the impact of such facility-types in a region. However, the purpose of this research is to illustrate more comprehensive ways of establishing the connection between facility-crime relationship, so it is also possible that certain facilities within such an index are not truly criminogenic. Nonetheless, for the purposes of the current study, the indices provided some indication of the impact of facilities beyond drinking establishments in the regions under investigation.

surrounding areas. The technical aspects of creating the spatially lagged variables are discussed in the next chapter. Figure 9 provides an overview of the general relationships investigated within the final analyses. Since this is an exploratory study, relationships were examined as direct impacts on crime rates.

Figure 9: Variable List for Analyses



The current chapter provided a detailed overview of the process for creating the new geographic units and estimating the social and economic characteristics of these new entities. This chapter also outlined the variables that will be used to explore whether areas within the drinking establishment buffer zones have higher crime rates when controlling for other factors that could be contributing to this relationship in these areas. Chapter 6 provides a detailed discussion of the analytic technique used to examine the relationships outlined in Figure 9. More specifically, results from negative binomial models were used to examine the impact of drinking establishments on crime with geographic units created through both the union and update methods.

Chapter 6

RESULTS FROM NEGATIVE BINOMIAL MODELS

The current chapter presents results from various models used to explore the relationship between property and violent crime incident rates and the built environment within newly created geographic entities. The primary focus of this dissertation concerned the impact of being part of a drinking establishment buffer zone on crime within these units. Two methods for geographic unit creation were used in this study: the union method and the update method. The union method merged drinking establishment buffer zones with census block groups in a manner in which the original block group was subdivided into areas that were part of a buffer zone versus areas that were not part of a buffer zone. On the other hand, the update method overlaid the buffer onto block groups, keeping the buffer intact as a new geographic unit.

This chapter highlights the results from models seeking to answer the following questions:

2) *Does the relationship between drinking establishments and crime (found from the location quotients in chapter 4) remain after controlling for the larger social environment in which these facilities operate?*

3) *Do the different methodological techniques used to create the new units of analysis affect the results and shape our interpretations of the impact of these facilities on crime?*

4) *Does the operationalization of the dependent variable (i.e., looking at crime density in terms of population versus area) impact which variables are significant predictors of crime within these newly created geographic units?*

The purpose of the current chapter is to provide the results from the statistical analyses for the models outlined in Table 5:

Table 5: Overview of Negative Binomial Models

Model	Unit Creation	Outcome Variable
1	Union	Property incidents /per capita
2	Update	Property incidents /per capita
3	Union	Violent incidents /per capita
4	Update	Violent incidents /per capita
5	Union	Property incidents /per sq. km
6	Update	Property incidents /per sq. km
7	Union	Violent incidents /per sq. km
8	Update	Violent incidents/per sq. km

While the current chapter briefly outlines some differences, more detailed comparisons between models are provided in Chapter 7. Similarly, while connections between findings and the research questions are noted, a more thorough discussion of these relationships is provided in subsequent chapters.

6.1 Descriptive Statistics

Before exploring the results from the models used to address this project's research questions, it is important to get a sense of the descriptive nature of the data in terms of univariate and bivariate relationships. Tables 6 and 7 provide the descriptive statistics of the variables used in these models for the union and update geographic areas respectively.

Table 6: Descriptive Statistics for Union Geographic Areas

Variable	M	SD	Minimum	Maximum
Property offenses (average)	20.87	36.78	0	501.67
Violent offenses (average)	9.21	14.14	0	148
Economic Disadvantage	-0.00	1	-1.18	4.78
Percent White	65.04	26.56	0.00	100.00
Percent Moved	12.86	10.49	0.00	59.45
Percent Renters	28.92	22.20	0.00	99.99
Drug Incidents (average)	15.36	34.66	0	621
Crime Generator Index	1.20	2.55	0	44
Local Guardianship Index	0.86	1.46	0	20
Percent Males (15-24)	6.29	5.19	0.00	44.08
N	668	-----	-----	----

Table 7: Descriptive Statistics for Update Geographic Areas

Variable	M	SD	Minimum	Maximum
Property offenses (average)	34.41	70.26	0	801.67
Violent offenses (average)	15.19	46.27	0	799.67
Economic Disadvantage	-0.00	1	-1.19	5.12
Percent White	65.16	25.67	0.00	100.00
Percent Moved	12.37	9.94	0.00	59.45
Percent Renters	28.14	21.65	0.00	99.99
Drug Incidents (average)	25.33	59.73	0	692.33
Crime Generator Index	1.98	5.55	0	70
Local Guardianship Index	1.41	3.45	0	50
Percent Males (15-24)	6.24	4.84	0.00	44.08
N	405	-----	-----	----

For the union method, there were 325 geographic units that were created from part of a drinking establishment buffer zone and 343 units that were not part of a buffer zone. For the update method, 62 geographic units emerged from drinking establishment buffer zones compared to 343 that were not part of these zones. On average, the update units had a population of around 1,268 and a size of 1.23 square kilometers. Comparatively, the union units had an average population of 769 and an average size of 0.75 square kilometers. Overall, the means for the characteristics of the

social contexts between these two types of geographic units were fairly close. For instance, both the union and update geographic units had an average of almost two-thirds of the percentage of the population being white and an average of almost thirty percent of the households being rented. Recall that the economic disadvantage index is a regression-based factor with a mean of 0 and a standard deviation of 1. The ranges for this index between the union and update units were similar with the update units having a slightly higher maximum range (5.12 compared to 4.78). Thus, on average, there appeared to be only slight variation in the descriptive statistics for most of the control variables between the union and update geographic units.

However, there were several noteworthy differences concerning crime-related variables. More specifically, the geographic units created using the update method had higher means for property, violent, and drug offenses as well as considerably larger standard deviations for these offenses. In other words, there is more variance for offenses between these larger geographic units created using the update method compared to the smaller units created using the union method. The ranges of these variables provide useful information for understanding the significant differences between these models. For instance, the union model had a high value of about 502 for property offenses, 148 for violent offenses and 621 for drug offenses compared to a high of 802 for property offenses, 800 for violent offenses and 692 for drug offenses for the update units. While not surprising that the larger areas would have higher crime counts, this difference nonetheless highlights the importance in standardizing the dependent variable when making comparisons across different unit types. As such, the

following analyses focus on crime per capita and crime per square kilometer rather than crime counts in general.

To check for issues of multicollinearity, variance inflation factors (VIF) were examined after the models were run as linear regressions. Evidence from the OLS models indicated VIF scores were all below the commonly used threshold of 10[5] (Salkind, 2007; Stevens, 2002; Wo, 2016). Correlation matrices were also examined to check for issues. Overall, the correlation matrices generally revealed weak to moderate associations between the independent variables except for a strong correlation (correlation=0.83) between the crime generator index and the local guardian index in the models with the geographic update units. This finding is not surprising as facilities tend to cluster in space. Caution is necessary when examining the impact of these variables within the update units[6]. Because of this potential issue with multicollinearity within the update units, models were run with robust standard errors. The correlation matrices and VIF scores are provided in Appendix A.

---

[5] There is debate concerning what the appropriate VIF cutoff should be (Thompson, Kim, Aloe, & Becker, 2017). Some researchers have relied on a value of 10 as the cut off (Stevens, 2002; Wo, 2016) while others have gone with a more conservative value (Thompson, Kim, Aloe, & Becker, 2017).

[6] A common practice for dealing with highly correlated variables is to include these items together in an index (Stevens, 2002). However, combining these facilities into one index is inappropriate because these facility-types have opposite directions of impact (i.e., the crime generator index is associated with increased crime rates while the local guardian index is associated with decreased crime rates).

Before analyzing the data, the dependent variables were inspected for potential influential outliers. For the property crime models, four values within the update model and two values in the union model were considered to be outliers and were recoded to the next highest value. The approach of transforming extreme values in count-based dependent variables is known as winsorizing and has been used in other studies exploring crime patterns (e.g., Askey, Taylor, Groff & Fingerhut, 2018). All four values in the update model were located within drinking establishment buffer zones. For the union models, one outlier value was within a drinking establishment buffer zone, while the other value did not fall within a drinking establishment buffer zone. For violent crime models, two values within the update model and one value in the union model were considered outliers and were recoded to the next lowest value. For both the union and update models, all outlier values concerning violent incidents were located within drinking establishment buffer zones. As will be discussed in the next section, it is important to address potential outliers because extreme outliers can impact coefficients in terms of magnitude, direction, and/or significance of coefficients.

All models predicting crime rates for property and violent offenses were analyzed using spatially-adjusted negative binomial regression models. Negative binomial models were appropriate because of overdispersion in the outcome measures. Overdispersion violates the assumption of the Poisson distribution that the mean equals the variance, which makes the negative binomial model more appropriate for

these analyses (Hoffman, 2016)[7]. In models 1-4, the population size of these geographic units was included as an exposure variable, transforming the outcomes to per capita rates (Osgood, 2000; Donnelly et al. 2022; Lardier et al. 2021). Next, models 5-8 were conducted with area as the exposure variable, transforming the outcomes to rates per square kilometer.

The spatially adjusted negative binomial model also accounts for spatial autocorrelation in the outcome variables. Autocorrelation relates to Tobler's first law of geography: "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970, p. 236). In this context, geographic areas in close proximity may have crime rates that are more similar than geographic units that are a greater distance away. Autocorrelation violates the assumptions of other statistical models including the Poisson requirement of independent observations (Hoffman, 2016) and the assumption of uncorrelated error terms for ordinary least square regression models (Donnelly et al. 2022). In all models, evidence of spatial autocorrelation was present for both property and violent offenses. To account for spatial autocorrelation in the dependent variables, spatially lagged variables were included in the models using Stata's spmat command (Drukker et al. 2013). First, a

[7] To confirm the appropriateness of the negative binomial model, the analyses were first conducted as Poisson models. As expected, goodness of fit statistics indicated Poisson models were inappropriate. In addition, likelihood-ratio tests performed after fitting all eight negative binomial models provided supporting evidence to reject of the null hypothesis that alpha is equal to zero. Rejection of the null hypothesis provides support for using the negative binomial model over the Poisson model (Mozahem, 2021).

spatially weighted matrix was created using the inverse-distance method that applies a greater weight to units nearby compared to those that are farther away. Next this weight was used to compute the weighted averages of property crimes and violent crimes in neighboring geographic units.

6.2 Negative Binomial Results: Population as Exposure Variable

The following section focuses on models in which total population is used as the exposure variable, thus transforming the outcome to crime per capita rate. The following section examines four models to explore the relationship between geographic units created from drinking establishment buffers and crime. The first two models examine the relationship between drinking buffer zones and property crimes while controlling for the social context of geographic areas. Model one provides the results using geographic units created from the union method, while model two presents the findings based on the update creation method. This is followed by models examining the link between drinking establishment buffer zones and violent crime rates within the geographic units emerging from the union and update methods. All results are net of other variables within the models. The following section subdivides the results based on offense types.

6.2.1 Negative Binomial Results for Models 1 and 2: Property Offenses Per Capita

Results concerning property offenses per capita are provided in Table 8. The following interpretations are adjusted by holding all other variables constant within the model and is limited to variables that were significant at a level of 0.05 or less. Across both the union and update models, being part of a drinking establishment buffer zone was positively associated with property crime rates (IRR: 3.75; 4.08 respectively). More specifically, being part of a buffer zone was associated with a property crime rate that was about 3.75 times greater than that found within areas outside of a drinking establishment buffer zone for geographic units created using the union method. For geographic units created using the update method, being part of a drinking establishment buffer zone was associated with a property crime rate about 4 times greater than areas found outside of a drinking establishment buffer zone. Thus, when crime was measured as property offenses per capita, the association between being part of a drinking establishment and crime occurred even after controlling for various social and structural factors of the surrounding area (i.e., research question 2). Furthermore, this association was present within both the union and update units (research question 3).

Table 8: Models Analyzing Property Offenses per Capita

	Union Method (Model 1)			Update Method (Model 2)		
	B	(SE.)	IRR	β	(SE.)	IRR
Buffer Zone Area	1.322***	(0.142)	3.753	1.406***	(0.252)	4.080
Economic Disadvantage Index	0.121	(0.086)	1.129	0.003	(0.073)	1.003
Percent White	0.004	(0.003)	1.004	-0.003	(0.002)	0.997
Percent Renter	-0.002	(0.004)	0.998	0.010*	(0.004)	1.010
Percent Moved	0.006	(0.007)	1.006	-0.004	(0.006)	0.996
Percent Male 15-24	-0.020	(0.011)	0.980	-0.009	(0.010)	0.991
Drug Incidents	0.008	(0.005)	1.008	0.001	(0.002)	1.001
Local Guardian Index	-0.094*	(0.041)	0.910	-0.157***	(0.035)	0.854
Crime Generator Index	0.163***	(0.040)	1.177	0.097**	(0.032)	1.102
Area	-0.006	(0.047)	0.994	0.097	(0.051)	1.102
Spatial Weight	0.054*	(0.024)	1.056	0.045**	(0.013)	1.046

Note: β= coefficient; SE= Robust Standard Error; IRR= incidence rate ratio
*p≤.05. **p ≤.01. ***p≤.001

In addition to the positive association between buffer zone status and property crime rates, the presence of other crime generators was also positively associated with higher property crime rates across the geographic units. For instance, an increase of one facility within the crime generator index is associated an increase of 18% (IRR=1.18) and 10% (IRR=1.10) in the property crime rate for geographic units created through the union and update methods respectively. On the other hand, the presence of facilities considered to be local guardians was negatively associated with property crime rates for both models. More specifically, an increase of one facility within the local guardianship index was associated a decrease of about 9% (IRR=0.91) and 15% (IRR=0.85) in the property crime rate for geographic units created through the union and update methods respectively. The spatial weight was also significant across both models suggesting that higher property crime rates in neighboring areas

positively impact the property crimes rates in a focal area (IRR= 1.06 and 1.05 for the union and update models respectively).

Overall, the two models generally converged in terms of which factors were significantly associated with property rates per capita. However, there was one variable that was significantly associated with the property rate per capita in only one model. More specifically, for the update model, a one percentage increase in the percentage of households occupied by renters was associated with an increase (1%; IRR=1.01) for property crime rates per capita in an area. Thus, with this exception, the update and union models produced consistent results on most factors that were significant. To reiterate, being part of a drinking establishment buffer zone, having higher numbers of crime generator facilities in an area, and being surrounded by areas with more property crimes were all associated with higher property crime rates per capita while having more facilities that were considered to be local guardians in an area had a diminishing influence on property crime rates per capita.

6.2.2 Negative Binomial Results for Models 3 and 4: Violent Offenses Per Capita

Results concerning violent crime rates per capita are provided in Table 9. The following interpretations are adjusted by holding all other variables constant within the model. Across both the union and update models, being part of a drinking establishment buffer zone was positively associated with violent crime rates (union IRR: 2.99; update IRR:2.76). More specifically, being part of a drinking establishment

buffer zone was associated with a violent crime rate per capita that was approximately 3 times higher than rates in areas outside the buffer zone regardless of how the geographic units were created. Thus, when crime was measured as violent offenses per capita, the association between being part of a drinking establishment and crime remained net of relevant controls (research question 2) for both the union and update units (research question 3).

Table 9: Models Analyzing Violent Offenses per Capita

	Union Method (Model 3)			Update Method (Model 4)		
	β	(SE)	IRR	β	(SE)	IRR
Buffer Zone Area	1.094***	(0.139)	2.987	1.014***	(0.207)	2.757
Economic Disadvantage Index	0.263***	(0.074)	1.300	0.258***	(0.071)	1.294
Percent White	-0.008**	(0.003)	0.992	-0.008**	(0.003)	0.992
Percent Renter	-0.002	(0.003)	0.998	0.009*	(0.003)	1.009
Percent Moved	-0.002	(0.007)	0.998	-0.010	(0.007)	0.990
Percent Male 15-24	-0.007	(0.012)	0.993	0.003	(0.011)	1.003
Drug Incidents	0.012*	(0.006)	1.012	0.004	(0.002)	1.004
Local Guardian Index	-0.008	(0.063)	0.992	-0.092*	(0.046)	0.912
Crime Generator Index	0.078*	(0.032)	1.082	0.045	(0.029)	1.046
Area	-0.116**	(0.042)	0.891	0.005	(0.043)	1.005
Spatial Weight	0.053*	(0.023)	1.054	0.063***	(0.016)	1.065

Note: β= coefficient; SE= Robust Standard Error; IRR= incidence rate ratio
*p≤.05. **p ≤.01. ***p≤.001

In addition to the positive association between buffer zone status and violent crime rates per capita, a one unit increase on the economic disadvantage index was associated with about a 30% greater violent crime rate for both geographic units created using the union method (IRR=1.30) and the update method (IRR=1.29) while a one unit increase in the percentage of the population that was white was associated with about a 1% decrease in the violent crime rate across these models (IRR=0.99).

Across both models, the spatial weight was positively associated with violent crime rates suggesting that geographic units are positively influenced by the crime rates of other areas within close proximity (union IRR=1.05; update IRR=1.07).

While there was some convergence between models examining violent crimes per capita, there were several notable differences. More specifically, five variables were significant in only one model type. Three variables were significant only in the union model. The number of drug offenses within an area was positively and significantly related to violent crime per capita (IRR=1.01) while the unit area was negatively associated with violent crime rates (IRR=0.89). Moreover, for every additional facility in the crime generator index, there was an 8% increase in the violent crime rate per capita in the union model (IRR=1.08). Variables significant only to the update model included the percentage of households with renters which was associated with, on average, a one percentage increase in the households occupied by renters associated with a one percentage increase in the violent crime rate per capita (IRR=1.01). Conversely, a one facility increase in the local guardianship index was associated with about a nine-percentage decrease in the violent crime rate per capita within the update model.

To reiterate, several variables were consistent predictors across both models. Being part of a drinking establishment buffer zone, higher scores on the economic disadvantage index and having more violent crime counts in surrounding areas were all associated with higher violent crime rates per capita. Meanwhile, areas with higher percentage of the population who was white had lower violent rates per capita across

models. Despite these similarities, there were notable differences with five variables significant in only one model. For the union models only, higher counts of drug incidents and more crime generator facilities were significantly associated with violent crime per capita, while area was negatively associated. For the update models only, the percentage of the households occupied by renters was positively associated with violent incidents per capita while more local guardian facilities in an area were negatively associated with violent incidents per capita. In summary, there was considerably more variation between significant predictors across models when exploring the update and union models for violent crime per capita relative to the models examining property crime per capita.

6.3 Negative Binomial Results: Area as Exposure Variable

While the above results focused on per capita rates, it is important to explore whether the operationalization of the dependent variable may be impacting the relationships uncovered. As such models were conducted using area as the exposure variable, which transforms the outcome into crime per square kilometer. All results are net of other variables within the models. Once again, the following section subdivides the results based on offense types. Only results significant at the 0.05 level or lower are discussed.

6.3.1 Negative Binomial Results for Models 5 and 6: Property Offenses per Area

Table 10 provides the results for both the union and update geographic units concerning property offenses per square kilometer. The following interpretations are adjusted by holding all other variables constant within the model. Overall, models exploring property offenses per square kilometers converged on which variables were significant and the direction of impact. For both the union and update models, being part of a drinking establishment buffer zone was positively associated with property incident rates per square kilometer (IRR:1.80; 1.97). More specifically, being part of a drinking establishment buffer zone was associated with a property crime rate per square kilometer that was nearly twice as high as areas falling outside of buffer zones. Thus, concerning research questions two and three, these results provided evidence that the positive association with buffer zone status occurred across both unit types when controlling for relevant social and structural factors when examining property offenses per square kilometer.

Table 10: Models Analyzing Property Offenses per Square Kilometer

	Union Method (Model 5)			Update Method (Model 6)		
	β	(SE)	IRR	β	(SE)	IRR
Buffer Zone Area	0.586***	(0.119)	1.796	0.678***	(0.204)	1.970
Economic Disadvantage Index	0.040	(0.066)	1.041	-0.027	(0.071)	0.974
Percent White	-0.006*	(0.002)	0.994	-0.011***	(0.002)	0.989
Percent Renter	0.008**	(0.003)	1.008	0.013***	(0.003)	1.013
Percent Moved	0.001	(0.005)	1.001	-0.001	(0.007)	0.999
Percent Male 15-24	0.006	(0.009)	1.006	0.011	(0.011)	1.011
Drug Incidents	0.007	(0.004)	1.007	0.003	(0.002)	1.003
Local Guardian Index	-0.093**	(0.034)	0.911	-0.083**	(0.030)	0.921
Crime Generator Index	0.111***	(0.030)	1.118	0.089**	(0.028)	1.093
Tot Population	-0.00***	(0.000)	1.000	-0.000**	(0.000)	1.000
Spatial Weight	0.122***	(0.017)	1.130	0.071***	(0.012)	1.073

Note: β= coefficient; SE= Robust Standard Error; IRR= incidence rate ratio
*p≤.05. **p ≤.01. ***p≤.001

In addition, for every one percentage increase in the population that identified as white, there was a one percent decrease in the rate of property incident per square kilometer (IRR for both models= 0.99). The local guardianship index was also negatively associated with the rate of property incidents per square kilometer with a one facility increase in this index linked to an 8% and 9% decrease in the property incident rate per square kilometer in the update and union models respectively. Meanwhile, the percentage of the households with renters (union IRR=1.01; update IRR=1.01), the crime generator index (union IRR=1.12; update IRR= 1.09) and the spatial weight for property crime (union IRR=1.13; update IRR= 1.07) were all positively associated with the property crime rate per square kilometer. Thus, for both models, a one percentage increase in households occupied by renters was associated with a one percent increase in the rate of property offenses per square kilometer. A

one facility increase in the crime generator index was associated with a 9% and 12% increase in property offenses per square kilometer in the update and union models respectively. Finally, increases in property crime in surrounding areas were associated with higher property crime per square kilometer in a focal unit. While the total population was also significant in both models, the effect was negligent as the incident rate ratio was equal to one. Importantly, there were no divergences concerning the significance of variables across the union and update models for the rate of property incidents per square kilometer. To reiterate, in both models, buffer zone status, the percentage of households occupied by renters, the number of crime generators in an area, and the amount of property offenses in neighboring geographic units were all positively associated with crime. Meanwhile, the percentage of the population who were white and the number of local guardian facilities in an area negatively impacted property offenses per capita.

6.3.2 Negative Binomial Results for Models 7 and 8: Violent Offenses per Area

The final set of models explore the impact of buffer zone status and other predictor variables on violent crime incident rates per square kilometer. All interpretations are adjusted for other variables within the model. This section begins with variable convergence and concludes with a short discussion of the two variables that were significant to one model only. Table 11 provides the results for both the union and update geographic units concerning violent offenses per square kilometer.

Table 11: Models Analyzing Violent Offenses per Square Kilometer

	Union Method (Model 7)			Update Method (Model 8)		
	β	(SE)	IRR	β	(SE)	IRR
Buffer Zone Area	0.565***	(0.133)	1.759	0.617***	(0.158)	1.853
Economic Disadvantage Index	0.127	(0.068)	1.136	0.185*	(0.082)	1.203
Percent White	-0.015***	(0.002)	0.985	-0.013***	(0.003)	0.987
Percent Renter	0.012***	(0.003)	1.012	0.018***	(0.004)	1.018
Percent Moved	-0.014*	(0.006)	0.986	-0.019*	(0.008)	0.981
Percent Male 15-24	0.025**	(0.008)	1.026	0.027*	(0.011)	1.027
Drug Incidents	0.010*	(0.005)	1.010	0.006	(0.003)	1.007
Local Guardian Index	-0.079*	(0.038)	0.924	-0.072*	(0.036)	0.930
Crime Generator Index	0.039	(0.022)	1.040	0.025	(0.023)	1.025
Total Population	-0.000***	(0.000)	1.000	-0.000*	(0.000)	1.000
Spatial Weight	0.176***	(0.020)	1.192	0.115***	(0.016)	1.122

Note: β= coefficient; SE= Robust Standard Error; IRR= incidence rate ratio
*p<.05. **p <.01. ***p<.001

Overall, there was a considerable amount of convergence between the union and update models examining violent incident rates per square kilometer. Concerning the primary variable of interest, being part of a drinking establishment buffer zone was associated with a violent crime rate per square kilometer that was nearly twice as high as areas falling outside of buffer zones (union IRR=1.76; update IRR=1.85). In addition, the percentage of households with renters, the percentage of the population who are males between the ages of 15 and 24, and the spatially lagged violent crime variable had a positive association with violent crime per square km. More specifically, for every one percentage increase in the percent of households with renters, there was a 1% and 2% increase in the violent incident rate per square km in the union and update units respectively (union IRR=1.01; update IRR=1.02). For

every one percent increase in the percent of the population who were males between the ages of 15 and 24, there was a 3% increase in the violent incident rate per square kilometer for both the union and update geographic units (union IRR=1.03; update IRR=1.03). Finally, for every one crime increase in the weighted average of violent offenses in surrounding geographic units, there was a corresponding increase in violent incident rates per sq km of 19% in the union geographic units (IRR=1.19) and 12% increase in the update geographic units (IRR=1.12%).

Several variables were also associated with a diminished effect on crime across both geographic units. The percent of the population who moved in the past calendar year, the number of local guardianship facilities in an area, and the percentage of the population who were white were all associated with lower violent crime incident rates per square kilometer across both geographic units. For instance, a one percentage increase in the population who were white as associated with about a 1% decrease in the violent crime incident rate per square kilometer (union IRR=0.99; update IRR=0.99).Interestingly, a one percentage increase in the percentage of the population who moved in the past calendar year was associated with a 1% decrease in the union geographic units and 2% decrease in the update units for violent crime incidents per square kilometer (union IRR=0.99; update IRR=0.98). This finding, which will be discussed in more detail in the following chapter, goes against the expected direction based on social disorganization studies which would suggest that measures of residential instability increase crime rates. In addition, a one facility increase in the number of local guardianship facilities in an area was associated with a decrease in the

violent incident rate per square km of about 8% (IRR=0.92) in the union geographic units and 7% in the update geographic units (IRR=0.93). Finally, although the total population was negatively associated with the violent crime rates per sq km in both units, this finding appears to be negligible as the incident rate ratio is 1.00.

While there was general convergence between the union and update models concerning which variables were significantly associated with the violent incident rate per square kilometer, there were two variables that were significant to only one model. A one unit increase on the economic disadvantage index was associated with a 20% increase in the violent crime incident rate per square kilometer for units created using the update method (IRR=1.20). Meanwhile, for every one incident increase in the number of drug offenses in an area, there was a 1% increase in the violent crime incident rate per square kilometer when examining the model using union geographic units (IRR=1.01).

6.4 Summary

The current chapter presented results from eight models exploring the impact of being part of a drinking establishment buffer zone on property and violent incident rates. In all models, regardless of the geographic unit or the operationalization of the dependent variable, crime rates were significantly higher in areas that were part of a drinking establishment buffer zone relative to areas that were not part of a zone (research questions 2 and 3). In addition, this chapter briefly touched upon differences between the union and update models. For instance, results demonstrated the union

and update models exploring property crime rates per square kilometer converged completely on which factors were significant, with seven variables consistently associated with the crime rate. On the other hand, the union and update models exploring property crime per capita had four consistent associations and one variable that was significant to only the update model. For the models exploring violent crime per square kilometer, there were eight consistent associations between the models and two divergences between union and update models. Finally, models exploring the violent crime rate per capita demonstrated the most variation between union and update models. More specifically, only four variables were consistently significant in both models while five variables were significant to one model only. Taken together, these findings provide some evidence of the role the operationalization of the dependent variable can have on shaping results (i.e., research question four).

While the current chapter presented the results from the various negative binomial models, these findings need to be situated in terms of the primary research questions in this study. As such, the following chapter has three main objectives. First, the discussion aims to reflect upon the potential for expanding research using census enhanced geographies to capture a more nuanced understanding of the impact of certain facilities on crime. The fact that being part of a drinking establishment buffer zone was consistently linked to higher crime rates across all models is an important finding. Next, the discussion shifts to exploring the potential impact (or lack thereof) concerning the modifiable areal unit problem (MAUP) when examining differences between union versus update models. In other words, while it is clear that MAUP

matters, it could be that it has a particularly important influence on capturing specific processes. Finally, comparisons between models with different operationalizations of the dependent variable as per capita rates versus per square kilometer are investigated. The operationalization of the dependent variable needs to be carefully considered when exploring crime in geographical analyses. As will be discussed in more detail, the choice in operationalization can lead to varied conclusions on which factors are important in linking crime and place. As such, the next chapter provides a more thorough discussion of the similarities and differences between models in terms of magnitude, significance, and direction of coefficients.

Chapter 7

EXPLORING MODEL COMPARISONS

The present study went beyond the use of pre-defined census boundaries to examine how census enhanced GIS spatial units can help sharpen our understanding of the relationships between potentially criminogenic facilities and crime patterns. The previous chapter outlined the results from eight negative binomial models that varied in terms of methods of geographic unit creation, operationalizations of the dependent crime variables, and offense type examined. The current chapter provides a critical assessment of these results and explores similarities and differences among these models. The discussion is limited to variables that were significant in at least one model, investigating differences between models in terms of significance, direction, and magnitude of the coefficients.

Before diving into model comparisons, a few comments on the comparison process are necessary. While p-values are relied on to compare significance across models, scholars warn against placing too much emphasis on these values because the threshold of $p \leq 0.05$ is not necessarily strong or definitive proof against the lack of an effect (i.e., the null hypothesis) (Wasserstein & Lazar, 2016). However, because the models produced in this study are exploratory in nature and the sample size across models is relatively large, the p-value significance levels are used to draw attention to differences between relevant indicators. In addition, to compare coefficients in terms

of equality of effect or magnitude, the formula provided by Paternoster, Brame, Mozerolle, and Piquero (1998) is used[8]:

$$Z = \frac{b_1 - b_2}{\sqrt{(SEb_1^2 + SEb_2^2}}$$

Where b_1 and b_2 are the unstandardized coefficients and SEb_1^2 and SEb_2^2 represent the respective standard errors for the coefficients. Because the difference between nonsignificant and significant results will be higher in magnitude, the discussion of magnitude comparisons is limited to instances in which both variables are significant indicators. Finally, significant results are discussed in reference to theoretical expectations of the direction of impact (i.e., negative, or positive).

7.1 Model Comparisons: Union versus Update Units with Population as Exposure

Table 12 compares models for the union and update units concerning property crime per capita. There was general consistency between the models concerning significant coefficients. More specifically, the opportunity variables of being part of a drinking establishment buffer zone, the number of local guardian facilities and the number of crime generator facilities in an area were all significant for both unit types. Moreover, these variables were all in the expected theoretical direction with the

[8] While this formula was originally used for linear regression models to determine if the influence of significant variables is consistent across groups/models, recent research has relied on this formula for negative binomial model comparisons (e.g., Donnelly, Wagner, Anderson & O'Connell, 2022).

property crimes per capita having a positive association with the buffer zone status and crime generators and a negative association with the local guardian facilities. In addition, both the union and update units had a positive relationship with property crime in neighboring units. Nonetheless, the percentage of the households occupied by renters, which can be seen as a potential indicator of residential stability, was positively associated with property crime per capita in the update units only. Thus, overall, there appeared to be more support for opportunity variables across both geographic units when looking at property crime per capita and limited support for social disorganization indicators. In addition, when looking at variables that were significant across both models, there did not appear to be a statistically significant difference in the magnitude of the coefficients.

Table 12: Property Crime per Capita: Union versus Update

	Z - score	Significance Union	Significance Update	Direction Union	Direction Update
Buffer Zone Area	-0.29	***	***	+	+
Percent Renter	-1.97	NS	*	-	+
Local Guardian Index	1.17	*	***	-	-
Crime Generator Index	1.29	***	**	+	+
Spatial Weight	0.33	*	**	+	+

Note: NS= not significant; *p≤.05. **p ≤.01. ***p≤.001

Table 13 compares models for the union and update units concerning violent crime per capita. Relative to the property crime per capita models, there was considerably more variation in significant predictors between the union and update geographic units. While four variables were significant across both units, five variables were significant to one model only. All significant indicators were in the expected theoretical direction. Concerning opportunity related variables, the only

consistent predictor was the positive relationship involved with being part of a drinking establishment buffer zone. Various other opportunity variables were significant to one model only. Within the union geographic units, the number of drug incidents and crime generators in an area were positively associated with violent crime per capita. These relationships were not present for the update units. On the other hand, the number of local guardian facilities was negatively associated with violent crime per capita in the update geographic units only.

Table 13: Violent Crime per Capita: Union versus Update

	Z-score	Significance Union	Significance Update	Direction Union	Direction Update
Buffer Zone Area	0.32	***	***	+	+
Economic Disadvantage Index	0.05	***	***	+	+
Percent White	-0.08	**	**	-	-
Percent Renter	-2.17	NS	*	-	+
Drug Incidents	1.33	*	NS	+	+
Local Guardian Index	1.08	NS	*	-	-
Crime Generator Index	0.79	*	NS	+	+
Area	-2.02	**	NS	-	+
Spatial Weight	-0.37	*	***	+	+

Note: NS= not significant; *p≤.05. **p ≤.01. ***p≤.001

Concerning variables potentially linked to structure, two variables were consistent indicators across both the union and update units. The percentage of the population that was white was negatively associated with violent crime per capita while the economic disadvantage in a region was positively associated with violent crime per capita. Nonetheless, one additional indicator of social disorganization was positively associated with violent crime per capita in one model containing update units: the percentage of households occupied by renters. Recall that this was also true

when predicting property crimes. Finally, the spatial weight was significant in models for both the update and union geographic units, with violent crime in neighboring regions positively associated with the violent crime rate in a focal area regardless of the geographic unit type. Notably, concerning variables that were significant indicators across models, there did not appear to be a substantial difference in the magnitude of coefficients.

7.2 Model Comparisons: Union versus Update Units with Area as Exposure

Table 14 compares models for the union and update units concerning property offenses per square kilometer. Within the property offenses per square kilometer models, there was complete convergence between the union and update models. There were seven significant indicators for both types of geographic units. Moreover, several indicators linked to opportunity theories and social disorganization were significant and in the expected theoretical direction. For the proxy measures potentially linked to social disorganization, the percentage of the population who was white had a diminishing impact on property crime per square kilometer while the percentage of households with renters was positively associated with property crime per square kilometer. Concerning indicators of opportunity, being part of a drinking establishment buffer zone and the number of crime generators in an area had a positive association while the number of local guardianship facilities had a negative association. Also of note, the spatial weight was significant in both models but had a

greater impact on the union units. In other words, while the property offenses in surrounding areas had a positive association in both models, this impact was greater within the smaller geographic union units.

Table 14: Property Offense/Sq. Km.: Union versus Update

	Z-score	Significance Union	Significance Update	Direction Union	Direction Update
Buffer Zone Area	-0.39	***	***	+	+
Percent White	1.48	*	***	-	-
Percent Renter	-1.07	**	***	+	+
Local Guardian Index	-0.22	**	**	-	-
Crime Generator Index	0.54	***	**	+	+
Total Population	-0.98	***	**	-	-
Spatial Weight	**2.51**	***	***	+	+

Note: NS= not significant; *p≤.05. **p ≤.01. ***p≤.001

Table 15 compares models for the union and update units concerning violent offenses per square kilometer. Overall, there was considerable consistency between the union and update units concerning the violent crimes per square kilometer, with eight indicators significant in both models. Concerning opportunity indicators, being part of a drinking establishment buffer zone and the percent of the population who were males between the ages of 15 and 24 had a positive association while the number of local guardian facilities was negatively associated with the violent crime per square kilometer within both geographic units. Concerning variables potentially linked to social disorganization, the percentage of the population who was white and the percentage of households occupied by renters were significant in the expected theoretical directions within both geographic units. However, the percentage of the population who moved within the past year was negatively associated with the violent crime rates per square kilometer. This finding is inconsistent with the expectation of

social disorganization theory. As an indicator of residential instability, it would be predicted that the higher the percentage of the population who moved, the greater the crime rate.

Nonetheless, this theoretically inconsistent finding calls attention to measurement issues alluded to in previous chapters. First, as proxy measures these variables may not adequately capture the underlying processes shaping crime patterns. More specifically, this measure is a static indicator that does not capture change over time. Other scholars have pointed to the need to capture the dynamic nature of these variables as social disorganization theory is predicated on how changing structural conditions influence crime (Bursick, 1988; Kubrin & Weitzer, 2003; Martinez, Stowell, & Lee, 2010; Wenger, 2021a). Moreover, models focused on static rather than dynamic factors do not control for aspects such as gentrification and (re)investment, which could complicate the relationship between these indicators and crime.

Table 15: Violent Crime/Sq. Km.: Union versus Update

	Z-score	Significance Union	Significance Update	Direction Union	Direction Update
Buffer Zone Area	-0.25	***	***	+	+
Economic Disadvantage Index	-0.54	NS	*	+	+
Percent White	-0.41	***	***	-	-
Percent Renter	-1.15	***	***	+	+
Percent Moved	0.51	*	*	-	-
Percent Male 15-24	-0.12	**	*	+	+
Drug Incidents	0.65	*	NS	+	+
Local Guardian Index	-0.12	*	*	-	-
Total Population	-1.53	***	*	-	-
Spatial Weight	**2.40**	***	***	+	+

Note: NS= not significant; *p≤.05. **p ≤.01. ***p≤.001

The divergent indicators between these models are also of note. For instance, while the union geographic units had an additional opportunity variable that was significant, the update geographic units had an additional indicator of social disorganization that was significant. More specifically, for the union geographic units, drug incidents within an area were positively associated with violent crime per square kilometer. This finding would suggest that areas with higher illegal drug markets or activity have a greater amount of crime. For the update geographic units only, the economic disadvantage in a region was positively associated with violent crime per square kilometer.

Before concluding this section, it is important to note that the magnitude of the coefficients did not significantly differ between the geographic units for either of the models concerning crime per square kilometer except for one indicator: the spatial weight (Z-score≥1.96). For both property and violent offenses per square kilometer, the respective crime in neighboring units had a greater impact in the union geographic units relative to the update units. In other words, these smaller geographic entities were influenced by crime in surrounding areas to a greater extent than the larger, update units.

7.3 Comparison of Property Crime Models: Population versus Area as Exposure

Tables 16 and 17 focus on comparisons for models with property offenses using population and area as the exposure variables. Several noteworthy findings

emerge across the models. First, for both the union and update units, being part of a drinking establishment buffer zone had a greater impact for models using population as the exposure variable compared to models using area. The difference in magnitude is apparent from the z-score comparisons (union Z-score=3.98; update Z-score= 2.24). The magnitude of the spatial weight was also greater in the property crime per square kilometer model for the union units (Z=2.31). This difference in magnitude was not apparent for the update units. In addition, several variables were significant in the models with area as an exposure that were not significant in models with population as the exposure. For both the union and update units, the percentage of population who was white was associated with a reduction in the property crime rate per square kilometer but not the property rate per capita. In addition, the percent of households with renters was positively correlated with property crime rates per square kilometer for both the union and update models but was only positively associated with property crime per capita within the update model.

Table 16: Union Method-Property Offenses: Crime per Capita Vs. Crime/ Sq. Km.

	Z-score	Significance (capita)	Significance (sq. km.)	Direction (capita)	Direction (sq. km.)
Buffer Zone Area	**3.98**	***	***	+	+
Percent White	2.63	NS	*	+	-
Percent Renter	-2.01	NS	**	-	+
Local Guardian Index	-0.03	*	**	-	-
Crime Generator Index	1.05	***	***	+	+
Spatial Weight	**-2.31**	*	***	+	+

Note: NS= not significant; *p≤.05. **p ≤.01. ***p≤.001

Table 17: Update Method-Property Offenses: Crime per Capita Vs. Crime/ Sq. Km.

	Z-score	Significance (capita)	Significance (sq. km.)	Direction (capita)	Direction (sq. km.)
Buffer Zone Area	**2.24**	***	***	+	+
Percent White	2.12	NS	***	-	-
Percent Renter	-0.64	*	***	+	+
Local Guardian Index	-1.61	***	**	-	-
Crime Generator Index	0.20	**	**	+	+
Spatial Weight	-1.49	**	***	+	+

Note: NS= not significant; *p≤.05. **p ≤.01. ***p≤.001

Concerning variables linked to the two theoretical traditions used within these models, the support for indicators pertaining to opportunity seemed to be consistent across the models looking at property crime per capita and property crime per kilometer for both the union and update geographic units. More specifically, the buffer zone status, presence of facilities that were local guardians and presence of other crime generators were all significant and in the expected theoretical direction. Compared to property crime per capita models, there was slightly more support for indicators of social disorganization in the property offenses per square kilometer models. More specifically, the only social disorganization variable that was significant in the property crime per capita models occurred within the update geographic units, with the percentage of households occupied by renters being significant and positively associated with property offenses per capita. No social disorganization variables were significant within the union model predicting property crime per capita. Meanwhile, for both the union and update geographic units, two social disorganization indicators were significant and in the expected theoretical direction when looking at property

crime per square kilometer. The percentage of the population that was white was negatively associated while the percentage of households occupied by renters was positively associated with property crimes per square kilometer in both geographic unit types.

7.4 Comparison of Violent Crime Models: Population versus Area as Exposure

Tables 18 and 19 demonstrate the similarities and differences within the union and update units when comparing violent crime per capita with violent crime per square kilometer. There was considerably more variation within the union method across these model types with four variables serving as significant predictors consistent in both models and six variables showing significance in one model only. Of the diverging variables within the union units, four variables were significant specifically to the model with area as exposure: the percentage of households with renters, the percentage of the population who moved in the last calendar year; percentage of the population who were males between the ages of 15 and 24 and the number of local guardian facilities. Comparatively, two variables within the union units were specific to the population exposure models only: the economic disadvantage index and the crime generator index.

Two important differences in terms of equality of coefficients emerged for union units between models of violent crime per capita compared to violent crime per square kilometer. More specifically, the impact of being part of a buffer zone was greater in the model with population as the exposure variable compared to the model

with area as the exposure (Z=2.75). In addition, the impact of crime in surrounding areas was greater for the model examining violent crime per square kilometer compared to the model investigating violent crime per capita (Z=4.05).

Table 18: Union Method- Violent Offenses: Crime per Capita Versus Crime per Sq. Km

	Z-score	Significance (capita)	Significance (sq. km.)	Direction (capita)	Direction (sq. km.)
Buffer Zone Area	**2.75**	***	***	+	+
Economic Disadvantage Index	1.34	***	NS	+	+
Percent White	1.66	**	***	-	-
Percent Renter	-3.25	NS	***	-	+
Percent Moved	1.22	NS	*	-	-
Percent Male 15-24	-2.26	NS	**	-	+
Drug Incidents	0.26	*	*	+	+
Local Guardian Index	0.96	NS	*	-	-
Crime Generator Index	1.01	*	NS	+	+
Spatial Weight	**-4.05**	*	***	+	+

Note: NS= not significant; *p≤.05. **p ≤.01. ***p≤.001

The update model appears to provide more consistency when exploring crimes per capita compared to crimes per square kilometer as six variables were significant predictors across models. In contrast, two variables were significant to the model with area as exposure only. More specifically, the opportunity variables of buffer zone status and the number of local guardian facilities in an area were associated with violent crime rates per capita and per square kilometer for update units. In addition, several variables that are potential indicators of social disorganization were also significant across both models including the level of economic disadvantage (+), percentage of the population who was white (-), and the percentage of households occupied by renters (+). The impact of these variables was in the expected theoretical

direction. Finally, the spatial weight was significant for both violent crime per capita and violent crime per kilometer for the update units, but the coefficients were not equal. More specifically, a z-score comparison revealed that the impact of violent crime in the surrounding areas had a greater effect in the model with area as the exposure variable (z=2.29).

Concerning the two variables that were significant in the area as exposure model only, one factor was linked to opportunity while the other indicator was associated with social disorganization. More specifically, the percentage of the population that was male between the ages of 15-24, which served as an indicator of the potential offender population, was positively associated with violent crime per square kilometer. Results concerning the percentage of the population who moved in the past year went in the opposite direction of theoretical expectations with an increase in the percentage of the population who moved linked to a decrease in violent crime per square kilometer. As discussed in the previous section, this contradictory finding may demonstrate the weakness is using static variables to capture dynamic processes.

Table 19: Update Method- Violent Offenses: Crime per Capita Versus Crime per Sq. Km

	Z-score	Significance (capita)	Significance (sq. km.)	Direction (capita)	Direction (sq. km.)
Buffer Zone Area	1.53	***	***	+	+
Economic Disadvantage Index	0.67	***	*	+	+
Percent White	1.37	**	***	-	-
Percent Renter	-1.77	*	***	+	+
Percent Moved	0.89	NS	*	-	-
Percent Male 15-24	-1.58	NS	*	+	+
Local Guardian Index	-0.34	*	*	-	-
Spatial Weight	**-2.29**	***	***	+	+

Note: NS= not significant; *p≤.05. **p ≤.01. ***p≤.001

7.5 Key Takeaways

This chapter examined differences across models in terms of relevant factors by looking at the magnitude, significance, and direction of coefficients. This study demonstrates how different methodological choices in terms of units of analysis, operationalization of the dependent variable, and crime type can impact results and subsequent conclusions. For instance, models varied in terms of consistency and divergence concerning significant predictors. When comparing models based on the union and update geographic units, the property per square kilometer models converged completely while the violent crime per capita models contained the most variation (see Table 20). In addition, the models exploring the violent offenses per square kilometer had the largest number of significant indicators, with both models for the update and union geographic units containing nine significant variables. On the other hand, the models analyzing property offenses per capita had the least amount of significant variables, with four and five significant predictors for the union and update geographic units respectively.

Table 20: Model Comparisons for Union and Update Units

Offense Type	Exposure	Consistent Predictors	Divergent Predictors
Property	Population	4	1
Violent	Population	4	5
Property	Area	7	0
Violent	Area	8	2

With one exception, significant predictors across models had an impact that was in the expected theoretical direction. The only variable that did not match the theoretical expectation occurred within the models analyzing violent crime per square

kilometer. While structural theories such as social disorganization would suggest that an increase in the percent of the population who moved in the past year would be linked to an increase in crime rates, the opposite occurred. For both the union and update units, higher percentage of the population who moved was associated with lower violent crime per square kilometer. As discussed above, this finding may be linked to the limitations of proxy measures. It is also important to note that this variable was not significant when the operationalization of the dependent variable was violent crime per capita.

Another important consideration concerns the roles of opportunity theories and social disorganization variables as significant predictors in these models. Overall, the opportunity-based variables seemed to gain general support across these models. In contrast, structural variables gained more support in the models concerning violent crime. In fact, the model with the greatest support for the impact of structural factors on crime was the model analyzing violent offenses per square kilometer in the update units. Meanwhile, the social disorganization variables received the least support in the model analyzing property offenses per capita within the union units.

Finally, and most central to the main purpose of this dissertation, across all models, regardless of the unit of analysis, operationalization of the dependent variable, or the crime type being investigated, being part of a drinking establishment buffer zone was associated with increased crime in the area compared to geographic areas that were not part of a buffer zone. This finding is discussed in more detail in the next chapter. Notably, there was a difference in magnitude when comparing the impact of

buffer zone status on property crime per capita compared to property crime per square kilometer for both the union and update units of analysis. There was also a significant difference in magnitude for being part of a drinking establishment buffer zone for the models with violent crime per capita compared to violent crime per square kilometer when union units were examined. More specifically, it appears the impact was greater for the population-based measures compared to the area-based measures. Notably, the spatially lagged crime variables were also consistent predictors in all models, demonstrating the importance of controlling for spatial autocorrelation. Moreover, the magnitude of the spatial weight was greater for violent crime per square kilometer than violent crime per capita in both the union and update units. In addition, the magnitude was greater for property crime per square kilometer compared to property crime per capita within the union units.

The final chapter of this dissertation discusses the implications of these findings for future research. While this study provides further support for the potential utility of using census enhanced GIS units in analyzing the crime-facility nexus, the importance of various methodological steps along the way should not be underestimated. The final chapter fully situations these findings in terms of the original research questions. The conversation also reflects on limitations and areas for improvements.

Chapter 8

DISCUSSION

The present study explored the spatial distribution of crime around drinking establishments and investigated whether the relationship between these facilities and crime held after controlling for socially relevant factors and other elements of the built environment. Although the relationship between alcohol outlets and crime has been studied extensively using pre-established boundaries such as census blocks (Bernasco & Block, 2011), block groups (Pridemore & Grubesic, 2011), and tracts (Franklin et al. 2010), only a limited number of studies have moved beyond reliance on these traditional census boundaries (for exceptions, see McCord & Ratcliffe, 2007; Rengert, Ratcliffe & Chakravorty, 2005). Drinking establishments are often included in models as a summed index for independent or control variables in studies exploring the impact of these establishments on crime within official census geographies or street segments.

The current study contributed to existing scholarship by incorporating drinking establishments themselves as a central component of the units of analysis through the use of buffer zones and an areal weighted interpolation method. Eight negative binomial models were examined, varying in terms of units of analysis (union versus update geographic units), operationalization of the dependent variable (crimes per capita versus crimes per kilometer) and offense type (property versus violent). Overall, results from this dissertation align with past research demonstrating the need for

caution when choosing the appropriate unit of analysis for analyzing spatial crime outcomes (Ouimet, 2000; Gerell, 2017; Ramos et al., 2021). New geographic units were created within the Wilmington metropolitan area through merging buffer zones around drinking establishments with census block groups. Two approaches were compared. With the union approach, new geographic units were created out of areas in which the buffer zones and block groups intersected. Consequently, the original block groups were dissected into new units that were either part of a drinking establishment buffer zone or units that were not part of the buffer zone. Conversely, the update approach produced new geographies through the overlay of buffer zones onto block groups, leaving the drinking establishment buffer zone intact. To date, research has not compared outcomes between these two diverse methods of geographic unit creation. Therefore, the following sections demonstrate how findings from these analyses using these new geographies can inform future research exploring the relationship between facilities and crime.

8.1 The Impact of Being Part of a Drinking Establishment Buffer Zone

> ***Research Question***: Does the relationship between drinking establishments and crime remain after controlling for the larger social environment in which these facilities operate?

One of the major findings within this study is that the positive relationship between being part of a drinking establishment buffer zone and the crime rate in an area held across all models examined. In other words, regardless of geographic unit (update versus union), crime type (property versus violent), or operationalization of

the dependent variable (crime rate per capita versus crime rate per square kilometer), there was significantly more crime within buffer zone regions compared to areas that were not part of a buffer zone. Even after controlling for various social and economic characteristics of the newly created units, this association was significant. The empirical evidence supporting the connection between drinking establishments and crime rates aligns with support found within research relying on traditional boundaries (e.g., Bernasco & Block, 2011; Pridemore & Grubesic, 2011).

This finding demonstrates the potential power of census enhanced GIS spatial units in capturing the relationships between allegedly criminogenic facilities and crime. While the majority of previous studies have relied on boundaries defined for administrative purposes (e.g., block groups, tracts), the current study carved out new geographic units through the merger of census block groups and drinking establishment buffer zones. As such, the drinking establishment becomes a central component of place in the sense that it is embedded within the unit of analysis itself. Rather than looking at the number or density of these facilities and how they impact crime in a specific geographic unit, the establishment and the surrounding vicinity become the center point and are compared to areas falling outside the reach of this facility type. Thus, while previous studies have provided a plethora of information linking the impact of alcohol establishments on crime in areal units, this study demonstrates the relationship holds once the facility is central to the unit of analysis.

Importantly, the magnitude of this association differed depending on how the crime rate was operationalized. A larger impact was found in models using

population-based rates compared to area-based rates. This result reinforces the need for careful consideration of outcome measurements. Some scholars have critiqued the use of population for the denominator in crime rate investigations because this measure may fail to capture the number of potential targets at risk of victimization (Boivin, 2013; Zhang & Peterson, 2007; Zhang, Suresh, & Qiu, 2012). Density measures per area serve as an alternative estimation to uncover the intensity of crime within a region (Zhang, Suresh, & Qiu, 2012). While this dissertation does not provide a definitive answer concerning which type of measurement is better, the impact differences between these two operationalizations provide a need for caution and careful reflection when selecting dependent variables for investigation. Future studies should continue to explore differences between population and area-based measures when using census enhanced GIS units.

8.2 Examining the Impact of Geographic Creation Methods and Operationalization of Crime

Research Questions: Do the different methodological techniques used to create the new units of analysis affect the results and shape our interpretations of the impact of these facilities on crime? Does the operationalization of the dependent variable (i.e., looking at crime density in terms of population versus area) impact which variables are significant predictors of crime within these newly created geographic units?

At the center of this study is the modifiable areal unit problem (MAUP). MAUP is an issue with which all criminological research relying on geographic areal units must contend (Openshaw, 1984; *Gerell, 2017*). Essentially, changing the scale (size) and boundaries (shape/zone) of polygons can produce significantly different

spatial patterns that impact subsequent results (Fotheringham & Wong, 1991; Openshaw, 1984). While there is a general acknowledgment that aggregation bias is an important issue, there is some debate concerning just how important or serious of an issue MAUP really is with scholars drawing attention to the continued need for systematically examining MAUP in criminological research (Andresen & Malleson, 2013; Gerell, 2017). As such, the current research further contributed to the field of geographic criminology by exploring how different methods of geographic unit creation using drinking establishment buffer zones may impact substantive results.

While the results for variables such as buffer zone status and the level of crime counts in neighboring units appeared to be robust predictors across methods, there was considerable variability concerning other significant indicators across the models examined. For example, when comparing the union and update units, the percentage of households occupied by renters was only significant within the update units when considering property and violent crimes per capita. The conditionality of the finding reinforces that scale matters for capturing some processes. This aligns with a critical issue raised within the crime and place literature which acknowledges a potential risk that broader neighborhood effects may be obscured when relying on smaller units of analysis (Weisburd, Bruinsma, Bernasco, 2009; Tita & Radil, 2010). However, when looking at property and violent crimes per square kilometer, the percentage of households occupied by renters was significant for both the update and union units of analysis. Thus, these findings suggest that certain social and opportunity factors may

experience more vulnerability to the modifiable areal unit problem depending on the process under examination.

When examining support for structural and opportunity variables, opportunity variables tended to have support for both property and violent offenses across operationalizations of the crime rate. Meanwhile, structural variables appeared to be (slightly) more relevant in the models exploring violent offenses with the most support within the violent crime per square kilometer models. These results demonstrate the importance of exploring the impact of processes across crime types and operationalizations. The variation in significant indicators across models could again point to the importance of considering the wider social context within which these new geographic entities operate. For instance, prior studies have found relative deprivation (i.e., looking at the disadvantage in neighboring units) to be a significant predictor of property crime (Chamberlain & Hipp, 2015). Further insight may also be gained by moving away from the variable centered approach of the current study. In a recent investigation at the census-tract level, Kubrin, Branic and Hipp (2021) used latent-class analysis to identify specific clusters of neighborhood typologies based on social disorganization measurements concerning poverty, ethnic heterogeneity, and residential instability. Their findings revealed a more complex reality in which neighborhood typologies with heterogeneity, high poverty and residential instability experienced higher levels of property crime. Thus, latent class examinations may provide additional insight on the newly created geographic units within the current study that are overlooked when utilizing a simplified variable-centered approach.

Generally, all indicators operated in accordance with theoretical expectations. However, there was an exception. The percentage of the population who moved within the past calendar year was negatively associated with violent crime per square kilometer within both the union and update units. Thus, instead of crime increasing with an increase in mobility in and out of an area, it decreased. As described in the previous chapter, this finding may reflect the limitations of proxy measures and static indicators to capture dynamic processes. Variables within the present study may have been insufficient for capturing more complex underlying processes shaping crimes. One aspect that may be overlooked from such proxy measures concerns the impact of gentrification. Recent studies have revealed that gentrification is generally linked to a reduction in neighborhood crime (Papachristos et al. 2011; Barton, 2016; MacDonald & Stokes, 2020). However, this relationship may not be universal. Using the number of coffee shops as a measure of gentrification in a longitudinal study of Chicago, Papachristos et al. (2011) found the impact of gentrification was racialized and crime contingent. While declining homicide rates were experienced across gentrifying neighborhoods for majority black, white or Hispanic populations, gentrification was associated with increased street robberies for communities with majority Black residents.

In addition, the limitation of crude indicators aimed at measuring complex processes could be seen in the use of indices for crime generators and local guardianship facilities. This study demonstrated that MAUP reinforces the need to move away from indices to measure the impact of facilities on crime as the larger units

exhibited higher correlation between facility types that have opposing effects (e.g., local guardian facilities versus crime generators). Nonetheless, the union geographic units, which did not experience issues of collinearity, did appear to reinforce that crime generators and local guardian facilities matter for some crime measurements. An alternative option could involve taking an approach similar to the one used in Groff and Lockwood's (2014) exploration of facility impact on street segments in which facilities are inversely weighted based on distance from the centroid of the unit of analysis. Ultimately, MAUP can have an impact on any point-based data, whether it is the independent or dependent variable, reinforcing the need for caution in choice of unit of analysis and careful selection of measurements.

8.3 Guidance on Selecting the Appropriate Model

The different techniques examined in this dissertation demonstrated similar substantive results across techniques concerning being part of a drinking establishment buffer zone and higher crime rates within an area. However, there were contextual differences regarding the importance of other relevant variables across the analyses examined. Variation in findings for models which differed in terms of unit of analysis, operationalization of the dependent variable and type of crime investigated suggest that researchers need to provide clear justification for their methodological decisions. Considering that there were both convergences and divergences between the models, how does a researcher determine which model is best suited for such analyses? While it is highly recommended that researchers investigate geographic relationships using

different aggregations of data, limitations in resources and time constraints may preclude such sensitivity analyses. As such, the following section provides some guiding principles for choosing the appropriate model for investigating relationships between facilities and crime when using census enhances spatial units.

First, the research question must always be central to guiding the parameters used to investigate this relationship. When considering whether to operationalize the dependent variable as a rate per population or a rate per area unit, the researcher should carefully consider if personal risk or spatial intensity is at the root of the question being investigated. In other words, if the investigator is curious about whether the distribution of crime is more spatially concentrated within areas related to drinking establishment buffer zones, crime rates per area would be a more useful operationalization of the dependent variable. On the other hand, if the focus of the research is on standardizing crime in terms of potential targets at risk, the population-based rate may be more appropriate. Approaching investigations of the relationship between facilities and crime with a carefully crafted research question can help inform the best approach for operationalizing the dependent variable.

An important factor shaping the research question is often: who is the audience? The suitability of a model may depend on who the researcher is attempting to communicate with and/or who is seeking information. The audience invariably influences the purpose of the study and can help inform the choice in selecting a unit of analysis. For instance, preparing an analysis for investigating the relationship between drinking establishments and crime will look different depending on whether

the primary audience consists of community members as opposed to business owners. More specifically, community members may be more concerned with how alcohol establishments may influence crime rates within neighborhood areas. Although there is debate concerning what classifies a neighborhood, a researcher may want to rely on the union units of analysis to investigate this question for community stakeholders. If a drinking establishment is present, the union units divide a census block group into areas that are part of a drinking establishment buffer zone and areas that are not part of the zone. As such, the union units may allow community members a better visualization and understanding of the connection between crime and parts of neighborhood falling within a drinking establishment buffer zone extent. On the other hand, business owners may gain more insight from the use of the update units which keep the buffer zones around drinking establishment intact. Rather than dissecting the areas around drinking establishments into several pieces, keeping these buffer zones as whole units may appeal more to business owners who seek to understand the connections between facilities and crime.

However, it is imperative that regardless of the audience and selection of the unit of analysis, researchers must adequately convey that the inferences from these types of investigates cannot be reduced to individual facilities. In other words, if findings demonstrate there is an association between crime and facility buffer zone regions using the union or update units, this result does not provide validity to the conclusion that the areas surrounding *all* of the investigated facilities are associated with higher levels of crime. Conclusions must correspond to the unit of analysis used

within the study (Bachman & Schutt, 2014). In addition, the units of analysis need to be embedded within the theoretical justifications believed to explain the relationship between crime and place (Hipp, 2007). Scholars within this body of research have cautioned against the use of sophisticated techniques without ensuring that such methods or models "flow from or are informed by theory" (Tita & Radil, 2010, p.475).

While the study's purpose, audience, and theoretical basis can all be used to inform the choice in selecting a model, it is highly recommended that relationships are tested at various levels of aggregation. Performing sensitivity analyses using different units of analyses can help increase confidence in results if substantive conclusions are similar across different geographic units. On the other hand, if results are drastically different across different methods of geographic data aggregation, caution is required when drawing inferences from such findings as MAUP is clearly biasing results (Fotheringham & Wong, 1997).

8.4 Methodological Choices and Limitations

In all studies, researchers must make various methodological decisions that have the potential to shape outcomes. As the economist William Baumol (1984, p.7) argued:

> A well-designed model is, after all, a judiciously chosen set of lies, or perhaps more accurately put, partial truths about reality, which have been chosen so as to permit us to reason more effectively about some issue than we otherwise could. The model must be an oversimplification if it is to be tractable analytically. Optimality in model constructions must be based on the trade-off between these two desiderata—accuracy of representation of reality and usability in analysis.

While the research question and theory should be the driving force behind our methodological decisions, there is inevitably room for discretion. From choosing the unit of analysis to constructing a measurement of economic disadvantage to determining the most appropriate approach for calculating spatial weights, the power/influence of the researcher is present throughout every step of the process. Although the current study attempted to highlight the importance of choosing the appropriate unit of analysis and how different approaches could influence results, discretion was still unavoidable in the process. For instance, the choice was made to investigate location quotients using buffer zones at 400-foot increments up to 1600 feet. The choice of 400-foot buffer areas followed previous research (e.g., McCord & Ratcliffe, 2007), yet it is also possible that exploring more refined increments (e.g., 100-feet) could have provided a more nuanced insight into the spatial distribution of criminal incidents occurring around these establishments (Furr-Holden et al. 2016).

Another issue that researchers doing this type of analysis must contend with concerns the appropriateness and/or trustworthiness of the data sources. While the current study goes beyond the predefined census boundaries and constructs new geographic units using drinking establishment buffers, the construction of these units still relies on the pre-defined boundaries and uses data aggregated to that geographic level as the source for areal interpolation. Although the present study incorporated spatially lagged variables and examined different scales for constructing new geographic units, the limitations of the source data must be acknowledged. The fact remains that census boundaries are constructed for administrative purposes and may

not adequately reflect true patterns of activity nor the social contexts therein. In other words, human activity, including criminal conduct, does not neatly fit within the arbitrary boundaries that we rely on for analytical purposes.

In addition, this study is limited by the assumption of the areal weighted interpolated method used: that the population is evenly distributed throughout the geographic unit being analyzed. It is more likely that individuals are more concentrated in certain parts of the geographic unit. However, it is important to recognize that this is an issue that plagues all studies relying on areal units (e.g., census tracts, block groups, blocks). Future studies should explore other, more complex techniques for estimating values from the source data to the target data such as the synthetic estimation approach (see Boessen & Hipp, 2015).

Finally, a further limitation is associated with geocoding, which is the process of transforming an address into geographic coordinates. Accurate geocoding is essential for spatial analysis. However, administrative data are subject to issues arising from human error and/or lack of standardized recording practices. Issues such as name misspellings, incorrect street type designation (e.g., road instead of avenue), and address omissions can all produce challenges for researchers attempting to map out the data (Ratcliffe, 2004). While data from DELJIS was already geocoded, data on business locations were geocoded using R's tidygeocoder package and the geo_combine function, which relies on multiple sources for the reference data. In addition to the human error in data collection discussed above, it is important to recognize that geocoding solutions vary in terms of positional accuracy (see Chow,

Dede-Bamfo, & Dahal, 2016). Future research should empirically examine if variation of the reference source significantly influences the spatial patterns under investigation.

8.5 Directions for Future Research

While the current study provides insight into how census enhanced spatial units and areal weighted interpolation can be used to gain a better understanding of the facility-crime relationship, many avenues for future research exist. First, although the present research relied on aggregated property and violent crime measures, subsequent studies should use disaggregated crime measures (e.g., assault, theft). Previous research demonstrates how looking at these disaggregated measures can lead to a better understanding of the spatial patterns and their relationship to more homogeneous types of crime (Andresen & Linning, 2012).

While this research provides further evidence of the utility of the underutilized census enhanced GIS units for analyzing the facility-crime nexus, there are several areas upon which this study and others can be expanded to gain further support for this methodological technique. For instance, the current study used the 1600- foot buffer range to construct the new geographic units and based this decision on location quotients demonstrating considerably higher crime density within this range compared to the rest of the study area. Future research should consider using only the buffer zone range with the highest location quotient to construct the new geographic units. While the current study went with the farthest buffer zone and may face the potential of overestimating the spatial extent of drinking establishments on crime, it is also

possible that going with the smaller buffer zone underestimates the spatial extent. Thus, testing this relationship through analyses models with geographic units created from multiple buffer sizes may provide further support for the underlying relationships revealed in the current study. In addition, different mechanisms beyond location quotients could be used to determine a more appropriate buffer size for exploring these relationships further such as change point regression (Ratcliffe 2012a, 2012b) and Ripley's bivariate k-function (De Biasi & Circo, 2021).

Another potential area in which research can expand upon this work concerns the replication of these methods using different facility types. More specifically, testing whether relationships hold across the different geographic units, crime types and dependent variable operationalizations that were part of this study can provide further evidence of whether certain facilities that have been classified as potentially "criminogenic" are deserving of that title. Such replications may be particularly important for other establishments that have been subject to the "not in my back yard" narrative such as alcohol and drug treatment centers. While some evidence shows a positive association between substance use treatment centers and certain offenses (Rengert, Ratcliffe, and Chakravorty, 2005; Taniguchi & Salvatore, 2012), other studies suggest a negative relationship (McCord & Ratcliffe, 2007) or suggest that the relationship between these facility-types and crime may be more nuanced (Groff & Lockwood, 2014). The methods utilized as part of the current research could help clarify this relationship further. By placing drug treatment facilities at the center of the analysis and controlling for factors of the surrounding area, researchers can gain a

better understanding through analyzing models with different crime types and operationalizations of crime rates. The present study provides a guide for such research.

Moreover, future investigations should incorporate different characteristics of facilities as previous research demonstrates the relationship between facility type and crime is not uniform across all such facilities. In fact, a narrow focus on places characterized as "unpopular," without considering the characteristics of the facility, can be problematic because of a common pattern within the literature known as the "Iron Law of Troublesome Places" (Wilcox & Eck, 2011). The "Iron Law" has three components: that a few places have most of the crime, most places have little or no crime and "there is extreme skewness in the norm" (Wilcox & Eck, 2011, p. 477). Research incorporating facilities into models exploring crime have garnered evidence that business characteristics such as size, number of employees, and sales volume are important factors in understanding this relationship (e.g., see Askey, Taylor, Groff & Fingerhut, 2018; Tillyer & Walter, 2019). For instance, in their multi-level approach exploring the relationship between robbery patterns and public housing communities, Haberman, Groff, and Taylor (2013) found that proximity effects varied based on community size. Within the context of the current study which places the facility at the center of the unit of analysis, finding ways to incorporate different facility related characteristics into the analysis can provide a deeper understanding of the spatial patterns linking crime and place.

Finally, because of the potential for both local and higher order effects, scholars have called upon the need for analyzing relationships between crime and place using multiple scales simultaneously (Boessen & Hipp, 2015; Gerell, 2017; Quick, 2019). In fact, Wenger (2021b) draws attention to the susceptibility of research to suffer from omitted level bias (OLB) when relying on a single level of aggregation. OLB occurs when researchers fail to include measures that capture all levels at which a variable may be associated with crime. Placing these arguments within the context of the current research, it may be helpful for future studies to consider how nesting these new units within larger geographic entities such as census tracts could future enhance our understanding of the nuances of social processes operating at different levels. Analyzing the relationships found between buffer zone status and crime using a multi-level model may be particularly important as recent research suggests that the relationship between crime generators may be contingent upon neighborhood context (Jones & Pridemore, 2019; Tillyer, Wilcox & Walter, 2021). For instance, Jones and Pridemore (2019) found that the impact of crime generators was weaker in stables neighborhoods. Thus, looking at cross-level interactions between the newly created units in this study and the larger environmental context in which they are situated may provide additional insight into the relationships uncovered within the current study.

8.6 Conclusion

This dissertation explored how census enhanced GIS spatial units sharpen our understanding of the relationship between drinking establishments and crime. New

geographic units were created using two approaches. The first method, which is referred to as the union method, involved creating new geographic units in places where drinking establishment buffer zones and block groups intersected. The second method, which is referred to as the update method, involved placing the buffer zones over the census block groups and creating new areas from the overlay, keeping the drinking establishment zone intact. Models varying in terms of geographic units (union versus update), crime type (property versus violent) and dependent variable operationalization (crime per capita versus crime per square kilometer) were examined and compared. While the results for variables such as buffer zone status and the level of crime counts in neighboring units appeared to be robust predictors across methods, the differences in terms of significance, magnitude, and direction between the coefficients of other socially relevant variables reinforce the notion that basic methodological decisions should not be underestimated. Careful consideration is essential when choosing the appropriate unit of analysis and crime outcome measurement.

This dissertation advanced the literature on census enhanced GIS spatial units in several important ways. Not only did it produce empirical evidence on how these underutilized geographic units provide insight into the relationship between facilities and crime, this research also explored these relationships across different merger methods of geographic unit creation. Such comparisons are largely missing within the limited body of literature in this area. Moreover, few studies have systematically explored the impacts of varying the geographic unit, the operationalization of the

dependent variable, and the crime type examined within one study. By highlighting the importance of methodological choices in geographic analysis, the current research provides a call to action for both authors and audiences of scholarly work. Authors must carefully consider the implications of choosing one unit of analysis over another and should always test geographic relationships at multiple levels to ensure validity of their findings when possible. Audiences should be critical of geographic research that does not provide a justification for geographic unit choice and/or work that fails to acknowledge the modifiable areal unit problem. While this dissertation is an important step in increasing awareness of the implications of modifying the unit of analysis and the operationalization of the outcome variable, scholars should continue to explore these relationships in different settings. Failing to do so will weaken progress made within the field of geographic criminology.

REFERENCES

Andresen, M. (2014). *Environmental Criminology: Evolution, Theory, and Practice*. New York: Routledge.

Andresen, M. A., & Linning, S. J. (2012). The (in)appropriateness of aggregating across crime types. *Applied Geography*, *35*(1-2), 275–282. https://doi.org/10.1016/j.apgeog.2012.07.007

Andresen, M. A., & Malleson, N. (2013). Spatial heterogeneity in crime analysis. In M. Leitner (Eds.), *Crime modeling and mapping using geospatial technologies* (pp. 3-23). Springer, Dordrecht. https://doi-org.udel.idm.oclc.org/10.1007/978-94-007-4997-9_1

Askey, A. P., Taylor, R., Groff, E., & Fingerhut, A. (2018). Fast food restaurants and convenience stores: Using sales volume to explain crime patterns in Seattle. *Crime & Delinquency*, *64*(14), 1836-1857. https://doi.org/10.1177/0011128717714792

Bachman, R. & Schutt, R. K. (2014). *The practice of research in criminology and criminal justice* (Fifth ed.). Los Angeles: SAGE.

Barton, M. S. (2016). Gentrification and violent crime in New York City. *Crime & Delinquency*, *62*(9), 1180-1202. https://doi.org/10.1177/0011128714549652

Baumol, W. J. (1984). On my attitudes: sociopolitical and methodological. *The American Economist*, *28*(1), 5–9.

Bernasco, W., & Block, R. (2011). Robberies in Chicago: A block-level analysis of the influence of crime generators, crime attractors, and offender anchor points. *Journal of Research in Crime and Delinquency*, 48(1), 33-57.

Beyerlein, K., & Hipp, J. R. (2005). Social capital, too much of a good thing? American religious traditions and community crime. *Social Forces*, *84*(2), 995–1013.

Boehme, H. M., Malhotra, R., & Mulrooney, T. (2022). More gas, more crime: a geospatial examination of the concentration of gas stations and predatory crime. *Southeastern Geographer*, *62*(1), 59-78.

Boessen, A., & Hipp, J. R. (2015). Close-ups and the scale of ecology: Land uses and the geography of social context and crime. *Criminology*, *53*(3), 399-426. https://doi.org/10.1111/1745-9125.12074

Boivin, R. (2013). On the use of crime rates. *Canadian Journal of Criminology and Criminal Justice*, *55*(2), 263-277.

Bowers, K. (2014). Risky facilities: crime radiators or crime absorbers? a comparison of internal and external levels of theft. *Journal of Quantitative Criminology*, *30*(3), 389–414. https://doi.org/10.1007/s10940-013-9208-z

Brantingham, P. J., & Brantingham, P. L. (1981). *Environmental criminology* (Ser. Sage focus editions, 39). Sage Publications.

Brantingham, P. L., & Brantingham, P. J. (1993). Nodes, paths and edges: considerations on the complexity of crime and the physical environment. *Journal of Environmental Psychology*, *13*(1), 3–28. https://doi.org/10.1016/S0272-4944(05)80212-9

Brantingham, P., & Brantingham, P. (1995). Criminality of place. *European journal on criminal policy and research*, 3(3), 5-26.

Brantingham, P.J., Brantingham, P. L. & Andresen M.A., (2017). The Geometry of Crime and Crime Pattern Theory. In R. Wortley & M. Townsley (Eds.), *Environmental Criminology and Crime Analysis, 2nd Edition* (pp. 98-115). New York: Routledge.

Bromley, R. D.F., & Nelson, A. L. (2002). Alcohol-related crime and disorder across urban space and time: evidence from a British city. *Geoforum*, *33*(2), 239-254. https://doi.org/10.1016/S0016-7185(01)00038-0

Bruinsma, G. J. (2017). From countries to street segments: a brief history of 200 years of geographical criminology. *Jerusalem Review of Legal Studies*, *15*(1), 27-43. https://doi.org/10.1093/jrls/jlx003

Burgess, E. W. (1925 [2019]). The growth of the city: an introduction to a research project. In *The City* (pp. 47-62). Chicago: The University of Chicago Press

Bursik, R. (1988). Social Disorganization and Theories of Crime and Delinquency: Problems and Prospects. *Criminology, 26*(4), 519–552. https://doi.org/10.1111/j.1745-9125.1988.tb00854.x

Chainey, S., & Ratcliffe, J. (2005). *GIS And Crime Mapping* (Ser. Mastering GIS). Wiley.

Chamberlain, A. W., & Hipp, J. R. (2015). It's all relative: Concentrated disadvantage within and across neighborhoods and communities, and the consequences for neighborhood crime. *Journal of Criminal Justice, 43*(6), 431-443. https://doi.org/10.1016/j.jcrimjus.2015.08.004

Chow, T. E., Dede-Bamfo, N., & Dahal, K. R. (2016). Geographic disparity of positional errors and matching rate of residential addresses among geocoding solutions. *Annals of GIS*, *22*(1), 29-42. https://doi.org/10.1080/19475683.2015.1085437

City of Wilmington, DE, The. (2021, May 7). Mayor Purzycki Addresses Rising Gun Violence. https://www.wilmingtonde.gov/Home/Components/News

Cohen, L.E., & Felson, M. (1979). Social Change and Crime Trends: A Routine Activity Approach. In M. Andresen, P. Brantingham, & J.B. Kinney (Eds.), Classics in Environmental Criminology (2010) (pp. 187-216). Simon Fraser University Publications.

Costanza, S. E., Bankston, W. B., & Shihadeh, E. (2001). Alcohol availability and violent crime rates: a spatial analysis. *Journal of Crime and Justice, 24*(1), 71–83. https://doi.org/10.1080/0735648X.2001.9721617

Cullen, F. T., Agnew, R., & Wilcox, P. (2014). *Criminological theory: Past to present: Essential readings*. New York: Oxford University Press.

De Biasi, A., & Circo, G. (2021). Capturing crime at the micro-place: a spatial approach to inform buffer size. *Journal of Quantitative Criminology, 37*(2), 393–418. https://doi.org/10.1007/s10940-020-09488-0

Demeau, E., & Parent, G. (2018). Impacts of crime attractors and generators on criminality in Montreal. *Canadian Journal of Criminology and Criminal Justice, 60*(3), 387-412. https://doi.org/10.3138/cjccj.2017-0028.r1

Donnelly, E. A., Wagner, J., Anderson, T. L., & O'Connell, D. (2022). Revisiting neighborhood context and racial disparities in drug arrests under the opioid

epidemic. *Race and Justice*, *12*(2), 322-343. https://doi.org/10.1177/2153368719877222

Donnelly, E. A., Wagner, J., Stenger, M., Cortina, H. G., O'Connell, D. J., & Anderson, T. L. (2021). Opioids, race, and drug enforcement: exploring local relationships between neighborhood context and black–white opioid-related possession arrests. *Criminal Justice Policy Review*, *32*(3), 219–244. https://doi.org/10.1177/0887403420911415

Drukker, D. M., Peng, H., Prucha, I. R., & Raciborski, R. (2013). Creating and managing spatial-weighting matrices with the spmat command. *The Stata Journal*, *13*(2), 242–286. https://doi.org/10.1177/1536867X1301300202

ESRI. (n.d.). Network Analysis Layers: Service Area Analysis Layer. Retrieved from: https://pro.arcgis.com/en/pro-app/2.8/help/analysis/networks/service-area-analysis-layer.htm

Felson, M. (2017). The Routine Activity Approach. In R. Wortley & M. Townsley (Eds.), *Environmental Criminology and Crime Analysis, 2nd Edition* (pp. 87-97). New York: Routledge.

Felson, M., & Clarke, R. V. (1998). Opportunity makes the thief: Practical Theory for Crime Prevention. *Police research series, paper*, *98*(1-36), 10.

Fotheringham, A.S., & Wong, D.W.S. (1991). The modifiable areal unit problem in multivariate statistical analysis. *Environment and Planning A: Economy and Space*, *23*(7), 1025–1044. https://doi.org/10.1068/a231025

Franklin, F. A., LaVeist, T. A., Webster, D. W., & Pan, W. K. (2010). Alcohol outlets and violent crime in Washington D.C. *The Western Journal of Emergency Medicine*, *11*(3), 283–290.

Furr-Holden, C. D. M., Milam, A. J., Nesoff, E. D., Johnson, R. M., Fakunle, D. O., Jennings, J. M., & Thorpe Jr, R. J. (2016). Not in my back yard: a comparative analysis of crime around publicly funded drug treatment centers, liquor stores, convenience stores, and corner stores in one mid-Atlantic city. *Journal of studies on alcohol and drugs*, *77*(1), 17-24.

Gehlke, C. E., & Biehl, K. (1934). Certain effects of grouping upon the size of the correlation coefficient in census tract material. *Journal of the American Statistical Association*, *29*(185), 169–170.

Gerell, M. (2017). Smallest is better? the spatial distribution of arson and the modifiable areal unit problem. *Journal of Quantitative Criminology*, *33*(2), 293–318. https://doi.org/10.1007/s10940-016-9297-6

Glyde, J. (1856). Localities of crime in Suffolk. *Journal of Statistical Society of London*, 19(2), 102–106. https://doi-org.udel.idm.oclc.org/10.2307/2338263

Groff, E. (2011). Exploring 'near': Characterizing the spatial extent of drinking place influence on crime. *Australian & New Zealand Journal of Criminology*, 44(2), 156-179.

Groff, E. R., & Lockwood, B. (2014). Criminogenic facilities and crime across street segments in Philadelphia: Uncovering evidence about the spatial extent of facility influence. *Journal of Research in Crime and Delinquency*, 51(3), 277-314. https://doi.org/10.1177/0022427813512494

Grubesic, T., & Pridemore, W. (2011). Alcohol outlets and clusters of violence. *International Journal of Health Geographics*, *10*(1), 1–12. https://doi.org/10.1186/1476-072X-10-30

Grubesic, T. H., Pridemore, W. A., Williams, D. A., & Philip-Tabb, L. (2013). Alcohol outlet density and violence: the role of risky retailers and alcohol-related expenditures. *Alcohol and alcoholism*, *48*(5), 613-619. https://doi.org/10.1093/alcalc/agt055

Gruenewald, P. J., Freisthler, B., Remer, L., LaScala, E. A., & Treno, A. (2006). Ecological models of alcohol outlets and violent assaults: crime potentials and geospatial analysis. *Addiction*, *101*(5), 666–677. https://doi.org/10.1111/j.1360-0443.2006.01405.x

Gruenewald, P. J., & Remer, L. (2006). Changes in outlet densities affect violence rates. *Alcoholism: Clinical and Experimental Research*, *30*(7), 1184-1193.

Haberman, C. P., Clutter, J. E., & Henderson, S. (2018). A quasi-experimental evaluation of the impact of bike-sharing stations on micro-level robbery occurrence. *Journal of Experimental Criminology*, *14*(2), 227-240. https://doi.org/10.1007/s11292-017-9312-4

Haberman, C. P., Groff, E. R., & Taylor, R. B. (2013). The variable impacts of public housing community proximity on nearby street robberies. *Journal of Research in Crime and Delinquency*, *50*(2), 163-188.

Haberman, C. P., & Ratcliffe, J. H. (2015). Testing for temporally differentiated relationships among potentially criminogenic places and census block street robbery counts. *Criminology, 53*(3), 457-483. https://doi.org/10.1111/1745-9125.12076

Hawley, A. H. (1950). *Human ecology: a theory of community structure*. Ronald Press.

Hipp, J. R. (2007). Block, tract, and levels of aggregation: neighborhood structure and crime and disorder as a case in point. *American Sociological Review, 72*(5), 659–680.

Hipp, J. R., & Williams, S. A. (2020). Advances in spatial criminology: The spatial scale of crime. *Annual Review of Criminology*, *3*, 75-95. https://doi.org/10.1146/annurev-criminol-011419-041423

Hodgkinson, T., & Andresen, M. A. (2019). Changing spatial patterns of residential burglary and the crime drop: the need for spatial data signatures. *Journal of Criminal Justice*, *61*, 90–100. https://doi.org/10.1016/j.jcrimjus.2019.04.003

Hoffmann, J. P. (2016). *Regression models for categorical, count, and related variables : an applied approach*. University of California Press. http://www.jstor.org/stable/10.1525/j.ctv1wxrfr

Hunt, J. (2019). From crime mapping to crime forecasting: The evolution of place-based policing. *National Institute of Justice. Available online: https://www. ncjrs. gov/pdffiles1/nij/252036. pdf (accessed on 1 December 2019)*.

Inlow, A. R. (2021). A comprehensive review of quantitative research on crime, the built environment, land use, and physical geography. *Sociology Compass*, *15*(7). https://doi.org/10.1111/soc4.12889

Jennings, J. M., Milam, A. J., Greiner, A., Furr-Holden, C. D. M., Curriero, F. C., & Thornton, R. J. (2014). Neighborhood alcohol outlets and the association with violent crime in one mid-Atlantic City: the implications for zoning policy. *Journal of Urban Health*, *91*(1), 62-71. https://doi.org/10.1007/s11524-013-9821-z

Jones, R. W., & Pridemore, W. A. (2019). Toward an integrated multilevel theory of crime at place: Routine activities, social disorganization, and the law of crime concentration. *Journal of quantitative criminology*, 35(3), 543-572. https://doi.org/10.1007/s10940-018-9397-6

Kim, Y.-A. (2018). Examining the relationship between the structural characteristics of place and crime by imputing census block data in street segments: is the pain worth the gain? *Journal of Quantitative Criminology*, *34*(1), 67–110. https://doi.org/10.1007/s10940-016-9323-8

Kim, Y. A., & Hipp, J. R. (2021). Small Local versus Non-Local: Examining the Relationship between Locally Owned Small Businesses and Spatial Patterns of Crime. *Justice Quarterly*, 1-25. https://doi.org/10.1080/07418825.2021.1879899

Kornhauser, R. (1978). Social Sources of Delinquency: An Appraisal of Analytic Models. Chicago: University of Chicago Press.

Kubrin, C. E., Branic, N., & Hipp, J. R. (2021). (Re) conceptualizing Neighborhood Ecology in Social Disorganization Theory: From a Variable-Centered Approach to a Neighborhood-Centered Approach. *Crime & Delinquency, (20210901)*, https://doi.org/10.1177/00111287211041527.

Kubrin, C. E., & Mioduszewski, M. D. (2019). Social Disorganization Theory: Past, Present and Future. In M. Krohn, N. Hendrix, G.P. Hall, & A.J. Lizotte (Eds.), *Handbook on Crime and Deviance* (pp. 197-211). Springer, Cham. https://doi.org/10.1007/978-3-030-20779-3_11

Kubrin, C. E., & Weitzer, R. (2003). New directions in social disorganization theory. *Journal of Research in Crime and Delinquency*, 40(4), 374-402.

Kubrin, C. E., & Wo, J. C. (2016). Social disorganization theory's greatest challenge: Linking structural characteristics to crime in socially disorganized communities. In A. Piquero (Eds.), *The Handbook of Criminological Theory* (pp. 121-136). Wiley-Blackwell.

Lardier, D. T., Opara, I., Lin, Y., Roach, E., Herrera, A., Garcia-Reid, P., & Reid, R. J. (2021). A spatial analysis of alcohol outlet density type, abandoned properties, and police calls on aggravated assault rates in a northeastern US city. *Substance use & misuse*, *56*(10), 1527-1535. https://doi.org/10.1080/10826084.2021.1942053

Lipton, R., & Gruenewald, P. (2002). The spatial dynamics of violence and alcohol outlets. *Journal of studies on alcohol*, *63*(2), 187-195.

Lowenkamp, C. T., Cullen, F. T., & Pratt, T. C. (2003). Replicating Sampson and Groves's test of social disorganization theory: revisiting a criminological classic. *Journal of Research in Crime and Delinquency*, *40*(4), 351–373.

MacDonald, J. M., & Stokes, R. J. (2020). Gentrification, land use, and crime. *Annual Review of Criminology*, *3*, 121-138. https://doi.org/10.1146/annurev-criminol-011419-041505

Madensen, T. D., & Eck, J. E. (2008). Violence in bars: Exploring the impact of place manager decision-making. *Crime Prevention and Community Safety*, *10*(2), 111-125.

Madero-Hernandez, A. & Fisher. B. (2013) Routine Activity Theory. In F. Cullen & P. Wilcox (Eds.), The Oxford Handbook of Criminology Theory (pp. 513-534). New York: Oxford University Press.

Martin, S. E. (2001). The links between alcohol, crime and the criminal justice system: explanations, evidence and interventions. *The American Journal on Addictions*, *10*(2), 136–158.

Martinez, R., Stowell, J. I., & Lee, M.T. (2010). Immigration And Crime in An Era of Transformation: A Longitudinal Analysis of Homicides in San Diego Neighborhoods, 1980-2000. *Criminology*, *48*(3), 797–829. https://doi.org/10.1111/j.1745-9125.2010.00202.x

May, C. (2015, February 5). Report: Camden Most Dangerous in the U.S. https://www.nbcphiladelphia.com/news/local/local-city-named-most-dangerous-in-us/1998894/

McCord, E. S., & Ratcliffe, J. H. (2007). A micro-spatial analysis of the demographic and criminogenic environment of drug markets in Philadelphia. *Australian & New Zealand Journal of Criminology*, *40*(1), 43-63.

McCord, E. S., & Ratcliffe, J. H. (2009). Intensity value analysis and the criminogenic effects of land use features on local crime patterns. *Crime Patterns and Analysis*, 2(1), 17-30.

Meier, R. F., & Miethe, T. D. (1993). Understanding theories of criminal victimization. *Crime and Justice*, *17*, 459–499.

Melo, S. N. de, Frank, R., & Brantingham, P. (2017). Voronoi diagrams and spatial analysis of crime. *The Professional Geographer*, *69*(4), 579–590. https://doi.org/10.1080/00330124.2017.1288578

Mooney, J. (2019). The Theoretical Foundations of Criminology : Place, Time and Context, Routledge.

Mozahem, N. A. (2021). *Modeling Count Data Using Poisson and Negative Binomial Models*. SAGE Publications Ltd.

Murray, R. K., & Roncek, D. W. (2008). Measuring diffusion of assaults around bars through radius and adjacency techniques. *Criminal Justice Review*, *33*(2), 199-220.

Oberwittler, D., & Wikström, P. O. H. (2009). Why small is better: Advancing the study of the role of behavioral contexts in crime causation. In D. Weisburd, W. Bernasco, & G. Bruinsma (Eds.), Putting *crime in its place: units of analysis in geographic criminology* (pp. 35-59). Springer. https://doi-org.udel.idm.oclc.org/10.1007/978-0-387-09688-9_2

Openshaw, S. (1984) Concepts and techniques in modern geography number 38: the modifiable areal unit problem. Geo Books, Norwich.

Osgood, D. W. (2000). Poisson-based regression analysis of aggregate crime rates. *Journal of Quantitative Criminology*, *16*(1), 21–43.

Ouimet, M. (2000). Aggregation bias in ecological research: How social disorganization and criminal opportunities shape the spatial distribution of juvenile delinquency in Montreal. *Canadian Journal of Criminology, 42*(2), 135-156. https://doi.org/10.3138/cjcrim.42.2.135

Papachristos, A. V., Smith, C. M., Scherer, M. L., & Fugiero, M. A. (2011). More coffee, less crime? The relationship between gentrification and neighborhood crime rates in Chicago, 1991 to 2005. *City & Community*, *10*(3), 215-240. https://doi.org/10.1111/j.1540-6040.2011.01371.x

Park, R. E., & Burgess, E. W. (1925, [2019]). The city. In *The city*. University of Chicago Press.

Parker, R. N. (2004). Alcohol and violence: connections, evidence, and possibilities for prevention. *Journal of Psychoactive Drugs*, *36*(sup2), 157-163. https://doi.org/10.1080/02791072.2004.10400051

Parker, R. N., & McCaffree, K. J. (2013). *Alcohol and violence: the nature of the relationship and the promise of prevention*. Lexington Books.

Parker, R. N., Mccaffree, K. J., & Skiles, D. (2011). The Impact of Retail Practices on Violence: The Case of Single Serve Alcohol Beverage Containers: The

Influence of Retail Practices on Violence. *Drug and Alcohol Review*, *30*(5), 496–504.

Paternoster, R., Brame, R., Mazerolle, P., & Piquero, A. (1998). Using the correct statistical test for the equality of regression coefficients. *Criminology*, *36*(4), 859–866. https://doi.org/10.1111/j.1745-9125.1998.tb01268.x

Peterson, R. D., Krivo, L. J., & Harris, M. A. (2000). Disadvantage and neighborhood violent crime: Do local institutions matter?. *Journal of research in crime and delinquency*, *37*(1), 31-63.

Pratt, T. C., & Cullen, F. T. (2005). Assessing macro-level predictors and theories of crime: a meta-analysis. *Crime and Justice*, *32*, 373–450.

Prener, C. G., & Revord, C. K. (2019). Areal: An R package for areal weighted interpolation. *Journal of Open Source Software*, *4*(37), 1221. https://doi.org/10.21105/joss.01221

Pridemore, W. A., & Grubesic, T. H. (2012). Community organization moderates the effect of alcohol outlet density on violence. *The British Journal of Sociology*, *63*(4), 680–703. https://doi.org/10.1111/j.1468-4446.2012.01432.x

Pridemore, W. A., & Grubesic, T. H. (2013). Alcohol outlets and community levels of interpersonal violence: spatial density, outlet type, and seriousness of assault. *Journal of Research in Crime and Delinquency*, 50(1), 132-159. https://doi.org/10.1177/0022427810397952

Prosperity Now. (2019). The Racial Wealth Divide in Wilmington, DE. https://prosperitynow.org/sites/default/files/resources/RWD__Profile_Wilmington.pdf

Quick, M. (2019). Multiscale spatiotemporal patterns of crime: a Bayesian cross-classified multilevel modelling approach. *Journal of Geographical Systems : Spatial Theory, Models, Methods, and Data*, *21*(3), 339–365. https://doi.org/10.1007/s10109-019-00305-2

Ratcliffe, J. (2004). Geocoding crime and a first estimate of a minimum acceptable hit rate. *International Journal of Geographical Information Science*, *18*(1), 61–72.

Ratcliffe, J. H. (2012a). The spatial extent of criminogenic places: a changepoint regression of violence around bars. *Geographical Analysis*, 44(4), 302-320. https://doi.org/10.1111/j.1538-4632.2012.00856.x

Ratcliffe, J. H. (2012b). How near is near? Quantifying the spatial influence of crime attractors and generators. In M.A. Andresen & B.J. Kinney (Eds.), *Patterns, Prevention, and Geometry of Crime* (pp. 125-139). Routledge.

Ratcliffe, J. H., & Rengert, G. F. (2008). Near-repeat patterns in Philadelphia shootings. *Security Journal*, *21*(1), 58-76.

Ratcliffe, J. H., & Taniguchi, T. A. (2008). Is crime higher around drug-gang street corners? Two spatial approaches to the relationship between gang set spaces and local crime levels. *Crime Patterns and Analysis*, *1*(1), 17-39.

Ratcliffe, J. H., Taniguchi, T., Groff, E. R., & Wood, J. D. (2011). The Philadelphia Foot Patrol Experiment: A Randomized Controlled Trial of Police Patrol Effectiveness in Violent Crime Hotspots.(report). *Criminology*, *49*(3), 795-831. https://doi.org/10.1111/j.1745-9125.2011.00240.x

Ramos, R. G., Silva, B. F. A., Clarke, K. C., & Prates, M. (2021). Too fine to be good? Issues of granularity, uniformity and error in spatial crime analysis. *Journal of Quantitative Criminology*, *37*(2), 419–443. https://doi.org/10.1007/s10940-020-09474-6

Rice, K. J., & Smith, W. R. (2002). Socioecological models of automotive theft: integrating routine activity and social disorganization approaches. *Journal of Research in Crime and Delinquency*, *39*(3), 304–336.

Rengert, G. F., & Lockwood, B. (2009). Geographical units of analysis and the analysis of crime. In D. Weisburd, W. Bernasco, & G. Bruinsma (Eds.), *Putting crime in its place: Units of Analysis in Geographic Criminology*, (pp. 109-122). Springer. https://doi-org.udel.idm.oclc.org/10.1007/978-0-387-09688-9_5

Rengert, G. F., Ratcliffe, J., & Chakravorty, S. (2005). *Policing illegal drug markets: Geographic approaches to crime reduction*. Monsey, NY: Criminal Justice Press.

Roncek, D. W., & Maier, P. A. (1991). Bars, blocks, and crimes revisited: Linking the theory of routine activities to the empiricism of "hot spots". *Criminology*, *29*(4), 725-753.

Salkind, N. J. (2007). Multicollinearity. In *Encyclopedia of measurement and statistics* (pp. 639-640). Sage Publications, Inc., https://dx.doi.org/10.4135/9781412952644.n293

Sampson, R. J. (1987). Communities and crime. In M. Gottfredson & T. Hirschi (Eds.), *Positive Criminology* (pp. 91-114). Sage Publications.

Sampson, R. J., & Groves, W. B. (1989). Community structure and crime: testing social-disorganization theory. *American Journal of Sociology*, *94*(4), 774–802.

Shaw, C. R., & McKay, H. D. (1942). *Juvenile Delinquency and Urban Areas: A Study of Rates of Delinquents in Relation to Differential Characteristics of Local Communities in American Cities* (Ser. Behavior research fund monographs). University of Chicago Press.

Shen, J.-L., & Andresen, M. A. (2021). A tale of two theories: whither social disorganization theory and the routine activities approach? *Canadian Journal of Criminology and Criminal Justice*, *63*(2), 1–22. https://www.muse.jhu.edu/article/806313.

Smith, W.R., Frazee, S. G., & Davison, E. L. (2000). Furthering The Integration of Routine Activity and Social Disorganization Theories: Small Units of Analysis and the Study of Street Robbery as a Diffusion Process. *Criminology*, *38*(2), 489–524. https://doi.org/10.1111/j.1745-9125.2000.tb00897.x

Snipes, J. B., Bernard, T. J., & Gerould, A. L. (2019). *Vold's theoretical criminology* (Eighth). Oxford University Press.

Slocum, L.A., Rengifo, A.F., Choi, T., & Herrmann, C. R. (2013). The Elusive Relationship Between Community Organizations and Crime: An Assessment Across Disadvantaged Areas of The South Bronx. *Criminology*, *51*(1), 167–216. https://doi.org/10.1111/1745-9125.12001

Snowden, A. J. (2019). Exploring violence: the role of neighborhood characteristics, alcohol outlets, and other micro-places. *Social Science Research*, *82*, 181–194. https://doi.org/10.1016/j.ssresearch.2019.04.018

Snowden, A. J., & Freiburger, T. L. (2015). Alcohol outlets, social disorganization, and robberies: Accounting for neighborhood characteristics and alcohol outlet types. *Social Science Research*, 51, 145-162. https://doi.org/10.1016/j.ssresearch.2015.01.011

Snowden, A. J., Stucky, T. D., & Pridemore, W. A. (2017). Alcohol outlets, social disorganization, and non-violent crimes in urban neighborhoods. *Journal of Crime and Justice*, 40(4), 430-445.

Stark, R. (1987). Deviant Places: A Theory of The Ecology of Crime. Criminology, 25(4), 893–911. https://doi.org/10.1111/j.1745-9125.1987.tb00824.x

Taniguchi, T., Ratcliffe, J., & Taylor, R. (2011). Gang Set Space, Drug Markets, and Crime Around Drug Corners in Camden. *Journal of Research in Crime and Delinquency*, *48*(3), 327–363.

Taniguchi, T. A., Rengert, G. F., & McCord, E. S. (2009). Where Size Matters: Agglomeration Economies of Illegal Drug Markets in Philadelphia. *Justice Quarterly*, *26*(4), 670-694. https://doi.org/10.1080/07418820802593378

Taniguchi, T. A., & Salvatore, C. (2012). Exploring the relationship between drug and alcohol treatment facilities and violent and property crime: A socioeconomic contingent relationship. *Security Journal*, 25(2), 95-115. https://doi.org/10.1057/sj.2011.8

Thompson, C. G., Kim, R. S., Aloe, A. M., & Becker, B. J. (2017). Extracting the variance inflation factor and other multicollinearity diagnostics from typical regression results. *Basic and Applied Social Psychology*, *39*(2), 81-90. https://doi.org/10.1080/01973533.2016.1277529

Tillyer, M. S., & Walter, R. J. (2019). Busy businesses and busy contexts: The distribution and sources of crime at commercial properties. *Journal of Research in Crime and Delinquency*, *56*(6), 816-850. https://doi.org/10.1177/0022427819848083

Tillyer, M. S., Wilcox, P., & Walter, R. J. (2021). Crime generators in context: examining 'place in neighborhood' propositions. *Journal of Quantitative Criminology*, *37*(2), 517-546. https://doi.org/10.1007/s10940-019-09446-5

Tita G. E., & Radil S. M. (2010). Making space for theory: The challenges of theorizing space and place for spatial analysis in criminology. *Journal of Quantitative Criminology*, *26*(4), 467–479. https://doi.org/10.1007/s10940-010-9115-5

Tobler, W. R. (1970). A computer movie simulating urban growth in the Detroit region. *Economic geography*, *46*(sup1), 234-240.

Toomey, T. L., Erickson, D. J., Carlin, B. P., Quick, H. S., Harwood, E. M., Lenk, K. M., & Ecklund, A. M. (2012). Is the density of alcohol establishments related to nonviolent crime? *Journal of Studies on Alcohol and Drugs*, *73*(1), 21–25.

Trangenstein, P. J., Curriero, F. C., Jennings, J. M., Webster, D., Latkin, C., Eck, R. H., & Jernigan, D. H. (2019). Methods for evaluating the association between alcohol outlet density and violent crime. *Alcoholism: Clinical and Experimental Research, 43*(8), 1714–1726. https://doi.org/10.1111/acer.14119

US Census Bureau. (2017). American Community Survey Information Guide. https://www.census.gov/content/dam/Census/programs-surveys/acs/about/ACS_Information_Guide.pdf

US Census Bureau. (n.d.). Metropolitan and Micropolitan: About. Retrieved from: https://www.census.gov/programs-surveys/metro-micro/about.html

US Census Bureau. (December 21, 2021). Population density in the U.S. by federal states including the District of Columbia in 2021 [Graph]. In Statista. Retrieved April, 2022, from https://www-statista-com.udel.idm.oclc.org/statistics/183588/population-density-in-the-federal-states-of-the-us/

Verma, A., Ramyaa, R. Marru, S., Fan, Y. and Singh, R. (2010). Rationalizing police patrol beats using Voronoi tessellations. In 2010 IEEE International Conference on Intelligence and Security Informatics (ISI), 165–167. Vancouver, BC: IEEE. https://doi.org/10.1109/ISI.2010.5484750

Wagner, J. (2020). *Crime in micro-places: beyond urban areas* [Doctoral dissertation]. Department of Sociology and Criminal Justice, University of Delaware.

Wasserstein, R. L., & Lazar, N. A. (2016). The ASA's statement on p-values: context, process, and purpose. *The American Statistician*, *70*(2), 129–133. https://doi.org/10.1080/00031305.2016.1154108

Weisburd, D. (2012). Bringing social context back into the equation: The importance of social characteristics of places in the prevention of crime. *Criminology & Public Policy, 11(2)*, 317-326. https://doi.org/10.1111/j.1745-9133.2012.00810.x

Weisburd, D., Bruinsma, G., & Bernasco, W. (2009). Units of Analysis in Geographic Criminology: Historical Development, Critical Issues, and Open Questions. In D. Weisburd, W. Bernasco, & G. Bruinsma (Eds.), *Putting crime in its place*: units of analysis in geographic criminology (pp. 3-31). Springer. https://doi-org.udel.idm.oclc.org/10.1007

Weisburd, D., & Eck, J. E. (Eds.). (2017). *Unraveling the Crime-place Connection, Volume 22: New Directions in Theory and Policy*. Routledge.

Weisburd, D., Groff, E., & Yang, S.-M. (2012). *The criminology of place : street segments and our understanding of the crime problem*. Oxford University Press.

Weisburd, D., Groff, E. R., & Yang, S.-M. (2014). Understanding and controlling hot spots of crime: the importance of formal and informal social controls. *Prevention Science, 15*(1), 31–43. https://doi.org/10.1007/s11121-012-0351-9

Wenger, M. R. (2021a). The multilevel effects of changes in disadvantage on changes in crime. *Crime & Delinquency, (20211011), 1-22*. https://doi.org/10.1177/00111287211047543

Wenger, M. R. (2021b). Omitted level bias in multilevel research: an empirical test distinguishing block group, tract, and city effects of disadvantage on crime. *Justice Quarterly*, *38*(5), 792–826.

Wheeler, A. P. (2019). Quantifying the local and spatial effects of alcohol outlets on crime. *Crime & Delinquency*, *65*(6), 845-871. https://doi.org/10.1177/0011128718806692

White, G. F., Gainey, R. R., & Triplett, R. A. (2015). Alcohol outlets and neighborhood crime: A longitudinal analysis. *Crime & Delinquency*, *61*(6), 851-872. https://doi.org/10.1177/0011128712466386

Wilcox, P., & Eck, J. E. (2011). Criminology of the unpopular: implications for policy aimed at payday lending facilities. *Criminology & Public Policy*, *10*(2), 473–482. https://doi.org/10.1111/j.1745-9133.2011.00721.x

Wilcox, P., Cullen, F. T., & Feldmeyer, B. (2018). *Communities And Crime : An Enduring American Challenge* (Ser. Urban life, landscape, and policy). Temple University Press.

Wo, J. C. (2016). Community context of crime: A longitudinal examination of the effects of local institutions on neighborhood crime. *Crime & Delinquency, 62*(10), 1286-1312. https://doi.org/10.1177/0011128714542501

Wooldredge, J. (2002). Examining The (Ir)Relevance of Aggregation Bias for Multilevel Studies of Neighborhoods and Crime with an Example Comparing Census Tracts to Official Neighborhoods in Cincinnati. *Criminology, 40*(3), 681–710. https://doi.org/10.1111/j.1745-9125.2002.tb00970.x

Wortley, R. & Townsley, M. (2017). Environmental Criminology and Crime Analysis: Situating the Theory, Analytic Approach and Application. In R. Wortley & M. Townsley (Eds.), *Environmental Criminology and Crime Analysis, 2nd Edition* (pp.1-26). New York: Routledge.

Xu, J., & Griffiths, E. (2017). Shooting on the street: measuring the spatial influence of physical features on gun violence in a bounded street network. *Journal of Quantitative Criminology*, *33*(2), 237–253. https://doi.org/10.1007/s10940-016-9292-y

Zhang, H., & Peterson, M. P. (2007). A spatial analysis of neighborhood crime in Omaha, Nebraska using alternative measures of crime rates. *Internet Journal of Criminology*, *31*, 1-31.

Zhang, H., Suresh, G., & Qiu, Y. (2012). Issues in the aggregation and spatial analysis of neighborhood crime. *Annals of GIS*, *18*(3), 173-183. https://doi.org/10.1080/19475683.2012.691901

Appendix

VIF TABLES AND BIVARIATE CORRELATIONS

Table 21: Variance Inflation Factors (VIF) for Per Square Kilometer Models

	Union Method (Per square km)		**Update Method (Per square km)**	
	Violent	Property	Violent	Property
Buffer Zone	1.73	1.73	1.44	1.43
Economic Disadvantage	2.33	2.31	2.43	2.37
Percent White	2.28	2.10	2.21	2.06
Percent Renter	2.08	2.09	2.11	2.13
Percent Moved	1.86	1.84	1.84	1.83
Percent Male 15-24	1.34	1.33	1.31	1.29
Drug Incidents	1.29	1.29	2.32	2.33
Local Guardian Index	1.52	1.52	4.43	4.42
Crime Generator Index	1.46	1.46	4.29	4.29
Total Population	2.06	2.13	2.85	2.91
Spatial Weight	2.03	1.77	2.08	1.75
Mean VIF	1.82	1.78	2.48	2.44

Table 22: Variance Inflation Factors (VIF) for Per Capita Models

	Union Method (per capita)		**Update Method (per capita)**	
	Violent	Property	Violent	Property
Buffer Zone	1.31	1.31	1.35	1.34
Economic Disadvantage Index	2.30	2.28	2.39	2.33
Percent White	2.22	2.06	2.18	2.04
Percent Renter	2.10	2.10	2.15	2.14
Percent Moved	1.86	1.84	1.84	1.83
Percent Male 15-24	1.34	1.32	1.31	1.29
Drug Incidents	1.23	1.23	2.13	2.12
Local Guardian Index	1.52	1.52	3.72	3.71
Crime Generator Index	1.46	1.46	4.27	4.28
Area	1.46	1.52	1.35	1.41
Spatial Weight	2.02	1.76	2.08	1.79
Mean VIF	1.71	1.67	2.25	2.21

Table 23: Bivariate Correlation Matrix: Union Units

	Economic Disadvantage Index	Percent White	Percent Renter	Percent Moved	Percent Male 15-24	Drug Incidents	Local Guardian Index	Crime Generator Index	Area	Total Population	Spatial Weight (property)	Spatial Weight (violent)
Economic Disadvantage Index	1	*	*	*	*	*	*	*	*	*	*	*
Percent White	-0.67	1	*	*	*	*	*	*	*	*	*	*
Percent Renter	0.53	-0.52	1	*	*	*	*	*	*	*	*	*
Percent Moved	0.28	-0.22	0.56	1	*	*	*	*	*	*	*	*
Percent Male 15-24	0.08	-0.01	0.16	0.45	1	*	*	*	*	*	*	*
Drug Incidents	0.21	-0.22	0.13	0.20	0.21	1	*	*	*	*	*	*
Local Guardian Index	0.11	-0.10	0.09	0.09	0.05	0.21	1	*	*	*	*	*
Crime Generator Index	0.03	-0.01	0.08	0.08	0.05	0.24	0.51	1	*	*	*	*
Area (sq km)	-0.17	0.10	-0.19	-0.10	0.01	0.12	0.23	0.08	1	*	*	*
Total Population	-0.11	-0.02	-0.04	0.01	0.11	0.28	0.26	0.08	0.63	1	*	*
Spatial Weight (property)	0.57	-0.47	0.40	0.22	-0.02	0.07	0.08	0.03	-0.37	-0.32	1	*
Spatial Weight (violent)	0.62	-0.59	0.42	0.24	-0.05	0.09	0.12	0.04	-0.29	-0.24	----	1

Table 24: Bivariate Correlation Matrix: Update Units

	Economic Disadvantage Index	Percent White	Percent Renter	Percent Moved	Percent Male 15-24	Drug Incidents	Local Guardian Index	Crime Generator Index	Area	Total Population	Spatial Weight (property)	Spatial Weight (violent)
Economic Disadvantage Index	1	*	*	*	*	*	*	*	*	*	*	*
Percent White	-0.67	1	*	*	*	*	*	*	*	*	*	*
Percent Renter	0.53	-0.51	1	*	*	*	*	*	*	*	*	*
Percent Moved	0.27	-0.24	0.57	1	*	*	*	*	*	*	*	*
Percent Male 15-24	0.07	-0.02	0.13	0.41	1	*	*	*	*	*	*	*
Drug Incidents	0.21	-0.22	0.16	0.23	0.23	1	*	*	*	*	*	*
Local Guardian Index	0.11	-0.11	0.10	0.08	0.05	0.63	1	*	*	*	*	*
Crime Generator Index	0.09	-0.06	0.11	0.09	0.05	0.65	0.83	1	*	*	*	*
Area (sq km)	-0.20	0.13	-0.23	-0.11	0.02	0.13	0.20	0.14	1	*	*	*
Total Population	-0.07	-0.02	-0.00	0.06	0.12	0.59	0.69	0.60	0.43	1	*	*
Spatial Weight (property)	0.55	-0.42	0.37	0.19	-0.01	0.03	0.05	-0.00	-0.41	-0.24	1	*
Spatial Weight (violent)	0.62	-0.56	0.38	0.21	-0.05	0.07	0.07	0.00	-0.36	-0.21	----	1