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I, James D Kelsay, hereby submit this original work as part of the requirements for the degree of Doctor of Philosophy in Criminal Justice.

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Testing the Criminology of the Unpopular: The Influence of Street Usage Potential, Facility Density, & Facility Site Selection on Nearby Crime

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Testing the Criminology of the Unpopular: The Influence of Street Usage Potential, Facility Density, & Facility Site Selection on Nearby Crime

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ABSTRACT

Environmental criminology and empirical research suggest that certain facilities and characteristics of the street network facilitate crime opportunities. These facilities are often referred to as potentially criminogenic facilities because the routine activities associated with their specific functions are thought to create crime opportunities. However, some scholars have contended that it is not the type of facility, but the traffic generated by them, that is responsible for their associations with crime. A separate body of research has linked the betweenness of streets, or their usage potential, to elevated crime levels, suggesting that busier streets are associated with more crime opportunities. This dissertation seeks to determine whether the density of facilities, a proxy for busyness, or specific types of facilities are the more robust predictor of robberies in Cincinnati, OH. The current study also assesses how the betweenness of streets influences the relationship between facilities and robbery. In addition, the potential interrelationship between facility density, street block betweenness, and robberies is examined using a path model. Results suggest that the busyness of facilities appears to be a more robust predictor of robberies than their individual types, but a handful of individual facilities were linked to elevated robberies even after accounting for the business of streets. The path model indicates that 1) facility density and betweenness are both positively associated with robberies, 2) betweenness is linked to a higher density of facilities, and 3) a significant portion of the effect of betweenness on robberies is indirectly transmitted through facility density.

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I'd like to thank my mom for her consistent support of my academic endeavors. I would not have made it this far without you.

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CHAPTER 1: INTRODUCTION

Environmental criminology can be advanced with a better understanding of how people shape the environment around them, and how law, policies, government actions, and the economy shape the environment in which we live. – Brantingham & Brantingham (1999) p. 21.

Environmental criminology emphasizes the role of the physical environment in structuring human movement patterns and the spatial and temporal distribution of crime opportunities (Wortley & Mazerolle, 2008). Environmental criminology makes several propositions about the factors that influence when and where crime will occur. First, crime events require that a motivated offender meets a suitable target in the absence of capable guardianship at the same place and time (Cohen & Felson, 1979). Second, offenders seek situations in which the risk and effort required to commit a crime are outweighed by the potential rewards (Clarke & Cornish, 1985). Third, crime pattern theory asserts that features of the urban environment shape crime opportunities by facilitating routine activities and determining when and where offenders and targets meet (Brantingham & Brantingham, 1991; 1993; 1995). According to this perspective, activity nodes, or places at which people spend time, and paths, such as streets and the transportation network, create crime opportunities by attracting both offenders and potential targets to specific places and determining when and where their routine activities overlap.

These propositions are supported by research demonstrating that certain types of activity nodes, or facilities, influence the distribution of crime opportunities (see Groff & Lockwood, 2014 for a brief review). For instance, studies have shown that bars (Groff, 2011; Ratcliffe, 2012; Roncek & Maier, 1991), check cashing businesses (Kubrin, Squires, Graves, & Ousey, 2011; Kubrin & Hipp, 2016), and pawn shops (Bernasco & Block, 2011; Bernasco, Block, & Ruiter, 2013) experience elevated levels of crime. These facilities, and others, are often referred to as potentially criminogenic facilities because the routine activities associated with their specific functions are thought to create crime opportunities (Groff & Lockwood, 2014; McCord & Ratcliffe, 2009). However, some scholars have contended that it is not the type of facility, but the traffic generated by them that increases the likelihood crime will occur nearby (Wilcox & Eck, 2011). In other words, busier places will have more crime simply because there are more opportunities available.

Similarly, paths or streets facilitate human movement through urban space (Hillier, 2007; Hillier & Sahbaz, 2009). Research has shown that significant heterogeneity in crime levels exists between street segments, even in high crime areas (Weisburd, Groff, & Yang, 2012), and studies have demonstrated that some of this variation can be explained by street network features (Bevis & Nutter, 1977; Davies & Johnson, 2015). For example, streets with a greater usage potential, or betweenness, are often linked to higher levels of crime compared to roads with a lower expected usage potential (Davies & Johnson, 2015; Frith, Johnson, & Fry, 2017). This suggests that busier streets may have more crime because they increase the probability that offenders and targets converge with one another.

While studies have demonstrated that direct links between facilities, characteristics of the street network, and crime exist, additional research has found that external forces shape the distribution of facilities in urban areas; one of which is the structure of the street network. More specifically, evidence suggests that zoning ordinances (Ottaviano & Thisse, 2002; Shertzer, Twinam, & Walsh, 2018; Twinam, 2020), economic principles (Ellison, Glaeser, & Kerr, 2010; Krugman, 1991), and facility site selection decisions made by business marketing managers (Damavandi, Abdolvand, & Karimipour, 2018; Litz, 2014) simultaneously act to create clustering of facilities, or agglomeration (Glaeser, 2010). Moreover, many studies find that the density of economic activity in urban areas is positively associated with the accessibility and usage potential of the street network (Ortiz-Chao & Hillier, 2007; Porta et al., 2009; Scopa & Peponis, 2015; Wang, Chen, Xiu, & Zhang, 2014).

Together, this research suggests that there are several important issues about the relationships between facilities, the street network, and crime that remain unaddressed. First, it is unclear whether certain types of facilities are inherently criminogenic or whether it is the traffic generated by them that produces their observed criminogenic effects (Wilcox & Eck, 2011). Second, the betweenness, a proxy measure for usage potential, of streets may influence the relationship between facilities and crime. Although, there is a limited amount of research examining how facilities and features of the street network influence crime independently or in conjunction with one another. Finally, research suggests that not only do facilities and characteristics of the street network have direct associations with crime, but they are also interrelated. Because street network features are robust predictors of economic activity, the street network may exhibit an indirect association with crime *through* facility density. The aim of this dissertation is to examine the effects of individual facility types as well as their associated traffic on crime. In addition, this dissertation seeks to disentangle the effects of facilities and the street network on spatial crime patterns.

This dissertation will address several conditional research questions. First, this study will assess whether the traffic generated by facilities *or* their specific routine activities are responsible for their previously observed relationships with crime. This will involve a comparison of measures of individual facilities, which represent facility specific routine activities, and facility density, a proxy measure for busy places. Accordingly, the first research question asks: Are individual facilities or facility density the more robust predictor of crime? Next, if the analyses used to answer the first research question suggest that individual facilities are the more robust predictor of crime, this study will then examine whether street block betweenness explains the relationship between individual facilities and crime. Because betweenness is considered a proxy measure for traffic on streets, the relationship between individual facilities and crime may be due to the busyness of street blocks. Therefore, research question 2a asks: If individual facilities are the more robust predictor of crime, does street block betweenness confound the relationship between types of facilities and crime? However, if the analyses used to address the first research question indicate that facility density is the more robust predictor of crime, this would suggest that the busyness of facilities is responsible for their association with crime. In this case, this study will attempt to disentangle the interrelationship between street block betweenness, facility density, and crime. Addressing this research question entails an examination of the direct and indirect effects of betweenness and facility density on crime. Therefore, research question 2b asks: If facility density is the more robust predictor of crime, does street block betweenness influence the density of facilities and how do each of these proxy measures influence crime? Finally, if the analyses used to address research question 1 and 2a suggest that individual facilities are the more robust predictor of crime, and betweenness influences the relationship between individual facilities and crime, this study will proceed to address research question 3. Because facilities and betweenness are thought to influence crime independently, it may be possible that they have a joint influence on crime as well. Thus, research question 3 asks: If the effects of individual facilities on crime are influenced by street block betweenness, are there interactions between types of facilities and betweenness?

This dissertation proceeds as follows. Chapter Two reviews the theoretical and empirical literature on environmental criminology and crime opportunity, crime and place, the street network and crime, and a discussion of the research examining the influence of zoning, agglomeration, and facility site selection decisions on the location of facilities. Chapter Three outlines the proposed methodology of this study, including the research questions, study site, data, measures, and analytical plan. The results of the analyses used to address the research questions are included in Chapter Four. Chapter Five concludes with a discussion of the results of this study as well as the implications and limitations.

CHAPTER 2: THEORY & LITERATURE REVIEW

This chapter is organized in four parts. First, the environmental criminology based theoretical framework is presented. This will include a discussion of the three primary opportunity perspectives that comprise this framework. Second, research on the criminogenic influence of facilities is reviewed. Third, a discussion of the influence of street network features on crime is considered. The final section will review the literature examining how zoning laws, agglomeration economics, and facility site selection decisions geographically constrain economic activity, and how facility site selection is influenced by the street network.

Environmental Criminology

Traditional perspectives in criminology have largely focused on explaining criminality or the causes of criminal behavior (Akers, 1973; Gottfredson & Hirschi, 1990; Moffitt, 1993; Sampson & Laub, 1990). Such causes range from the biological roots of deviant behavior to the social forces that drive individuals to commit crimes. By contrast, environmental criminology attempts to explain *crime*, not *criminality.* More specifically, environmental criminology is concerned with the immediate situational circumstances that precipitate crime events (Wortley & Mazerolle, 2008). Rather than focusing on understanding why offenders commit crime, the aim of environmental criminology is to understand how situational dynamics and features of the immediate environment make crime events possible. For example, environmental criminologists might be concerned with understanding why certain types of facilities tend to be associated with elevated crime in their proximity, why specific streets in a city tend to have a disproportional amount of crime than others, or what features of the individual places or areas make them attractive to offenders. This section outlines several perspectives subsumed by environmental criminology. It includes a discussion of the propositions each perspective makes about the elements of opportunity that make crime events possible and the features of the environment that are posited to influence spatio-temporal patterns of crime.

Environmental criminology is comprised of a handful of interrelated theoretical perspectives. These include (1) routine activity theory, (2) the rational choice perspective, and (3) crime pattern theory. All three theoretical frames share a common underpinning: opportunity. Within each theoretical framework, the element of opportunity is highlighted as the precipitating condition that makes crime events possible. The following section serves as a review of each of these perspectives and illustrates how environmental criminology provides a sufficient framework for this dissertation.

Routine Activity Theory

Routine activity theory (RAT) was developed by Cohen and Felson (1979) as an explanation for rising predatory crime rates in the U.S. during the 1960s and 1970s. The authors argued that the daily routines of Americans underwent a significant change at the end of the second World War, including a dispersion of activities away from households. Increases in female labor force participation and single person headed households were identified as causes of an increase in burglaries, since many more households were left unattended during the day. Moreover, the authors identified an increase in the availability of valuable and portable goods during this time to account for a rise in shoplifting.

Cohen and Felson (1979) introduced two ideas to explain these rising crime rates using the associated shift in activities among the population. First, all direct-contact predatory crimes require the spatio-temporal convergence of a motivated offender and suitable target in the absence of capable guardianship (Cohen & Felson, 1979). Without any one of these elements, the opportunity for crime events is diminished. For example, residential burglars would have difficulty burglarizing homes if vigilant homeowners are present. Second, routine activities suggested that "any recurrent and prevalent activities which provide for basic population and individual needs" dictate the probability that offenders and targets meet in the absence of capable guardians (Cohen & Felson, 1979, p. 593). In other words, the likelihood of having contact with a motivated offender is contingent upon the types and frequencies of human activities.

Other scholars have elaborated on RAT. For example, Sherman, Gartin, and Buerger (1989) suggested that the characteristics of particular places can influence crime opportunities. The authors argued that the supply of targets and offenders as well as the level of guardianship varies among places, creating opportunities for crime at some locations but not at others. Felson (1986) and Eck (1994), building on the concept of guardianship, introduced controllers, or those with an explicit responsibility to prevent crime through the supervision of targets, offenders, or places. More specifically, this addendum to RAT proposes that guardians supervise suitable targets, handlers supervise motivated offenders, and place managers supervise places.

Rational Choice Perspective

The rational choice perspective (RC) posits that offenders engage in an at least somewhat rational cost-benefit analysis prior to committing a crime (Clarke & Cornish, 1985). This analysis – as simple or complex as it may be – involves a calculation of the potential risks and rewards associated with committing a particular offense, as well as the effort required to complete it (Clarke & Cornish, 1985). When offenders perceive that the potential risks and effort required outweigh the possible rewards, the likelihood of a crime occurring is reduced. Alternatively, situations in which an offender perceives the effort required to complete an offense and risk of apprehension or detection as low and the rewards as high, the risk of a crime occurring increases.

Ethnographic research involving interviews with active robbers and burglars about their decision-making processes support this perspective (Wright & Decker, 1994; 1997). Wright and Decker (1997) observed that although the decision-making process may differ for specific forms of crime, the primary motivating factor among nearly all of the interviewed offenders was a pressing need for cash. Most offenders also considered both the suitability of possible targets and the characteristics of locations when deciding to commit an offense. For example, offenders prefer selecting targets who are less likely to resist and more likely to be carrying cash or valuables in order to minimize risk and effort and maximize potential rewards (Wright & Decker, 1994; 1997). Offenders also tended to select targets in areas they were more familiar with and where a larger pool of potential targets were concentrated. Research has shown that offenders rarely ventured long distances from their home locations to search for targets because they were less knowledgeable about the risks associated with unfamiliar areas (Bernasco, 2014). Certain types of establishments, such as sporting and entertainment venues, are often preferred for target selection since patrons of these establishments were more likely to carry cash or other valuables that could be stolen (Wright & Decker, 1997).

The rational choice perspective provides a basis from which to understand offender decision-making. Accordingly, the offender decision-making process takes into account not only motivation to commit crime, but the characteristics of targets and places, as well as the nature of guardianship (Sherman et al., 1989).

Crime Pattern Theory

Crime pattern theory discusses how characteristics of the physical environment influence offender decision making and crime opportunities. Drawing on routine activity theory and the rational choice perspective, crime pattern theory (CPT) emphasizes the role of the physical environment in shaping the distribution of crime opportunities (Brantingham & Brantingham, 1991; 1993). The architects of CPT, Patricia and Paul Brantingham, highlight the physical layout of urban space as a structuring influence on routine activity patterns and facilitator of the convergence of targets and offenders. Moreover, this perspective provides useful insight into how the routine activities of offenders shape their search for crime opportunities.

According to CPT, studying crime events requires a consideration of how offenders view, learn about, and react to their surroundings, including how the immediate environment influences decisions to commit crime. The "environmental backcloth" which encompasses the uncountable, ever-changing, and dynamic factors that influence offender decision-making, provides cues to offenders about when and where to commit crime (Brantingham & Brantingham, 1991). CPT emphasizes the role of several specific components of the backcloth in providing offenders with cues and opportunities to commit crime.

Brantingham and Brantingham (1993) argue that three fundamental geometric features of urban space – nodes, paths, and edges – facilitate routine activities, determine the likelihood that offenders and targets converge, and shape the distribution of crime opportunities. Routine activity patterns involve spending time at *nodes*. For example, homes, places of employment, school, restaurants, recreation centers, and bars are all considered activity nodes that individuals frequent during the course of their routines. Nodes can create crime opportunities by generating activity or attracting offenders due to their reputations for providing criminal opportunities (Brantingham & Brantingham, 1995). For instance, sporting events generate crime by drawing fans for legitimate patronage, some of whom are offenders seeking crime opportunities. Alternatively, pawnshops are often associated with fencing stolen goods (Kubrin, Squires, Graves, & Ousey, 2011; McCord, Ratcliffe, Garcia, & Taylor, 2007).

Paths, including roads, streets, highways, and public transportation networks also shape routine activities (Brantingham & Brantingham, 1995). Paths provide the means to travel between activity nodes and are responsible for facilitating human movement. Offenders rely on paths to carry out their own legitimate routines, but also search for potential targets along and near the paths they use regularly. However, paths vary in usage and ability to expedite travel because of speed limits, traffic congestion, and degree to which they are connected to other streets. Motorists and pedestrians typically prefer routes that provide the quickest and most efficient travel between origin and destination, often avoiding congested, secluded, and sinuous streets (Hillier, 2004). As a result, crime opportunities are not distributed randomly or uniformly along paths, but rather busier streets may provide many more crime opportunities (Brantingham & Brantingham, 1991; 1993). The overall structure of street networks can also facilitate or restrict movement patterns of offenders and targets. For example, grid shaped street network layouts may expedite offender travel, exploration, and escape relative to more complicated networks that require greater effort and risk to traverse.

Finally, *edges* are physical or perceptual barriers or boundaries that create juxtapositions in the landscape, such that one area can be readily distinguished from another (Brantingham & Brantingham, 1991). For instance, major roads and highways, rivers, topographical features, changes in land use, and neighborhood boundaries constitute edges. Edges are associated with greater crime opportunities for a variety of reasons. For example, homes on neighborhood boundaries are more easily accessed and exited by burglars than those in the interior. When a transition from residential to commercial land use comprises an edge, residents may have difficulty distinguishing patrons of nearby businesses from potential offenders and may be less likely to exercise territoriality as a result (Rengert & Wasilchik, 1985). Major roads and highways may also create crime opportunities by attracting many users, including high concentrations of potential targets and offenders.

CPT suggests that these three features – nodes, paths, and edges – are responsible for shaping routine movement patterns, which in turn influence spatial and temporal crime patterns. The areas in which daily activity patterns generally confine our movements – along paths and between activity nodes – are known as *awareness spaces*. Over time and through frequent use, awareness spaces become known in finer detail relative to less frequently traveled areas and are referred to as *activity spaces*. CPT suggests several key notions about awareness and activity spaces and their relationship to crime (Brantingham & Brantingham, 1991). First, the process of developing familiarization of areas occurs for offenders and law-abiding individuals alike, since offenders spend most of their time engaging in legitimate activities. Second, offenders search for potential targets within or near their activity spaces because they develop specific knowledge about available crime opportunities. Third, crime will be elevated where the activity spaces of offenders overlap with those of potential targets or victims (Brantingham & Brantingham, 1993). Thus, offenders are far more likely to select targets to victimize in relative proximity to where their daily routines take place, and in areas where they are knowledgeable about the potential risks and rewards available. Where the activity spaces of the general law-abiding population overlap with those with criminal motivation, crime is more likely to occur.

Numerous studies support the propositions of CPT about how nodes, paths and edges influence crime. For example, many studies have shown that specific types of activity nodes, or facilities, are associated with elevated crime nearby (Bernasco & Block, 2011; McCord & Ratcliffe, 2007; Block & Block, 1995). Other research has assessed the influence of streets and street networks (Bevis & Nutter, 1977; Davies & Johnson, 2015; Hillier, 2004; Summers &

Johnson, 2017; White, 1990) and edges (Kim & Hipp, 2018) in shaping human movement and crime opportunities.

Crime & Place

As previously discussed, crime pattern theory proposes that crime opportunities will emerge near activity nodes either because they are associated with increased activity and/or because they attract offenders (Brantingham & Brantingham, 1993; 1995). This relationship between activity nodes and crime stems from the opportunity created by the convergence of offenders and targets or victims. Drawing on this perspective, Eck and colleagues (Eck & Weisburd, 1995; Eck, Clarke, & Guerette, 2007) came to refer to activity nodes as “facilities,” or places that share the same function. For example, bars, grocery stores, and schools are all examples of facilities. For the purposes of this study, the term “facilities” is used to represent the construct of activity nodes.

In this section, the extensive body of literature assessing the relationship between many types of facilities and crime is reviewed. Although each type of facility is discussed separately within its own subsection, it is important to note that some of the studies reviewed examined a single type of facility while others assessed how many types of facilities influence spatial crime patterns. This section illustrates the empirical support for the notion that facilities are associated with elevated opportunities for crime.

Bars

An extensive body of research has examined how bars influence crime in their proximity (see Groff & Lockwood, 2014). The well-established link between bars and crime is explained as a product of the nature of the activity that occurs at this type of facility, namely alcohol consumption and intoxication (Gruenewald, 2007). Specifically, inebriation among patrons that may lead to lower self-control and increases in violent behavior (Exum, 2006; Giancola, Saucier, & Gussler-Burkhardt, 2003; Pihl, Lau, & Assaad, 1997), and offenders' perception of heavily intoxicated patrons as more suitable targets (Cohen & Felson, 1979). Research also suggests that a large portion of homicide victims were intoxicated when murdered (Greenfeld & Henneberg, 2001), and greater alcohol consumption increases the likelihood of victimization (Testa & Parks, 1996). Moreover, bars may create crime opportunities simply by generating activity and/or attracting offenders.

The earliest research on the relationship between bars and crime was conducted by Roncek and his colleagues. Roncek and Bell (1981) showed that census blocks with bars in Cleveland, Ohio were associated with higher levels of index and violent crimes compared to blocks without bars. Two additional studies (Roncek & Pravatiner, 1989; Roncek & Maier, 1991) support this conclusion, replicating these findings in San Diego and Cleveland. Each of these studies accounted for neighborhood level characteristics in their analyses suggesting that bars, not neighborhood conditions, were driving the observed higher levels of index crimes.

More recently, Bernasco and colleagues (2011; 2013; 2017) assessed this relationship in Chicago, IL. In each study, the number of bars in census blocks was positively associated with street robbery counts, while statistically accounting for the presence of a variety of other crime generators and attractors in each block. These findings suggest that bars are associated with increased opportunities for street robbery, net of other potentially criminogenic facilities. However, Haberman and Ratcliffe (2015) showed that the number of bars in census blocks in Philadelphia, PA was not associated with street robberies, although blocks adjacent to census blocks with bars were associated with higher street robbery counts.

Other research has examined whether the presence of bars exerts a criminogenic impact on nearby areas using street blocks, street segments, or buffer zones as units of analysis rather than census level units. For instance, Murray and Roncek (2008) found that street blocks with bars were associated with more assaults than those without, although this relationship was not observed when buffer zones extending 500 feet from bars were used as the unit of analysis. Groff (2011) used Euclidean and street network distance buffers to assess the impact of bars on nearby areas, finding that bars were associated with higher levels of general crime on street segments between 2 and 3 blocks away. Ratcliffe (2011; 2012) found that bars were associated with higher levels of violent crime, including homicides, robberies, and assaults, up to 325 and 85 feet away, respectively. Finally, Groff (2014) arrived at a similar conclusion by demonstrating that both simple counts of bars on street segments and inverse distance weighted measures to bars were associated with higher levels of violent crime up to 2,800 feet away.

Alcohol Outlets

Scholars have also examined how "alcohol outlets" or other types of establishments that sell alcohol contribute to crime opportunities in their vicinity. These include bars, taverns, restaurants, liquor stores, and convenience stores. Similar mechanisms underlying the link between bars and crime are expected to create opportunities for crime near alcohol outlets, since they too attract many patrons, some of whom may be inebriated and/or carrying cash.

The majority of studies examining the influence of alcohol outlets on crime have demonstrated similar findings to those assessing bars and crime. A handful of these have linked alcohol outlets and the density of these establishments to higher levels of crime at the city (Scribner et al., 1998), neighborhood (Britt, Carlin, Toomey, & Wagenaar, 2005), and census tract or block level (Bernasco & Block, 2011; Bernasco et al., 2013; 2017; Gyimah-Brempong, 2001; Grubesic & Pridemore, 2011; Snowden & Pridemore, 2014; Speer et al., 1998). For example, Scribner and associates (1995) showed that alcohol outlets, both on-premise and off-premise, were associated with elevated rates of assault among cities in Los Angeles County. Another study, conducted in Minneapolis, observed that neighborhood alcohol outlet density was significantly and positively associated with violent crime rates (Britt et al., 2005). Speer and colleagues (1998) found that alcohol outlet density at both the census tract and block-level were salient predictors of violent crime, including homicide, rape, robbery and assault.

More recently, Grubesic & Pridemore (2011) showed that census block alcohol outlet density (off-premise) in Cincinnati, Ohio, was positively and significantly associated with simple and aggravated assaults. Bernasco and Block (2011) found that the number of liquor stores in Chicago census blocks was a robust predictor of elevated street robbery counts (see also Bernasco et al., 2013). Similar findings are evident among studies including non-violent crime, including vandalism, nuisances, public alcohol consumption, driving while intoxicated, and underage alcohol possession and consumption (Toomey et al., 2012). Both Day and his associates (2012) and Xu and Griffiths (2017) found that distance to alcohol outlets was significantly and negatively associated with serious violent crime, including homicide, robbery, and assault, and gun violence, respectively. Two studies, however, did not find significant relationships between alcohol outlet density and violent crimes such as homicides, robberies, rapes, and assaults (Gorman, Speer, Labovie, & Subaiya, 1998; Haberman & Ratcliffe, 2015). One potential explanation for this inconsistency is that both of these studies were conducted at the census block level – meaning that alcohol outlets could have been associated with elevated crime at a finer scale of analysis, such as the street block.

Some studies examined how alcohol outlets influence crime at a smaller scale of analysis using risk terrain modeling (RTM) (Barnum et al., 2017a; Kennedy et al., 2016; Barnum et al., 2017b). This approach entails dividing a geographic area into raster grid cells of a specified size, determining the number of potentially criminogenic facilities within each cell, then creating a composite measure of risk for crime within each cell based on its potentially criminogenic features (Kennedy et al., 2016). Two studies using risk terrain modeling (RTM) showed that proximity to alcohol outlets was associated with an elevated risk of arrest for narcotics (Barnum et al., 2017a) and robbery incidents (Barnum et al., 2017b). An additional study utilizing RTM linked the density of alcohol outlets to elevated aggravated assaults (Kennedy et al., 2016).

Cash Businesses

Research has also examined how many different cash-oriented businesses influence spatial crime patterns. Such facilities include barbershops, convenience stores, gas stations, grocery stores, laundromats, restaurants, and retail stores. Theoretically, these facilities may increase crime opportunities because they attract cash carrying patrons who are sometimes targeted by would-be offenders (St. Jean, 2007; Wright & Decker, 1997).

For instance, studies have found elevated burglaries in residential blocks with fast food and dine-in restaurants (Brantingham & Brantingham, 1981). Others have observed elevated levels of street robberies in census blocks containing barbershops, gas stations, grocery stores, laundromats, restaurants, and retail stores (Bernasco & Block, 2011; Bernasco et al., 2013; 2017). Haberman and Ratcliffe (2015) showed that census blocks containing corner stores and fast food establishments were associated with more robberies compared to those census blocks without such facilities. A handful of studies using RTM have linked restaurants, grocery stores, gas stations, and variety stores to elevated drug related arrests (Barnum et al., 2017a) and robberies (Barnum et al., 2017b). Moreover, research has shown that grocery stores were associated with aggravated assaults (Kennedy et al., 2016) and gun violence (Xu & Griffiths, 2017).

Entertainment Places

Scholars have also examined the relationships between a handful of facilities designed to provide entertainment and crime. These facilities include casinos, sports stadiums, hotels museums, movie theaters, and amusement parks – all of which generate activity among potential victims and offenders. Each of these facilities is likely to attract cash carrying patrons who may be targeted by offenders (Wright & Decker, 1997). However, some of these facilities have received far more empirical attention than others. Despite the limited amount of research on this subset of establishments, it is important to consider what is currently known about how entertainment related facilities influence crime patterns.

The relationship between casinos and crime has long been of interest to scholars because gambling is sometimes considered immoral and detrimental to communities (Miller & Schwartz, 1998). Despite the negative connotations associated with gambling, the empirical evidence for the link between casinos and crime is mixed, with some studies showing casinos are associated with elevated crime, while others do not. There is also variation in the units of analysis among studies examining this relationship. For example, Hakim and Buck (1989) and Buck and colleagues (1991) both observed that assaults, robberies, burglaries, and auto thefts were inversely related to distance to casinos at the city level in Atlantic City, suggesting that crime was higher near casinos but dissipated moving further away. Alternatively, studies conducted 1 and 2 years following the opening of a casino in Biloxi, MS showed no increase in Part I or II crimes (Giacopassi & Stitt, 1993; Chang, 1996). Stitt and colleagues (2003) conducted an analysis of crime in six cities with newly opened casinos finding heterogenous effects across sites, with some cities seeing Part I and II crime increases, some decreases, and others with relatively stable crime trends. At the county level, Thompson and Gazel (1996) observed that Wisconsin counties with a casino, and their adjoining counties, had significantly elevated violent crime and arrest rates compared to those without casinos.

At the micro-level, Barthe and Stitt (2007; 2009) showed that violent, property, and disorder crime levels in casino buffer zones were not substantively different from comparison zones without casinos. The most recent study to assess casinos and crime found that the opening of a casino in Philadelphia had no significant impact on violent crimes, including homicides, street robberies, and aggravated assaults, vehicle crimes, or drug crimes (Johnson & Ratcliffe, 2016). It is important to note, however, the difficulty associated with studying crime around casinos due to the changes in population that occur as a result of their operation (Stitt et al., 2003). Increases in population because of a casino may create difficulty in measuring the population at risk for victimization and lead to increases in potential guardianship (Stitt et al., 2003; Albanese, 1985).

Research has also considered how the presence of sports stadiums influence crime. Sports stadiums naturally draw large numbers of people to events held on certain days and times which may increase the likelihood that crime will occur. Moreover, because these events are often associated with alcohol consumption, this likelihood is elevated even further (Breetzke & Cohn, 2013). Supporting these ideas, many studies have observed that state and city crime levels are higher on days with sporting events compared to those without (Card & Dahl, 2011; Rees & Schnepel, 2009; Sivarajasingam, Moore, & Shepherd, 2005; Kalist & Lee, 2016; Yu, Mckinney, Caudill, & Mixon, 2016). Research has also indicated that, at the neighborhood-level, assaults and motor vehicle thefts tend to be higher following NHL games in Vancouver, BC (Kirk, 2008).

Using buffer zones around the NFL stadium in Charlotte, NC, Billings and Depkin (2011) showed that combined violent and property crime were significantly higher within a half-mile of the arena. However, they did not find elevated crime levels around the NBA arena in the same city. Additional studies conducted in Tshwane, South Africa (Breetzke & Cohn, 2013) and London, UK (Kurland, Johnson, & Tilley, 2014) concluded that incidents of assaultive violence and theft were higher after events were held at their respective stadiums. A study by Kurland (2019), on the other hand, found that robberies tended to increase near a stadium in Newark, NJ following some events but not others.

Hotels and motels have also been considered among studies in the crime and place literature. These facilities often attract tourists and travelers who tend to be unfamiliar with the area making them attractive targets for potential offenders (Wright & Decker, 1997). Smith and colleagues (2000) showed that street blocks with hotels or motels had significantly higher robberies than those without them. Similarly, studies have also found that the density of hotels and motels is positively associated with aggravated assaults (Drawve & Barnum, 2018). At the neighborhood level, Krupa and her associates (2019) observed that violent, property, and drug crime were higher in neighborhoods with motels (also see de Montigny et al., 2011). Finally, Haberman and his colleague (2019) found that the presence of hotels on street blocks in Cincinnati, OH were associated with a significant increase in the expected number of street robberies.

As previously mentioned, it is apparent that some facilities have received limited scholarly attention compared to others. While casinos and sports stadiums have been studied by many, facilities such as amusement parks and museums have not. These facilities may have received somewhat less scholarly attention due to their relative scarcity compared to other facility types. However, a recent study examined how a variety of additional entertainment-oriented facilities influence robbery patterns on street blocks in Cincinnati, OH. More specifically, Haberman et al. (2020) found that a composite measure of entertainment sites, including amusement parks, arcades, art galleries, bowling alleys, museums, theaters, as well as other local landmarks and attractions, was a robust predictor of elevated street robberies. Thus, although it appears that these facilities do link to spatial crime patterns, additional research on these establishments is needed to bolster the external validity of the findings of this study.

Fringe Banking

A number of studies have found that the presence of fringe banking establishments is associated with higher crime (Haberman & Ratcliffe, 2015; Kim & Hipp, 2018; Kubrin, Squires, Graves, & Ousey, 2011). These facilities include check cashing businesses, pawn shops, and payday lenders (Kubrin et al., 2011). Kubrin and her colleagues (2011) observed that the relationship between fringe banking establishments and crime is likely a product of the nature of these businesses as well as their location. Specifically, these facilities are more likely to be located in low-income or disadvantaged neighborhoods and those who patronize them often leave with large sums of cash. Offenders, who may also use fringe banking establishments to withdraw cash in order to purchase drugs or use pawn shops to fence stolen goods, are likely to be familiar with the opportunity to rob other patrons. For these reasons, fringe banking is often equated with neighborhood disorder and decline.

Consistent with this reasoning, Kubrin and colleagues (2011) showed that the number of payday lending establishments in census tracts was associated with higher violent crime, including homicide, robbery, rape, and assault, as well as property crime. At the census block-level, research has also demonstrated a positive association between the presence of payday lenders and check cashing businesses and robberies, aggravated assaults, and larcenies (Kubrin & Hipp, 2016). Additional analyses revealed that these facilities were also associated with higher crime on adjacent blocks, that crime tended to be higher near check cashers and payday lenders, and that these effects were stronger in areas with greater disadvantage.

Other studies have assessed the relationship between fringe banking and spatial crime patterns at the census block-level by examining multiple types of facilities simultaneously (Bernasco & Block 2011; Bernasco et al., 2013; 2017; Haberman & Ratcliffe, 2015). For example, Bernasco and colleagues (2011; 2013) showed that, net of other facilities, pawnshops were salient predictors of street robberies. Likewise, Haberman and Ratcliffe (2015) observed that pawnshops and check cashing establishments were positively associated with robberies, although temporal effects suggested that these facilities were not consistently criminogenic throughout the day. Finally, two studies using RTM did not find any significant relationship between the density of, or proximity to, pawn shops and drug crimes or robberies in their analyses (Barnum et al., 2017a; 2017b).

Parks

Compared to many other potentially criminogenic facilities, the relationship between the presence of parks and crime has received relatively little scholarly attention. This is surprising considering there are competing perspectives about how the presence of parks might influence spatial crime patterns (Brantingham & Brantingham, 1993; Jacobs, 1961). The majority of the research on this facility has focused on how parks influence perceptions of crime or potential crime prevention programs geared toward them (McCormick & Holland, 2015; Payne & Reinhard, 2016; Schroeder & Anderson, 1984; Westover, 1985).

However, there are a handful of studies which have empirically assessed how parks influence crime. For example, one study examined how proximity to a large park in Boston, MA influenced calls for service (Crewe, 2001). They found that calls for service tended to be higher near the park, and this effect decayed with distance. Moreover, calls for service near the park were greater than those originating near busy streets with commercial activity. Groff and McCord (2012) and McCord and Houser (2017) compared the density of crime in Philadelphia, PA and Louisville, KY parks, respectively, to areas nearby as well as randomly selected intersections in the city. Both studies observed a higher density of violent, property, and disorder incidents near parks than the comparison areas. Moreover, parks in Philadelphia have been shown to be associated with an elevated risk for street robbery (Haberman & Ratcliffe, 2015). More recently, Taylor and his colleagues (2019) examined how park features and community-level characteristics influenced crime in parks in Philadelphia. The results of this study indicate that park crime levels, including drug crimes, prostitution, gambling, homicides, assaults, and rapes, are strongly influenced by nearby crime, community social cohesion, community SES, and security fencing. This suggests that the degree to which parks are criminogenic is shaped by their surrounding context.

Studies have also found inverse or inconsistent effects of parks on crime. For instance, Stucky and Ottensman (2009) assessed how the percentage of 1000x1000 foot grid cell areas in Indianapolis, IN that were comprised by parks influenced crime. This study showed that parks were inversely associated with homicide and aggravated assault. One study found that heroin arrests, but not crack, cocaine, or marijuana arrests, tend to cluster near parks (Barnum et al., 2017a). A similar study linked parks with elevated levels of robbery in only one out of three cities examined (Kansas City, MO) (Barnum et al., 2017b).

Public Housing

The relationship between public housing and crime has long been of interest to researchers (Newman, 1972). Part of this interest stems from the common perception among the public that public housing leads to decreased property values and higher crime and disorder (Dear, 1992). The very definition of publicly subsidized housing implies that residents are low-income, and scholars have argued that public housing communities act as anchors of disadvantage (McNulty & Holloway, 2000). It follows that communities with exceptionally concentrated disadvantage will likely have higher crime for a variety of reasons such as attenuated informal social control (Krivo & Peterson, 1996; Sampson & Wilson, 1995).

A handful of studies have demonstrated that crime is higher in census blocks containing public housing compared to those without it or farther away (Holloway & McNulty, 2003; McNulty & Holloway, 2000; Roncek, Bell, & Francik, 1981). In their analysis of crime around public housing in Cleveland, for instance, Roncek et al. (1981) found that property and violent crime were more prevalent in census blocks with public housing as well as those adjacent to blocks with public housing. Although generally confirming the positive association between public housing and crime, both Holloway and McNulty (2003) and McNulty and Holloway (2000) observed that other factors, such as the percentage of black residents in census blocks or the number of units and design of communities also played a role in shaping crime opportunities near public housing. One study did not find a significant relationship between the quantity of public housing and the number of juveniles and adults appearing before local courts in postcode areas of Sydney, Australia (Weatherburn et al., 1999).

Other research has taken a micro-spatial approach to understanding crime around public housing communities (Fagan & Davies, 2000; Haberman, Groff, & Taylor, 2013; Holzman, Hyatt, & Kudrick, 2005). Fagan and Davies (2000) used 100 yard incrementally expanding buffer areas around public housing communities to examine how concentrations of violent crime changed as distance increased. They observed that rapes, robberies, assaults, and homicides were higher in the first 100-yard buffer zone around public housing relative to those 100-200 yards away. Similarly, Haberman and his colleagues (2013) used 50, 450, and 850 feet buffer areas around public housing communities to examine crime spillover effects from public housing. Like Fagan and Davies (2000), they observed that buffer zones closer to public housing communities tended to have more robberies, although this effect was inconsistent across all communities.

Schools & Universities

Scholars have also assessed how the presence of educational institutions influence crime. This potential relationship stems from the increased human activity associated with schools. Research has examined the various types of schools – elementary to universities – and whether or not crime patterns emerge as a result of their presence.

Roncek and his associates (1983; 1985) conducted several studies to determine whether public and private high schools were associated with higher crime in their vicinity. Specifically, Roncek and Lobosco (1983) and Roncek and Faggiani (1985) examined whether residential blocks near high schools in San Diego and Cleveland (respectively) had higher Part I crimes than residential blocks farther away. Both studies showed that crime tended to be higher in residential blocks near public but not private high schools. Similarly, Kautt and Roncek (2007) observed that proximity to public high schools was associated with an increased risk for burglary.

LaGrange (1999) examined both junior and senior high schools, both public and private, finding again that only the public junior and senior schools were associated with property crime and citizen complaints. Continuing this trend, more recent studies have shown that middle and high schools, but not elementary schools, tend to be associated with higher levels of assaults and drug crimes at the census block group level (Willits, Broidy, & Denman, 2013; 2015).

A handful of studies have also found that educational institutions influence crime while statistically controlling for other nearby facilities. Groff and Lockwood (2014), for example, observed that disorder incidents were associated with the presence of junior and senior high schools but not elementary schools. Moreover, three additional studies linked high schools to elevated levels of street robbery in two cities (Bernasco et al., 2013; 2017; Haberman & Ratcliffe, 2015). Studies utilizing RTM have also found that drug offenses and robberies tend to be associated with schools (Barnum et al., 2017a; 2017b), but not aggravated assault (Kennedy et al., 2016). Finally, neither Xu and Griffiths (2017) or Stucky & Ottensman (2009) were able to demonstrate a positive link between the presence of schools and gun violence or homicide and rape (respectively). In the latter of these studies, the presence of schools was inversely related to both crime types.

In addition, studies have also assessed whether colleges and universities are associated with crime. Specifically, La Rue (2013) and LaRue and Andresen (2015) both demonstrated that burglaries and motor vehicle thefts were positively associated with the presence of universities at the neighborhood level. One additional study examined variation in the concentration of property crime at different parts of a university campus (McGrath, Perumean-Chaney, & Sloan, 2014). This study showed a greater concentration of property crime incidents on campus near a medical center suggesting that crime near these facilities may be impacted by additional facilities nearby.

Public Transportation Nodes

Crime pattern theory asserts that public transportation networks, as well as roads, streets, and highways, are the pathways that structure routine activities and shape the convergence of potential targets and offenders (Brantingham & Brantingham, 1993; 1995). Stops along these routes, however, are more consistent with activity nodes because they generate activity rather than facilitate movement. Public bus, subway, and train stops constitute public transportation nodes, and these facilities have occupied the focus of a number of studies attempting to determine how their presence influences spatial crime patterns. It is important to consider that studying the potentially criminogenic effects of public transportation nodes present a unique challenge for researchers. More specifically, although crimes may occur at or near public transportation nodes, it is also possible for criminal offenses to take place while travelling between stops (Newton, 2014). Nevertheless, research has demonstrated that these facilities do indeed influence spatial crime patterns.

First, a handful of qualitative studies have examined how public transportation nodes influence crime (Levine, Wachs, & Shirazi, 1986; Loukaitou-Sideris, 1999; Kooi, 2015). For example, Loukaitou-Sideris (1999) used observational data to compare high and low crime bus stops across several U.S. cities. She determined that high crime bus stops tended to be those with many negative environmental attributes, such as low visibility, more escape routes, and signs of disorder. This suggests that situational and environmental characteristics play a role in shaping the degree to which bus stops are criminogenic. Other studies have come to similar conclusions, finding that bus stops in high crime neighborhoods tend to be associated with more crime than bus stops in low crime neighborhoods (Newton, 2008).

Second, bus stops have also been studied at the micro-level. For instance, Kooi (2013) matched block groups with and without bus stops on their level of social disorder and found that outdoor robberies, drug crimes, and weapons offenses were more highly concentrated in block groups with bus stops in Lansing, MI. Stucky & Smith (2017) demonstrated that, among 500x500 foot grid cells in Indianapolis, robberies, rapes, aggravated assaults, and burglaries were significantly higher when a bus stop was also present within the cell. However, they also showed that this effect was conditioned by the presence of facilities land use characteristics, such that, the effects of bus stops on crime was more pronounced in commercial and industrial areas but attenuated in residential areas. Similar studies using RTM have arrived at similar conclusions, suggesting that levels of violent and drug crimes were significantly higher near bus stops (Barnum et al., 2017a; Kennedy et al., 2016). In addition, Hart and Miethe (2014) used conjunctive analysis of case configurations to show that, compared to other facilities, bus stops were more frequently featured in high crime profiles.

Studies have also examined how the presence of train and subway stations influence crime. For example, Groff and Lockwood (2014) studied subway stations in Philadelphia, PA finding that net of community structural characteristics, street block distance to subway stations was inversely related to violent, property, and disorder crimes. Additional research on Philadelphia subway stations confirms this finding, suggesting that street robberies tend to concentrate near subway stations or in the census block in which they are sited (Haberman & Ratcliffe, 2015; McCord & Ratcliffe, 2009).

Bernasco & Block (2011) demonstrated that Chicago census blocks with rail stations were subject to more street robberies compared to census blocks without such stations. A handful of additional studies conducted on Chicago rail stations support this finding (Block & Davis, 1996; Bernasco et al., 2013; 2017). Finally, scholars have assessed whether the introduction of rail stations influences crime (Billings, Leland, & Swindell, 2011; Ridgeway & MacDonald, 2017). None of the available studies suggested that implementing rail stations had any appreciable impact on crime.

The Criminology of the Unpopular

The available crime and place research discussed above generally finds that many types of facilities have direct and positive effects on crime. This finding has led to the labeling of certain types of facilities as potentially criminogenic facilities because of the specific function of the establishment (Groff & Lockwood, 2014). For example, bars and fringe banking establishments have been characterized as “unpopular” facilities because of the specific types of activity that they generate. More specifically, bars are associated with inebriation and violence (Exum, 2006; Gruenwald, 2007) while check cashing businesses and pawn shops have been implicated as predatory or nefarious in nature because of their business practices and potential for use by drug and property crime offenders (Kubrin et al., 2011; Kubrin & Hipp, 2016). Thus, such facilities are “unpopular” among criminologists, policy makers, and the general public alike because of the potentially deleterious effects they are perceived to have on communities.

However, other scholars have argued that it is not the specific nature or function of the facility that generates crime (Wilcox & Eck, 2011). In their seminal article, The Criminology of the Unpopular: Implications for Policy Aimed at Payday Lending Facilities, Wilcox and Eck (2011) charge that the available research on the influence of facilities on crime has painted an inaccurate picture. They argue that while many facilities may exhibit a positive association with area crime rates, it is the traffic generated by individual facilities that is responsible for this association rather than the type of activity that takes place there. In other words, facilities impact crime indirectly through the traffic they generate, rather than directly through facility specific routine activities. For example, a high-traffic community center may generate more crime than a low-traffic payday lender despite the evidence suggesting that payday lenders are used by offenders and tend to cause economic hardship (Kubrin et al., 2011).

These arguments made by Wilcox and Eck (2011) suggests two key points. First, the type, or function, of facilities is not responsible for their aforementioned direct effects on crime. Second, in order to estimate the impact of facilities on crime, researchers must also account for the traffic they generate. To test these hypotheses, studies must include a measure of the traffic associated with particular places, which is often difficult to find (Felson & Boivin, 2015; Malleson & Andresen, 2016).

One potential method of satisfying this data limitation, is to account for the expected traffic via characteristics of the street network. The next section will show, studies have demonstrated the utility of examining how the properties of street networks that facilitate movement patterns through urban space influence crime (Davies & Bowers, 2018). By accounting for the expected usage potential of street blocks, as well as the presence of facilities, it may be possible to disentangle the relationship between the presence of facilities, traffic, and crime. The next section includes a thorough discussion of the studies examining how features of the street network shape crime patterns.

The Street Network

The street network plays an important role in shaping routine human movement patterns and by extension, the distribution of crime opportunities (Brantingham & Brantingham, 1993). CPT notes that paths, which include streets, highways, and public transportation networks, facilitate individual routine activities and determine when and where offenders meet suitable targets. Because paths structure the routines of offenders and the non-offending population alike, features of the streets and/or the surrounding street network influence the volume of targets, level of guardianship, and offender awareness of available crime opportunities (Brantingham & Brantingham, 1993). However, competing perspectives make different predictions about how the volume of traffic influences crime through guardianship (Jacobs, 1961; Newman, 1972).

CPT makes several important and interrelated assertions about how streets influence crime opportunities. First, streets shape the configuration of urban form and facilitate travel during our routine activities (Brantingham & Brantingham, 1993). For instance, we must use streets to travel between our homes and places of employment, school, and where leisure activities take place, and the street network determines the arrangement of these locations. Second, because offenders must also use streets during their own legitimate routine activities, the street network influences when and where they encounter crime opportunities, such as areas or locations with an abundance of suitable targets and/or low guardianship. Third, through frequent use of streets during their routine activities, offenders develop activity spaces, or those areas they are familiar with. It is within these activity spaces that offenders search for crime opportunities since they are more familiar with the risks and rewards available.

Crime patterns will emerge when and where the activity spaces of offenders and the non-offending persons overlap – including along paths (Brantingham & Brantingham, 1993). The characteristics of streets, including their position in the surrounding street network, influence the likelihood that activity spaces overlap (Davies & Johnson, 2015). Specifically, streets vary in their ability to expedite travel between destinations, and most people prefer to take the quickest most direct routes between destinations (Zipf, 1950). Thus, many more people, including offenders, will use certain streets or take certain routes because of their characteristics or position in the network. Generally, it is on busier streets that the overlap between activity spaces of offenders and the non-criminal population is more likely to occur (Brantingham & Brantingham, 1993). Moreover, less complex street networks, such as those in a grid format, facilitate offender exploration, access, and escape. Routes within such networks are likely to be preferred by those seeking to commit crime, since the risk of detection is lower when offenses can be completed and escaped from quickly. This is all to say that street network characteristics influence the distribution of crime opportunities by shaping routine activities and offender awareness.

However, there is some debate in the literature surrounding the nature of the relationship between street *usage* and crime. Jacobs (1961) argued that greater pedestrian activity on streets promotes guardianship and leads to lower crime as a result. In her seminal work, *Eyes on the Street*, Jacobs (1961) encouraged urban planners and architects to increase pedestrian thoroughfares and the ability of residents to monitor street activity through changes to physical design. She hypothesized that increased pedestrian activity and supervision would encourage social interaction between residents on streets and discourage crime through greater surveillance and vigilance.

Alternatively, Newman (1972) in his analysis of physical design characteristics of public housing communities, suggested that the accessibility of streets should be reduced to promote "defensible space" or territoriality among residents. Among the public housing communities he discussed, those with more accessible routes facilitating through travel were often those with higher crime. Community accessibility, he argued, allows potential offenders to explore the area and search for crime targets, while residents are unable to determine which pedestrians are legitimately present from those with a criminal purpose. Alternatively, less accessible street blocks, including cul-de-sacs, dead ends, and pedestrian only streets may encourage territoriality among residents and restrict outsiders. Those residing on less accessible streets may be more likely to intervene or discourage crime within their defined space, and offenders may perceive a greater risk of standing out or facing challenge by residents. Newman's (1972) arguments are consistent with the propositions of CPT; that greater community accessibility and street usage facilitate crime opportunities.

Both arguments by Jacobs (1961) and Newman (1972) concern guardianship.

Specifically, both of their ideas suggested that increased surveillance and territoriality among residents may reduce crime opportunities by increasing the likelihood that potential offenders are detected and challenged by guardians. However, these perspectives differ in the specific predictions they make about how traffic influences guardianship. While Jacobs argued that increases in pedestrian activity will lead to more extensive guardianship and less crime, Newman suggested that residential guardianship is diminished by increased pedestrian flow and associated with more crime.

Scholars have recently elaborated on the nature of guardianship at places, finding that the effectiveness of guardians is contingent upon their willingness to supervise and ability to detect potential offenders (Reynald, 2010). Thus, not all guardians are created equal, nor will the effects of guardianship manifest uniformly. For instance, higher pedestrian volume on streets may impede the ability of residents and others to detect or distinguish offenders (Newman, 1972). This is all to say that there is no clear consensus about how the volume of traffic on streets influence crime, although studies have attempted to address this debate. I turn next to the research examining the relationships between the street network and crime.

Numerous studies have assessed the role of the street characteristics and the street network in shaping crime patterns (Armitage, 2007; Bevis & Nutter, 1977; Davies & Johnson, 2015; Johnson & Bowers, 2010; Hillier, 2004; White, 1990). The theoretical frameworks for this body of research are derived from the mechanisms outlined by Jacobs (1961), Newman (1972), and/or environmental criminology (Brantingham & Brantingham, 1993). Some have examined street network structures from the perspective of network science (Newman, 2018), including graph theory (Bollobas, 2002) or space syntax (Hillier, 2006), which will be elaborated upon below. A guiding principle of these studies is that streets do not exist in isolation but are part of a larger network. Movement patterns rarely involve travel on a single street segment – they involve routes that span many segments. This suggests that to fully understand the relationship between streets and crime, it is important to consider not only the characteristics of streets, but their position in the larger network and how their position influences usage and behavior (Davies & Johnson, 2015).

The first empirical assessment of street networks examined how burglary patterns in Minneapolis (MN) were influenced by the characteristics of streets and street networks (Bevis & Nutter, 1977). First, at the micro-level, street block accessibility or connectivity, measured as the number of directions a street could be entered or exited, was assessed. Second, the macro-level influence of street network permeability, or the ratio of street blocks (i.e., edges) to intersections (i.e., vertices), on burglary risk was examined. The authors found that burglary risk was lowest on less accessible street blocks, including dead ends, cul-de-sacs, and "L" shaped roads, and higher on through and "T" shaped roads. At the macro level, census tracts with a more permeable street network layout, or higher ratio of blocks to edges, had higher rates of burglary even after accounting for neighborhood sociodemographics.

Later studies examined how the presence of interstate highways influence crime at the county level, with hypotheses suggesting that interstate highways increase an area's accessibility to offenders as well as transients or potential victims (Jarrell & Howsen, 1990; Martin, 1995; McCutcheon, Weaver, Huff-Corzine, & Burraston, 2016; Rephann, 1999). For example, Jarrell & Howsen (1990) found that interstate highway exits in Kentucky counties were positively associated with burglaries and robberies. Martin (1995) and Rephann (1999), respectively, observed that robberies and homicides in Oklahoma counties, and crime generally among rural U.S. counties, were significantly higher in those counties with interstate highways. More recently, studies have found that the number of interstate highway exits in Georgia counties was significantly and positively associated with robbery rates (McCutcheon et al., 2016).

At a finer scale of analysis, White (1990) assessed how street network connectivity, or permeability, at the neighborhood level influenced burglary patterns in Norfolk (VA). Like Bevis and Nutter (1977), White (1990) hypothesized that more permeable neighborhoods, or those with more connections to arterial roads, would be more attractive to burglars because they are easier to access and escape from. His results supported this hypothesis, demonstrating that burglary risk was higher in census tracts with a larger number of connections to traffic arteries while accounting for neighborhood level demographics. Alternatively, Ward and his associates (2014) found that neighborhood level accessibility, or the ratio of streets to intersections and cul-de-sacs in census block groups, was not significantly associated with burglary rates in Jacksonville (FL). However, they did find a significant interaction between neighborhood disadvantage and accessibility, indicating that in more disadvantaged neighborhoods greater accessibility led to lower burglary rates, and greater accessibility in less disadvantaged neighborhoods was associated with a significantly higher burglary rate. This suggests that accessibility matters more in less disadvantaged areas.

A handful of studies examined how street network characteristics influence crime risk at the level of the individual address (Armitage, 2007; Armitage, Monchuk, & Rogerson, 2011; Chang, 2011; Hillier, 2004). Armitage (2007) conducted a descriptive analysis of the features of over 1,000 homes in West Yorkshire (UK), including the type of street on which the home was located, to determine which characteristics were associated with burglary risk. Homes located on major roads, or those with greater traffic, were at the greatest risk of burglary, while homes on cul-de-sacs had the lowest risk. However, homes on cul-de-sacs with “leaky footpaths” or pedestrian walks with access to another road had an elevated risk for experiencing a burglary. Identical findings were observed by Armitage and her associates (2011) when they used multivariate regression using the same data (also see Armitage, 2004; Armitage et al., 2006). A similar study conducted in several South Korean cities determined that most burglaries occurred at buildings situated near alleys and footpaths (Chang, 2011).

Shu (2000) considered the relationship between street network accessibility and risk for residential burglary at three sites in a descriptive analysis. He included two separate measures of street integration and a third item to account for street connectivity. Global integration was calculated by determining the degree to which each street in the network was included in the simplest routes, or those with the fewest changes in direction, between all other streets. Local integration was calculated in the same manner, but within a shorter "three steps" radius. Both items are intended to capture a street's accessibility and potential for to-movement, or the likelihood that a street will be a destination of a trip along a network, since highly integrated roads are more easily accessed, and less integrated roads are more secluded or difficult to reach. Connectivity was the number of neighboring streets intersecting a focal street and reflected a street's permeability or through-movement. Streets with more connections to other segments are considered more permeable. Homes on streets of similar types were grouped together (e.g., those dwellings on streets with higher integration were grouped) and burglary rates were calculated and compared afterwards by dividing the total number of houses by the number of burglaries that occurred at them. He found that burglary rates were lower on streets with greater potential for movement, including more highly integrated and connected streets, while more secluded or less integrated streets such as cul-de-sacs, had the highest rates of burglary. Shu and Huang (2003), Hillier and Shu (2000), and Shu (2009) observed nearly identical findings in similar descriptive analyses of burglaries in several Taiwanese and British cities.

Following the example of Shu (2000), Hillier (2004) conducted a multi-site assessment of burglary risk among houses in London and an Australian city in which he assigned each dwelling a spatial value based on the integration and connectivity of the street segment it was situated on. Integration captured how close a focal street is to all others in the network by determining the number of streets that would need to be used to reach a focal street segment. A highly integrated street would require travel using fewer segments, whereas a more secluded or less integrated street would require the use of many more streets to reach it. Connectivity, or permeability, was measured as the number of streets intersecting a focal segment. Homes on streets with a higher integration were associated with a significantly lower risk of burglary, while those on more connected streets were significantly more likely to experience a burglary. These results suggest that street segment accessibility reduces the risk for burglary while permeability increases this risk.

A sizeable body of literature has also assessed how street network characteristics impact crime at the street segment-level (Beavon, Brantingham, & Brantingham, 1994; Davies & Bowers, 2018; Davies & Johnson, 2015; Frith, Johnson, & Fry, 2017; Johnson & Bowers, 2010; Shu, 2000; Summers & Johnson, 2017; Reis & Rosa, 2012). Beavon and his colleagues (1994) assessed how property crime was influenced by the accessibility and level of traffic flow of street segments in British Columbia (CAN). Accessibility was defined by the number of “turnings” into each street segment (e.g., a dead-end street in a four-way intersection would have three turns). Traffic flow was measured as the type of street each segment corresponded to, such as feeder roads, minor and major arteries, and highways, where the volume of expected traffic flow should increase moving from feeder roads to highways. Both the number of turns and expected traffic flow of street segments were positively and significantly associated with property crime even after for controlling for commercial establishments, high schools, and apartment buildings on street blocks. Johnson and Bowers (2010) used hierarchical linear modeling to assess how several street segment characteristics influenced burglary patterns in Merseyside (UK) net of important sociodemographics. They observed that the number of connections to other streets, the number of connections to major streets, major roads, and minor roads were associated with significantly higher expected burglary counts. Moreover, the risk of burglary was significantly lower on cul-de-sacs.

Reis and Rosa (2012) assessed correlations between street segment global and local integration, connectivity, and burglaries at two Brazilian sites. Both integration and connectivity were measured in the same manner as described by Hillier (2004). The authors did not find a significant correlation between global or local integration and rates of burglary at either site.

Drawing on graph theory metrics, Davies and Johnson (2015) showed that residential burglaries in Birmingham (UK) were significantly and positively associated with street segment betweenness, a proxy for usage potential. Their measure of betweenness entailed first determining the shortest paths between every possible pair of junctions (e.g., intersections) in the street network. Second, each time a street segment appeared in a shortest path between pairs of junctions, its betweenness increased by the proportion of shortest paths it fell into. This process was repeated for each pair of junctions in the network. The authors argued that this measure captured not only the likelihood of use, since higher betweenness is associated with expedited travel between destinations, but also served as a proxy for offender awareness space, since offenders are more likely to use and be aware of crime opportunities on more frequently used segments.

Frith and his colleagues (2017) examined how different types of betweenness influenced burglars' choice of homes among several towns in Buckinghamshire (UK). The authors used a similar measure of betweenness as Davies and Johnson (2015) but included only the shortest paths originating at the offenders' home locations. *Idiosyncratic betweenness*, therefore, estimated how likely an offender was to use each street segment. Moreover, they used several betweenness measures calculated within varying radii to account for differences in travel distance between groups where each measure included only those segments within a specified radius or distance from each junction. First, pedestrian betweenness was measured by including all segments within 20 minutes of travel time from each focal street. Second, local betweenness was measured by including all segments less than 10 minutes of travel time from each focal street. Third, nonlocal betweenness included all segments between 10 to 20 minutes of travel time from each focal street. Fourth, vehicular betweenness included all segments within 25 minutes of travel time from each focal street. These measures were used to account for pedestrian trips, trips more likely to be used by local or nonlocal residents, and trips requiring vehicular travel, respectively. Local and nonlocal betweenness were used to represent guardianship, or the movement of local passersby and nonlocal passersby. Their results suggested that offenders were significantly more likely to select homes within 10 minutes of their home location and on streets with higher nonlocal betweenness, but less likely to select homes on streets with higher local and vehicular betweenness.

A similar study was conducted in London (UK) in which the authors examined the influence of street segment connectivity, betweenness or choice, and integration measures on violent crime (Summers & Johnson, 2017). While betweenness was used to reflect potential "through-movement potential" or usage potential, integration represented "to-movement potential" or the likelihood that a focal block was a destination. Connectivity was measured as the number of segments each focal block intersected with. Local choice (i.e., betweenness) represented a street segments' betweenness calculated within an 800 meter radius, while global choice used a 3,000 meter radius. Local and global integration were measured as the number of segments that must be traversed to reach all other segments within 800 or 3,000 meters, respectively. These radii were used to reflect pedestrian and vehicular trips in the network. Street segments with higher integration and choice, at both the 800 and 3,000 meter radii, were linked to significantly higher violent crime counts. The connectivity of streets, however, was not significantly associated with violent crime. These results suggest that a street segment's position in the overall network is more important for understanding crime patterns than the characteristics of individual streets.

Finally, Davies and Bowers (2018) demonstrated that street segment betweenness was positively and significantly associated with assaults on London (UK) roads. Not only did they replicate the findings of Summers and Johnson (2017), they showed that betweenness was a significant predictor of assaults at four different levels of granularity. Specifically, betweenness was linked to assaults when calculated using a 1,000, 1,500, 2,000, and 2,500-meter radius, net of sociodemographics.

Overall, the studies assessing the effects of street network characteristics on crime largely supported the key propositions of CPT (Brantingham & Brantingham, 1993) and Newman's (1972) arguments regarding defensible space. Most of the studies reviewed suggested that features of streets and street networks such as connectivity, accessibility, permeability, and betweenness, all of which are hypothesized to increase usage and facilitate exploration and escape among offenders, are linked to elevated levels of crime. However, a few notable exceptions provided support for Jacobs' (1961) "eyes on the street" perspective suggesting that increased traffic on streets leads to more extensive guardianship and lower crime (Summers & Johnson, 2017).

There are also important limitations to consider in this body of evidence. For example, many studies analyzed crime patterns using large spatial units that may have masked spatial heterogeneity of crime at a finer scale of resolution, such as the street segment (Weisburd, 2015). More recently, scholars have recognized this limitation and begun to examine spatial crime patterns at a smaller unit of analysis (Gill, Wooditch, & Weisburd, 2017; Haberman, Sorg, & Ratcliffe, 2018). Others used only descriptive or bivariate tests of association, which restricted the authors from drawing statistical inferences from their findings or ruling out alternative explanations through statistical controls. Moreover, most of the evidence for the relationship between street networks and crime focused only on patterns of burglary, ignoring the possibility that other types of crime are impacted by movement patterns on streets (see Davies & Bowers, 2018 for a review of this literature). In addition, the more recently available studies that did use more appropriate units of analysis and examined crimes other than burglary were primarily conducted in the UK. Thus, it is necessary to conduct additional research in different settings to bolster the external validity of these findings.

Street Robberies

As will be discussed in the next chapter, the current study will examine how facilities and features of the street network influence street robberies. Street robberies in this study are defined as incidents involving an assailant unknown to the victim who steals property by force, or threat of force, in a public or semi-public location (Monk, Heinonen, & Eck, 2010). Although some of the research discussed in the preceding sections examined how facilities or features of the street network influence spatial robbery patterns, it is important to first consider the specific spatial and temporal dynamics of this particular offense.

Street robberies are a particularly serious form of violent predatory crime in which offenders typically engage in a consideration of risks and rewards prior to committing the offense (Cohen & Felson, 1979; Jacobs & Wright, 1999). For instance, interviews with active robbers indicate that their primary motivation is a need for cash (Jacobs & Wright, 1999; Wright & Decker, 1997). Research also suggests that robbers tend to choose crime sites they are more familiar with in order to reduce the risk of apprehension by capable guardians (Jacobs & Wright, 1999). Thus, offenders are likely to select locations where there are potential targets carrying cash within areas they are more familiar with.

Similarly, active robbers also tend to consider physical features of the environment when choosing potential crime sites (Jacobs & Wright, 1999; Wright & Decker, 1997). Robberies tend to occur near areas of dense commercial activity, or those locations with many facilities, associated with cash carrying patrons (Monk et al., 2010). In addition, because busier streets are more likely to be used by members of the general public, including offenders, they may be more hospitable robbery locations if there are more potential targets available nearby and more familiar to the offenders. These findings are consistent with crime pattern theory's assertion that paths and nodes structure routine activities and facilitate when and where offenders and targets meet (Brantingham & Brantingham, 1993). Specifically, offenders and suitable targets are more likely to converge at or near activity nodes and along busier paths where their routine movement patterns overlap. Thus, theory and empirical research indicates that robberies are likely to be committed near facilities, busier locations, and those places more familiar to offenders where the chances of encountering a suitable target carrying cash is greater.

Scholars have observed that robberies also have a temporal dimension that is important to consider (Haberman & Ratcliffe, 2015; Monk et al., 2010). Studies have shown that robberies tend to occur during the nighttime hours and on weekends, for example (Monk et al., 2010). As previously mentioned, active robbers prefer locations with more facilities as potential crime sites because they are more likely to encounter potential targets carrying cash (Wright & Decker, 1997). However, most facilities are only open for a select number of hours in the day, and/or days of the week, so activity levels near facilities are likely to vary greatly throughout the day due to routine activity patterns (Pred, 1981). The need to sleep and work mean that many people will be at home during the evening and nighttime hours and at their places of employment during the day (Hawley, 1950). This suggests, as others have, that spatial crime patterns will likely vary by time of day because the number of potential targets at crime sites will naturally vary due to routine activities and regular business hours among facilities (Haberman & Ratcliffe, 2015). Facilities that are open for business during specific hours will likely be associated with elevated crime during those times compared to others that are closed. For example, bars are often open only during the evening and late at night, which may result in elevated robbery levels around these times. Fewer robberies are likely to occur near bars during the morning or midday because they are not open to patrons at these times and generate little activity. Supporting this notion, Haberman and Ratcliffe (2015) found that drug treatment centers and pawn shops were associated with elevated robberies during their open hours, but not outside of these hours.

Together, this research suggests that offender decision making with respect to robberies is multifaceted. To satisfy their need to acquire cash and/or valuables, offenders seek crime sites where they are more familiar with the risks and rewards available, and those places where they are more likely to encounter suitable targets. This decision making process also appears to vary temporally, since potential targets may only be available at specific crime sites during certain types of the day.

Facility Site Selection

In the preceding sections, the theoretical and empirical research associated with the relationship between crime and the physical features of the environmental backcloth was discussed. Studies have demonstrated that the presence of facilities and properties of street networks, which shape routine activities and movement patterns, are essential for understanding spatial crime patterns. However, these features are interrelated. Just as street segments exist within a larger network that impacts the amount of activity and crime that occurs on them, the location or siting of facilities is contingent upon a number of other factors, including the structure of street networks (Damavandi et al., 2018; Porta et al., 2009). Moreover, several factors, such as zoning laws and the location of preexisting facilities, influence the selection of locations for new facilities (Damavandi et al., 2018; Goodchild, 1984; Ottaviano & Thisse, 2002). Together, these factors are responsible for creating agglomerations or clustering of facilities (Ellison et al., 2010). In this section, drawing from research outside of criminal justice and criminology, I describe the ways in which local government zoning ordinances and facility siting decisions influence the location and density of facilities on street segments.

Zoning

Simply stated, zoning refers to the regulation of land use by local governments (Fischel, 1999). Legal scholars have argued that zoning is an inherent ‘police power’ of the government (Freund, 1904). Generally, municipal governments establish zoning laws to constrain or permit specific types of land use to certain parcels of land or zones. Zones represent geographically contiguous areas that maintain specific classifications dictating how the land within these boundaries may be used or developed (Fischel, 2000). Zoning ordinances regulate characteristics such as building height, residential density, the location of a structure on its site, and the purpose of its use (Shertzer et al., 2018; Walters & Read, 2014). Thus, zoning commonly dictate that single and multi-family homes are restricted to residential zones while retail establishments and restaurants are confined to commercial zones.

Although laws regulating the use and development of land in cities have existed for hundreds of years, zoning was originally used in the United States to alleviate several common problems in the heavily industrialized and quickly expanding cities such as New York City and Chicago (Schwieterman & Caspall, 2006; Shertzer et al., 2018). Unplanned growth in major urban centers along with increasing numbers of immigrants led to seriously disorganized and overcrowded neighborhoods (Shertzer et al., 2016). Residential areas were threatened by the continued outward expansion of commercial and industrial interests. Moreover, the pollution associated with industrialization and a lack of infrastructure for water and waste disposal created a number of deleterious public health problems for densely populated areas (Hall, 2002; pp. 36-47; Schilling & Linton, 2005; Troesken, 2004).

These issues were a major concern for members of the Progressive Movement who, during the early 20th century, sought to alleviate overcrowding and protect the urban population from heightened pollution and disease (Fischler, 2018; 2020). For instance, some of these reformers pursued restrictions on certain types of undesirable facilities and land uses that posed serious harm to the public health of the city's inhabitants (Platt, 1996; Schilling & Linton, 2005). Progressive reformers found common cause with major real estate investors who also perceived the harmful consequences of unplanned rapid expansion in cities (Bassett, 1922; Shertzer et al., 2018). Although not as benevolent as their counterparts in the progressive movement, those with an interest in real estate development understood that the unbridled expansion of undesirable land uses could cause serious detriment to property values. More specifically, property values were expected to decline as industrial land uses and their harmful effects encroached upon residential areas. Thus, both groups intended to create a regulatory system of development to protect either the health and well-being of the urban public or their own financial interests.

What stemmed from these problems was the advent of comprehensive zoning ordinances. The first of these was passed in New York City in 1916 (Shertzer et al., 2018). Efforts to control the development and use of land within municipalities were aided by the U.S. Department of Commerce (1926), who disseminated a zoning ordinance template that was quickly adopted by 700 U.S. cities by 1926. Although slight variation in the development and adoption of zoning ordinances among cities was evident, most ordinances included a dual-map system to regulate land use. Dual-map systems are characterized by contiguous districts or zones allowing for specific types of land use (Twinam, 2020). More specifically, districts were created that allowed for residential, apartment, commercial, and industrial land uses. Many believed that the harmful effects of industrial and commercial land use on public health and property values would be curtailed by restricting them from expanding further into residential areas, while limits on the density and height of housing structures were used to address overcrowding.

Although these efforts were largely successful in structuring the continued development of U.S. cities, early municipal zoning was criticized for its malign influence on disadvantaged social groups. Specifically, scholars have noted the discriminatory way in which early zoning ordinances were used (Sharkey, 2013). Predominantly African American neighborhoods in Chicago were often zoned to allow for a higher density of residents which continued to exacerbate overcrowding and disease (Shertzer et al., 2016). These same neighborhoods were also typically zoned to allow for industrial land uses known to be hazardous to public health. Inequitable zoning, as this process is known, was commonly used to further disenfranchise African American residents and restrict them from the economic advantages provided to white citizens who owned property in protected residential areas (Been & Gupta, 1997; Hirt, 2018). Thus, black homeowners had to decide between living in hazardous and highly populated areas or sell their home for less than its original worth and move elsewhere (Shertzer et al., 2016). Studies have shown that the economic consequences of inequitable zoning persist in the form of lower property values and more undesirable land uses in many black communities compared to their white counterparts (Maantay, 2001; Rothwell, 2011; Schertzer et al., 2016).

Despite the historically malign uses of zoning, contemporary zoning laws are largely used to manage growth by regulating the location of undesirable land uses believed to be detrimental to residential property values (Fischel, 1999). For example, industrial land uses such as manufacturing plants, refineries, public utilities, and waste management are often restricted to the outskirts of cities to protect property values and insulate the public from any pollutants emitted from factories and other manufacturing-oriented facilities (Lejano & Smith, 2006). More generally, residential and industrial land uses are considered incompatible land uses in most, if not all, zoning ordinances today due to the potential for spillover of negative externalities (e.g., decreased property values and health hazards) (Fischel, 1999; Lejano & Smith, 2006). Exclusionary zoning, as the restriction of undesirable and incompatible land uses is known, is used not only to curtail the expansion of land uses hazardous to public health and property values, but also to exclude specific types of commercial establishments from siting in certain areas (Bates & Santerre, 1994). For instance, certain types of facilities such as sexually oriented businesses and off-premise alcohol establishments are sometimes restricted from siting in or near residential areas or other types of land uses such as schools, churches, and public parks (Tucker, 1997). Thus, modern zoning powers may be used to restrict land uses believed to be detrimental to public health, safety, and morality.

There are two important ex post facto realizations of zoning regulations. First, zoning maps were largely drawn by municipalities in accordance with the preexisting landscape of cities (Twinam, 2018: 2020; Shertzer et al., 2018). More specifically, dual map systems drawn by local municipalities were heavily influenced by preexisting land uses, such that areas previously identified as largely residential or industrial remained in these categories. Future developments, however, were required to adhere to the new zoning regulations. Although exemptions and exceptions to these regulations were possible, research has demonstrated the difficulty associated with acquiring permits to develop land for uses inconsistent with predetermined zoning classifications (Owens, 2004; Sampson, 2007). However, city planners have also devised mixed use zones that allow for a combination of differing, but compatible land uses such as those for commercial and residential purposes (Taleai, Sharifi, Sliuzas, & Mesgari, 2007; Walters & Read, 2014).

Second, similar land uses tend to be co-located (Ridley, Sloan, & Song, 2008; Shertzer et al., 2018; Twinam, 2017). Naturally, the dual map system creates contiguous zones that facilitate the clustering of the same types of land uses within each zone. For this reason, homes are situated in residential zones, factories in industrial zones, hospitals in institutional zones, and retail establishments in commercial zones. Of particular interest for the purposes of this study, is the clustering of commercial establishments. Although zoning ordinances inherently caused the geographic concentration of commercial establishments, additional processes reinforced this clustering, or agglomeration of facilities in urban areas.

Agglomeration

Despite the substantial impact of zoning laws on the clustering of commercial establishments, additional factors are responsible for concentrating commercial activity within cities. Research has demonstrated that, within the contiguous U.S., only around 3% of the land is classified as urban, and half of this acreage is used for commercial purposes (Bigelow & Borchers, 2017). Moreover, nearly ¾ of the U.S. population resides in urban areas and 1.5% of all the land in the U.S. is used to serve the vast majority of consumers. This suggests that commercial activity is highly concentrated geographically.

However, the spatial clustering of commercial activity is not a new phenomenon; human activity has nearly always been unevenly distributed (Mulligan, 1984). For instance, there is evidence of human settlements dating as far back as 10,000 years ago (Cohen, 1989). Prehistoric humans recognized the inherent benefits of living in groups and residing in specific locations with the most obvious advantage being the optimization of survival and reproduction (Cohen, 1989; Galor & Moav, 2007; Robson, 2010).

Later, such settlements evolved into villages, towns, and cities where the clustering of economic activities first began (Bairoch, 1991; Robson, 2010). These populations centers eventually became the primary locations for the processing of locally sourced raw materials and marketplaces for the sale of goods and services, and their inhabitants provided both labor and patronage (Marshall, 1920). For these reasons, much of the industrialization and commercialization that began during the 17th century occurred in urban areas where it was easier to access resources and labor. This suggests that the macro-level geographic concentration of economic activity largely followed the civilization and urbanization of human development.

More contemporary economists have long recognized that economic activity is highly concentrated at the micro-level as well (Ellison et al., 2010; Krugman, 1991; Marshall, 1920;

Saxenian, 1996). This phenomenon has been the focus of a relatively small body of research (Duranton & Kerr, 2018). More specifically, studies have examined what is commonly referred to as agglomeration, or the geographical clustering of firms, or profit driven enterprises (Behrens & Robert- Nicoud, 2014; Duranton & Kerr, 2018). Shopping malls, retail strip centers, and Silicon Valley are but a few examples of agglomeration because they are characterized by a high geographical concentration of retail and service-related activity as well as technological industry (Saxenian, 1996; Teller & Reutterer, 2008).

The original rationale motivating agglomeration economies is the belief that co-locating firms decreases transportation costs for customers, maximizes access to labor pools, and facilitates the exchange of knowledge and ideas (Brown, 1993; Glaeser, 2010; Duranton & Puga, 2003). In effect, firms benefit from a geographically concentrated economic landscape because customers have greater accessibility to their goods and services, while the firms themselves have greater access to local sources of labor and talent, as well as the potential to increase productivity and maximize innovation (Ottaviano & Thisse, 2002). Thus, agglomeration economies provide benefits to both consumers and businesses.

Others have pointed out an added benefit of agglomeration: firms (particularly those of the retail and specialty store varieties) may take advantage of the traffic generated by nearby establishments to increase their own profits (Damavandi et al., 2018; Litz, 2014; Nelson, 1958). From a consumer standpoint, sites with many retailers clustered together present a more attractive shopping destination in terms of expedience and variety (Brown, 1993). Individuals on a multi-purpose shopping trip may choose to visit a shopping mall or retail strip center, rather than a stand-alone establishment, because they provide a greater variety of products and offer consumers the chance to compare products before making a purchase (Brown, 1993; Huff, 1964;

Teller & Reutterer, 2008). This suggests that siting a facility near other preexisting firms may increase access to customers, as well as potential profits, even if nearby facilities are considered competitors (e.g., two clothing retailers sited near each other).

Facility Site Selection

The potential benefits of agglomeration continue to drive the siting, or selection of a location for facilities (Damavandi et al., 2018; Duranton & Puga, 2003; Glaeser, 2010), and are often considered by individuals responsible for selecting locations for the siting of new firms (Goodchild, 1984; Hernandez, Bennison, & Cornelius, 1998; Vandell & Carter, 1994). Specifically, research has demonstrated that location-allocation decisions by individual firms frequently take into account a number of factors when deciding where to site facilities, including the location of preexisting establishments and the transportation network (Booms & Bittner, 1981; Damavandi et al., 2018).

Much of this research is concerned with developing optimal models for the placement of firms (e.g., businesses or facilities) to maximize market exposure and profits (see Damavandi et al., 2018 for a review of these methods). Many studies have presented and/or tested models and algorithms comprised of the factors that businesses should consider when determining the sites of new facilities (Chen & Tsai, 2016; Suarez-Vega et al., 2011). The three primary models include central place theory (Christaller, 1933), the principle of minimum differentiation (Hotelling, 1929), and spatial interaction theory (Reilly, 1931).

The first of these models is referred to as the central place theory (Christaller, 1933). The basic tenet of central place theory is that there is an inverse association between demand for a good or service and distance to its source (Arcaute et al., 2015; Brown, 1993). Thus, consumer demand for a particular good or service will decline as it becomes less accessible to them.

Moreover, this perspective asserts that demand for products or services will diminish entirely once its source reaches a certain distance from the consumer (Brown, 1993). This is known as the “range of a good” (Arcaute et al., 2015). Ultimately, central place theory reflects the notion that consumer accessibility of a good or service is tied to transportation costs, and individuals prefer to patronize establishments that are closer to them geographically.

Alternatively, the principle of minimum differentiation posits that demand for a product is contingent upon the supplier’s distance from their competitors (Hotelling, 1929; Litz, 2014; Nelson, 1958). Under this perspective, consumer distance from the source of a product is believed to influence demand less than the distance from alternative sources of the same good. For example, this principle continues to guide the siting of automobile dealerships who are often co-located (Damavandi et al., 2018). From this view, consumer demand for products is seen as inelastic, or unchanging regardless of transportation costs.

The third of these models guiding the selection of locations for facilities is known as spatial interaction theory (Reilly, 1931). Spatial interaction theory proposes that consumers consider both the accessibility of a store’s location and the attractiveness of their product (Litz, 2014). More specifically, demand for a product is contingent upon the proximity of the store’s location and the quality of the products sold there. This model suggests that individuals may travel longer distances for more attractive goods even if similar products are available closer to them. Later additions to this perspective include a model for the spatial distribution of retailers (Wilson, 1967), which suggest that retailers should also consider the locations of their competitors because they must compete for a limited market share (Piovani et al., 2017). This addendum is reinforced by the finding that consumers often select shopping locations based on their utility, which includes the potential for multi-purpose shopping trips (Huff, 1964; Teller &

Reutterer, 2008).

Among these perspectives, there are two primary factors that drive the siting of facilities, both of which are included in the calculations for selecting a facility's location. First, all three models of facility site selection require some measure of distance (Damavandi et al., 2018). The central place theory emphasizes that consumer distance from demand sources be minimized. The principle of minimum differentiation asserts that distance between suppliers and their competitors be minimized. Spatial interaction theory suggests that although consumers do consider product attractiveness, they also consider transportation costs. This means that regardless of which model a retailer uses to site facilities, they must measure the distance between demand and supply *or* supply and competition.

In practice, these models involve calculating the distance from population centers, such as residential areas, to potential locations for the siting of a facility (Kubis & Hartmann, 2007; Litz, 2014; Suarez-Vega et al., 2011). Naturally, because most consumers will use the street network in their travels to purchase goods or services, scholars have applied the same space syntax measures, discussed in an earlier section, to determine the optimal location for facilities (Porta et al., 2009; Suarez-Vega et al., 2011). For instance, central place theory and the principle of differentiation are most consistent with measures of centrality (Hillier, Hanson, & Peponis, 1984; Porta et al., 2009) while spatial interaction theory shares similarities with the gravity metric (Damavandi et al., 2018). Each of these metrics include either the Euclidean or street network distance (e.g., Manhattan distance) from population centers to a potential location for a facility (Storme & Witlox, 2016). Recall that space syntax measures are used to estimate the movement potential of streets within a network (Hillier, 1996). In effect, retailers use space syntax measures in their determination of optimal locations because they provide an estimate of consumer accessibility and street traffic, which are essential among profit driven enterprises (Brown, 1993; Hillier et al., 1993).

Second, the location of competing suppliers is important for facility site selection decisions (Brown, 1993; Goodchild, 1984; Vandell & Carter, 1994). Consistent with each of the three models above, it is beneficial for marketing managers to select locations that are as close, or closer, to population centers than their competitors. Moreover, the principle of minimum differentiation goes further by suggesting that optimal locations are those that are as close to competitors as possible. Even spatial interaction theory appears to suggest that retailers should co-locate near similar facilities to increase competition (Brown, 1993; Huff 1964), which is consistent with consumer preferences (Teller & Reutterer, 2008). Thus, business marketing decisions reinforce the agglomeration of economic activities, particularly in urban areas near large population centers.

A number of studies have examined the former proposition. More specifically, studies have revealed that street network features – often proxy measures for accessibility and/or usage potential – are highly correlated with commercial land use or density at the census tract, area, or street segment level. For instance, using London (UK) as an example, Hillier and colleagues (1993) demonstrated a strong positive correlation between street network integration (e.g., to movement potential or accessibility) and retail activity. Similarly, Kim and Dong (2002) showed that office building density in two different areas of Seoul (SK) was positively correlated with street network connectivity and integration.

Mora (2003) studied the relationship between the grid shaped street system in Barcelona (ES) and commercial activity using space syntax measures finding that, among Barcelona districts, those with more highly integrated streets tended to have denser commercial and retail activity. In Amsterdam (HL), van Nes (2005) assessed how different types of shopping environments are influenced by street network characteristics. Specifically, they examined how different types of retail areas were associated with the connectivity of the street network at a micro or meso scale (e.g., local vs. global connectivity). Certain types of retailers, such as automobile dealers, were associated with shopping areas with greater connectivity at a meso scale, while concentrations of pedestrian establishments tended to be located near areas with higher connectivity at the micro scale. A similar study conducted in Mexico City (MX) found that connectivity and integration were strong predictors of retail activity, but inversely related to residential land use (Ortiz-Chao & Hillier, 2007). Moreover, larger retailers tended to be located in areas with high global connectivity while small retailers were associated with a local measure of connectivity. Both of these studies suggest that commercial establishments designed to serve large geographic areas are often located near streets that are highly connected globally, while smaller facilities are associated with locally connected portions of the street network.

In Baton Rouge (LA), Wang et al. (2011) assessed the relationship between the average street centrality and land use intensity at the census tract level. The authors used three street centrality measures – closeness, betweenness, and straightness – to determine which of them was the more robust predictor of the density of economic activity, measured using kernel density estimation (KDE). Results suggested that employment and land use density were significantly associated with each centrality measure, but closeness was stronger predictor among them.

Using a similar procedure in Barcelona (ES), Porta and his associates (2012) observed that each of the centrality measures were highly correlated with the density of retail and gross economic activity. Both studies suggest that the location of dense commercial activity hinges upon multiple features of the street network. In Changchun, China, Wang and colleagues (2014) used the same method to examine how the three aforementioned centrality measures influenced the siting of different types of retail stores. This study showed that the intensity of land use (measured using KDE) was shaped by street network centrality overall, but there was significant variation among types of stores in terms of their "preferred" measure of centrality. More specifically, specialty stores were more strongly associated with closeness, while department stores and grocery stores were linked to betweenness. Finally, one study conducted at the level of the street segment in Buenos Aires (AR) found that connectivity and betweenness were robust predictors of the density of retail street-frontage (Scoppa & Peponis, 2015). These findings were evident even after accounting for the proximity of the central business district, suggesting that street network centrality plays a significant role in shaping the distribution of commercial activity.

To summarize, there are several political and economic forces that drive the concentration of economic activity. At an aggregate level, zoning laws tend to create areas with similar types of land uses. Within commercial zones, agglomeration economics reinforce this concentration even further by asserting that facilities should be co-located in order to maximize their exposure to consumers. Finally, business marketing managers constrain the geography of retailers even more by siting facilities based on features of the street network and the location of competitors. This is all to say that the economic landscape is the product of several factors, all of which have confined facilities to a very small amount of space.

Current Study

The literature review above has demonstrated four key points that help frame the current study. First, environmental criminology suggests that features of urban space, including nodes and paths, shape crime opportunities by facilitating the convergence of potential victims and offenders (Brantingham & Brantingham, 1993; 1995). Second, and supportive of the first point, there are many nodes or facilities that research has found to influence spatial crime patterns (e.g., Bernasco & Block, 2011; Groff & Lockwood, 2014; Kubrin et al., 2011; McCord & Ratcliffe, 2009). Some of these facilities, posited to increase crime opportunities due to their function or nature, have been labeled as "criminogenic facilities." Third, features of the street network also shape crime opportunities by structuring the routine activities of offenders and victims (e.g., Beavon et al., 1994; Bevis & Nutter, 1977; Davies & Bowers, 2018; Davies & Johnson, 2015). Busier streets, including those with higher betweenness, are often found to be associated with elevated crime levels (Davies & Bowers, 2018). Finally, many of the same facilities linked to crime patterns tend to be highly concentrated, and this concentration is influenced by features of the street network (e.g., Porta et al., 2009; Scopa & Peponis, 2015; Wang et al., 2014). This research has demonstrated that the density of commercial activity in urban space tends to increase in areas where street traffic is greater. Thus, the available literature indicates that there are direct links between facilities and crime, street network characteristics and crime, and facility density and features of the street network.

However, there are a number of limitations and empirical questions within this body of evidence that this study will attempt to address. First, scholars have argued that to capture the true extent of the influence of facilities on crime, studies must account for the traffic they generate (Wilcox & Eck, 2011). Specifically, Wilcox and Eck (2011) suggest that it may not be the type of facilities present that generates crime, but their associated traffic. This suggests that; 1) the nature or function of facilities is not responsible for their association with crime, 2) facilities affect crime patterns through their generated traffic, and 3) the density of facilities should be a more robust predictor of crime than measures of individual facilities. This critique is in direct opposition to much of the available literature surrounding the effects of facilities on crime. More specifically, many previous studies in this area point to facility specific routine activities to explain their observed relationships with crime (e.g., Groff & Lockwood, McCord & Ratcliffe, 2009). For instance, the relationship between bars and crime is theorized to result from intoxicated patrons who are considered more suitable robbery targets by offenders (Groff & Lockwood, 2014; Wright & Decker, 1997). Similarly, customers of pawn shops and check cashing businesses often leave these facilities carrying large amounts of cash, which makes them attractive targets to active street robbers (Bernasco & Block, 2009; Kubrin & Hipp, 2016). The critique raised by Wilcox and Eck (2011) charges that facility specific routine activities are inconsequential, arguing that criminogenic bars (and any other type of facility) have more crime because they are busier places. Thus, it is unclear whether it is facility specific routine activities or "busyness" that is responsible for the observed relationships between facilities and crime.

Second, although research has demonstrated that characteristics of the street network, such as betweenness (Davies & Bowers, 2018), and facilities (e.g., Groff & Lockwood, 2014) have independent relationships with crime, it remains unclear how or whether both of these features influence crime when considered together. For example, many studies assessing the effects of individual facilities on crime do not account for the features of the street network (e.g., Bernasco & Block, 2011; Kubrin et al., 2011). This indicates that much of the past research on potentially criminogenic facilities and crime may have overlooked the influence of the street network on crime. In other words, it is possible that facilities and street network characteristics shape crime patterns together. These relationships could take at least two forms: 1) The busyness of streets could confound the relationship between facilities and crime if Wilcox and Eck (2011) are correct *or* 2) facilities may exhibit interactive effects with characteristics of the street network (Felson, 2006). For instance, if the busyness of streets explains the relationship between facilities and crime, it suggests that busy streets confound the relationship between individual facilities and crime. Alternatively, facilities located on busier streets may be especially criminogenic compared to facilities located on streets with lower traffic (i.e., interaction). These possibilities remain unexplored.

Third, there is evidence to suggest that features of the street network predict the density of facilities (e.g., Omer & Goldblatt, 2016; Porta et al., 2009; Wang et al., 2014). Recall that the available literature indicates that facilities and the street network influence spatial crime patterns (Davies & Bowers, 2018; Groff & Lockwood, 2014). If facility density is a product of the street network, it seems plausible that an indirect path between features of the street network and crime *through* facility density may exist.

Finally, nearly all the aforementioned studies examining the effects of the street network on crime and the relationship between the street network and facility density have been conducted outside of the U.S. Because scholars have more vigorously investigated these relationships in international contexts compared to their American counterparts, there are concerns regarding the generalizability of their findings to other sites. In other words, it is unclear whether similar findings will be observed among urban areas in the U.S.

The current study seeks to address this critique (Wilcox & Eck, 2011) and fill these gaps in the literature by examining how facilities, facility density, and street block betweenness shape spatial street robbery patterns in Cincinnati, OH. Chapter 3, presented next, describes the methods and data used to address these issues. This includes a discussion of the research questions developed from the literature reviewed above.

CHAPTER 3: DATA & METHOD

The preceding sections have demonstrated several important concepts. First, environmental criminology suggests that crime opportunities are shaped by the physical features of urban space because they facilitate routine activities and movement patterns (Brantingham & Brantingham, 1993). Second, two separate bodies of literature show that facilities (Bernasco & Block, 2011; Groff & Lockwood, 2014) and features of the street network (Davies & Bowers, 2018) correlate with crime. Third, there are several economic forces that geographically concentrate economic activity (Damavandi et al., 2018), such as facilities, and the siting of facilities is often contingent upon the features of the street network (Porta et al., 2009; Wang et al., 2014).

However, scholars have hypothesized that the traffic generated by facilities, or their busyness, may be responsible for their association with crime rather than their specific function (e.g., alcohol purchases or check cashing) (e.g., Wilcox & Eck, 2011). It is also unclear whether or how facilities and features of the street network might shape crime patterns when considered together. Moreover, because street network characteristics influence the density of facilities, it is possible that street network features also influence crime *through* facility density. This study aims to disentangle the relationships between facilities, features of the street network, and crime. In the following section, this study's research questions, site, data, and analytical plan are outlined.

Research Questions

This study aims to answer several research questions derived from the literature reviewed in the preceding sections and the critique raised by Wilcox and Eck (2011) about the relationship between facilities and crime. In so doing, the current study seeks to fill gaps in the empirical knowledge associated with the relationships between facilities and crime. These relationships and their associated research questions are described below.

First, the critique issued by Wilcox and Eck (2011) suggests that the relationship between facilities and crime is a result of their traffic rather than their type or function. In other words, busyness – not facility specific routine activities – is responsible for their observed relationships with crime. To test this proposition, this study will assess how measures of individual facilities and facility density compare in their explanation of spatial crime levels. Measures of individual facilities are consistent with much of the available research on potentially criminogenic facilities, including the assertion that facility specific routine activities are responsible for their association with crime. Alternatively, a measure of the density of facilities ignores their specific types and routine activities by considering them as an agglomeration and proxy measure of busyness, since dense commercial activity is expected to spur increased traffic (Wilcox & Eck, 2011). If Wilcox and Eck's (2011) hypothesis can be supported, facility density should be a stronger predictor of crime than their individual counterparts. This leads to the following research question:

Research Question 1: Are individual facilities or facility density the more robust predictor of crime?

Because this first research question will result in one of two answers (i.e., either individual facilities or facility density will be the more robust predictor of crime), this study includes additional research questions that are conditional in nature as suggested by the underlying theoretical mechanisms being tested in this study. More specifically, if individual facilities are the more robust predictor of crime, this study will proceed to address research question 2a and 3. If facility density is found to be the more robust predictor of crime, this study will proceed to address research question 2b. For clarity, each of these research questions and their associated mechanisms are summarized in Table 1.

Following research question 1, if individual facilities are the more robust correlates of spatial crime levels, it suggests that the relationship between facilities and crime are due to facility specific routine activities. However, it remains to be seen how the relationship between facilities and crime might be impacted by characteristics of the street network. Research has demonstrated that betweenness – or the expected street block traffic – is positively associated with crime levels (Davies & Bowers, 2018). This suggests that crime opportunities tend to be more prevalent on busier streets. It is not readily apparent whether statistically accounting for street block betweenness might attenuate the relationship between facilities and crime levels, since both measures may exhibit associations with crime. For example, although it may appear that certain facilities are associated with elevated crime, they may be simply located on busier streets. In this scenario, the busyness of streets may be responsible for their observed association with crime, thereby confounding the relationship between facilities and crime. As such, this study will assess whether the effects of facilities on crime are confounded by the traffic facilitated by the street network (if individual facilities better explain spatial crime levels). Accordingly, this research question was posed:

Research Question 2a: If individual facilities are the more robust predictor of crime, does street block betweenness confound the relationship between types of facilities and crime?

If results from this study indicate that facility density is the more robust predictor of crime, it suggests that Wilcox and Eck's (2011) hypothesis that the relationship between facilities and crime is due to busyness is supported. In this case, busyness, or the traffic generated by facilities, may be responsible for the previously observed relationships between facilities and crime and not the specific routine activities associated with certain types of facilities.

The available literature suggests that an interrelationship exists between the structure of the street network and the distribution of facilities. Studies have shown that commercial activity tends to be highly concentrated generally, and even more so on streets with certain characteristics, such as, accessibility and usage (Porta et al., 2009; Wang et al., 2011). For example, facility site selection decisions often consider the traffic and accessibility of the streets surrounding potential locations (Damavandi et al., 2018; Litz, 2014). This means that facilities may "self-select" onto busier streets. At the same time, both facilities (Bernasco & Block, 2011; Groff & Lockwood, 2014) and the street network features (Davies & Johnson, 2015; Summers & Johnson, 2017) are often positively associated with crime when considered independently. This empirically supported interrelationship suggests that disentangling the effects of each feature upon one another is needed. Moreover, consistent with the arguments of Wilcox and Eck (2011), the traffic generated by the street network should maintain a relationship with crime, independent of the effects of facility density. Thus, this research question was included to address these issues:

Research Question 2b: If facility density is the more robust predictor of crime, does street block betweenness influence the density of facilities and how do each of these proxy measures influence crime?

Table 1. Summary of Research Questions, Theory, Mechanisms, & Analytic Plan

Research Question	Theoretical Idea Tested	Measure/Mechanism*	Analytical Approach
Research Question 1: Are individual facilities or facility density the more robust predictor of crime?	If individual facilities are the more robust predictors of crime, then it suggests that crime is a result of facility specific routine activities (RQ 2a; RQ 3). If facility density is the more robust predictor of crime, then it suggests that busyness is responsible for their association with crime (RQ 2b).	Individual Facilities – Facility specific routine activities Facility Density – Human movement volume ("Busy Places")	Negative binomial regression and model fit comparison.
Research Question 2a: If individual facilities are the more robust predictor of crime, does street block betweenness confound the relationship between types of facilities and crime?	The relationship between individual facilities and crime may be confounded by the busyness of street blocks.	Individual Facilities – Facility specific routine activities Betweenness – Human Movement Volume ("Busy Streets")	Add betweenness to negative binomial regression model and assess change in individual facility coefficients.
Research Question 2b: If facility density is the more robust predictor of crime, does street block betweenness influence the density of facilities and how do each of these proxy measures influence crime?	Facilities may be more likely to 'self-select' onto busier streets, but each can shape crime patterns. Both facility density and betweenness are proxies for human movement, so it is unclear whether they both simultaneously influence crime. See Figure 1 for a visual illustration of this relationship.	Betweenness – Human Movement Volume ("Busy Streets") Facility Density – Human Movement Volume ("Busy Places")	Use a path model to assess the relationships between betweenness, facility density, and crime.
Research Question 3: If the effects of individual facilities on crime are influenced by street block betweenness, are there interactions between types of facilities and betweenness?	If both individual facilities and expected street block traffic are linked to crime, specific types of facilities on busier streets may be associated with more crime than those on less busy streets.	Individual Facilities – Facility specific routine activities Betweenness – Human Movement Volume ("Busy Streets")	Add interaction terms (i.e., facility x betweenness) to negative binomial regression model.

**Note: The included measures are used to approximate the theoretical constructs of interest.*

Alternatively, if individual facilities are the more robust predictor of crime (i.e., compared to facility density), and betweenness helps explain the relationship between facilities and crime, it suggests that 1) facility specific routine activities are implicated in producing potentially criminogenic facilities and 2) busier streets are associated with elevated crime. If these findings are observed, then it may be possible for these features to jointly influence crime. Specifically, it may be possible that facilities located on busier streets will have higher crime than those on less busy streets. For example, consider two similar bars – both considered potentially criminogenic facilities due to the cash carrying and possibly inebriated clientele who are perceived by offenders as more attractive targets (Groff & Lockwood, 2014; Wright & Decker, 1997). One of these bars is located on a busy major thoroughfare while the other is located on a secluded road. The bar located on the busy street is likely to be associated with many more crime opportunities than the one located on the secluded road. The specific routine activities that take place at each bar associated with crime opportunities will likely be amplified on a busier street, since there is likely to be greater activity at this location (Felson, 2006). Thus, offenders and potential victims are more likely to converge at the bar located on the busy street. Alternatively, the bar on the secluded road will likely see less traffic than the first bar, which may correspond to fewer suitable targets meeting motivated offenders. This suggests that there may be interactions between individual facilities and the betweenness of street blocks. Accordingly, this final research question was included:

Research Question 3: If the effects of individual facilities on crime are influenced by street block betweenness, are there interactions between types of facilities and betweenness?

Study Site

The site of the current study is Cincinnati, Ohio. Cincinnati is located in the southwest corner of Ohio and situated along the Ohio River. Cincinnati has a population of around 300,000 residents (U.S. Census Bureau, 2018). The demographics of Cincinnati are as follows: 50.7 % white, 46.8% black, and 2.8% Latino(a). Cincinnati is a somewhat disadvantaged city, with a median household income of $34,000; $10,000 less than the national median income. Around 31% of Cincinnatians' income is at or below the poverty line (U.S. Census Bureau, 2015). Cincinnati's violent crime rate was around 910 per 100,000 in 2016, with a robbery rate of around 428 per 100,000 (Federal Bureau of Investigation, 2017).

Unit of Analysis

The unit of analysis for the current study is the individual street block. Street blocks were selected as the unit of analysis for several reasons. First, this study is concerned with the influence of the street network on spatial crime patterns. Street blocks, which comprise street networks, naturally provide an avenue to explore how the position of individual streets within a larger network shape crime patterns (Davies & Bowers, 2018). Second, street blocks are theoretically meaningful. Scholars have suggested that street blocks act as "behavior settings" in which individuals carry out their routines and interact with one another (Jacobs, 1961; Taylor, 1997). Repeated use of specific streets within individual activity spaces facilitates interactions between people and support the development and understanding of acceptable behavior and norms (Taylor, 1997). Third, CPT asserts that crime opportunities are the result of micro-level mechanisms, such as an abundance of suitable targets at a specific location, and that streets facilitate routines and offender awareness (Brantingham & Brantingham, 1999). Using larger units of analysis such as census blocks or tracts may restrict the examination of crime patterns at a finer scale of analysis where these micro-level mechanisms exist. Fourth, scholars have argued that analyzing crime patterns is best done at the micro-level, which includes street blocks and addresses (Weisburd et al., 2012), rather than the macro level, to reduce spatial heterogeneity among units of analysis (Oberwittler & Wikström, 2009; Smith, Frazee, & Davidson, 2000). For example, research has demonstrated that even within high crime areas, some street blocks will have little to no crime, which may not be apparent if larger units of analysis are used (Groff et al., 2009; Steenbeek & Weisburd, 2016; Weisburd, 2015). Finally, using street blocks as the unit of analysis reduces the likelihood of inaccurate geocoding of crime incidents which may occur when individual addresses are used as units of analysis (Ratcliffe, 2004). Crime incidents may also unfold over a larger area than a single address (Jacobs, 2012), while CPD officers are required to record a single address for each incident. It is unclear how CPD officers choose the individual address to record when the location of a crime is ambiguous. However, using street blocks with address ranges minimizes concerns of inaccuracy in crime data recording.

Street blocks were defined as both block faces bounded by two intersections at each end (Taylor, 1997). Street centerline data were collected from the Cincinnati Area Geographic Information System (CAGIS). The street centerline shapefile provided by CAGIS included all streets inside Hamilton County, Ohio. Prior to any analyses, the street centerline file required cleaning by a team of University of Cincinnati researchers. First, the cleaning process involved removing all streets outside Cincinnati city limits, excluding streets without valid address ranges (e.g., interstate highways and exit ramps), and repairing disconnected segments. Second, street blocks inside the boundaries of the University of Cincinnati and Xavier University campuses were excluded. These street blocks are within the jurisdiction of their own respective university police departments who record their own crime data that were not available for this study. Third, some individual street segments were digitized as multiple segments in the centerline file (i.e., duplicates) and were collapsed into single segments as part of this cleaning process. More specifically, some continuous turn lanes within intersections, which in reality were not individual street blocks, were represented as their own street block in the center line data. Other multi-lane street blocks, such as those with a median separating lanes with opposing traffic flow direction, were digitized as two separate blocks despite being a single block in reality. These extraneous streets were generalized into a single street block to maintain consistency with the definition of street blocks above (see Haberman & Kelsay, 2020). The final cleaned dataset included 10,940 valid street blocks[1] with an average length of roughly 500 feet.

Dependent Variable

The dependent variable in the current study is the count of street robberies occurring on each street block in Cincinnati in 2016. Robberies in this study included only incidents in which an assailant unknown to the victim stole property by force, or threat of force, in a public or semi-public location (also see Monk, Heinonen, & Eck, 2010). This definition of street robbery is consistent with past research (Bernasco & Block, 2011).

This operationalization also has several strengths. First, the dynamics of street robbery are closely tied to the theoretical frame being tested. CPT links human movement and offender spatial awareness to predatory crime opportunities. Specifically, street robberies are inherently associated with offender considerations of risk and reward stemming from their perceptions of the physical environment (Clarke & Harris, 1992; Wright & Decker, 1997). For example, active robbers seek familiar locations where there are many potential targets carrying cash or valuables

[1] It is unlikely that this procedure led to any meaningful loss in crime data since most of the affected street segments were only altered using ArcGIS, not deleted.

(Bernasco et al., 2013; St. Jean, 2007; Wright & Decker, 1997). This suggests that locations near facilities with cash carrying patrons and streets that are more familiar (i.e., used more frequently) are hospitable crime sites. Moreover, excluding bank robberies, commercial robberies, car-jackings, and prearranged robberies from the analysis is appropriate because the opportunity structures associated with those types of robbery are less strongly tied to routine human movement patterns. In other words, none of these types of robberies inherently require human movement, which is a tenet of the theoretical framework of this study. Additionally, predicting those types of robberies that occur at commercial locations with predictors that measure commercial locations is tautological. Second, while the link between features of the street network, including betweenness, and crime is well established, most of these studies examined only burglaries (but see Summers & Johnson, 2017 for an exception). Thus, this study examined a relatively understudied crime type to add to the limited empirical knowledge in this area. Moreover, because robbery is a particularly serious form of violent crime, developing a greater understanding of the characteristics of this offense may provide insight for law enforcement and policy makers who seek to prevent it or reduce the likelihood that it occurs.

The robbery data were procured from the Cincinnati Police Department (CPD). The data required a manual cleaning process prior to analysis. Incident reports and narrative data for each incident were reviewed and cases were included or excluded based on information from each report. In total, 1,374 robbery incidents recorded in 2016 were manually reviewed with 920 robbery incidents meeting the above definition. Robbery incidents were geocoded to street blocks using a dual ranges address locator with hit rate of around 99.9%, beyond the minimum acceptable hit rate of 85% (Ratcliffe, 2004). All incidents were aggregated to the street block they were reported to have occurred at using unique identifiers, and then summed to create a continuous measure. Univariate descriptive statistics for this variable, as well as those that follow are displayed in Table 2. This includes minimum and maximum values, means, and standard deviations for each item.

Independent Variables

Betweenness

Street block usage potential was measured using betweenness. Betweenness considers each street block's position in the larger street network and provides an estimate of each street's expected traffic (Davies & Johnson, 2015). In other words, betweenness is a proxy measure for the busyness of streets.

Using the Urban Network Analysis Toolbox for ArcGIS (Sevtsuk & Mekonnen, 2012), betweenness was calculated using a dual street network dataset[2] (Porta et al., 2006) where street segment midpoints were entered as nodes and street segments were used links or edges (Barthélemy, 2011; O'Sullivan, 2014). An unedited CAGIS street file was used to create the network dataset so that access roads and streets outside of Cincinnati were considered in the calculation of betweenness. This step limited edge effects and ensured accurate values for streets at the city limits (Gil, 2016). The actual calculation of betweenness entails establishing the shortest path between each pair of street blocks in the network, assigning higher scores to street blocks that fall into shortest paths more frequently, and standardizing values by the number of total street block pairs (Barthélemy, 2004; Bollobas, 2002). In other words, streets falling into a larger portion of shortest paths between each possible pair of street blocks should have a higher

[2] Some studies use primal street network datasets to conduct street network analysis (Davies & Johnson, 2015; Porta et al., 2006). This approach involves using street segment junctions or intersections as nodes and segments themselves as links. While the dual and primal representations of street networks have different parameters, it is unlikely that there will be any substantive differences between results obtained using one approach or the other (Porta et al., 2006).

traffic volume and a higher betweenness value. To demonstrate:

$$Betweeness^{r}[i] = \sum_{j,k \in G,\, j \sim k} \frac{n_{jk}[i]}{n_{jk}}$$

The betweenness of each street block (i) was determined by calculating the number of times i occurs in the shortest path between each pair of street blocks (j, k), within a radius r, in a network G, such that $j \sim k$ are within r distance of one another, and $n_{jk}[i]$ is the total number of shortest paths between j and k which pass through i (Davies & Johnson, 2015; Sevtsuk & Mekonnen, 2012). Higher scores indicate higher street block betweenness or usage potential.

In this study, betweenness was calculated for all street blocks within a ¼ mile bounding radius. Radial bounding for betweenness calculations is typically used to estimate variation in length of trips in the street network, and reflect street block usage potential, as well as offender awareness, at different scales (Davies & Bowers, 2018; Summers & Johnson, 2017). For example, larger radii are used to approximate longer trips in the network, such as those requiring vehicular travel, while smaller radii represent shorter, more local, or pedestrian trips (Davies & Johnson, 2015; Hillier, 2006).

The ¼ mile radius was selected for several reasons. First, there is no reason to suspect a priori that robbery incidents examined in the current study inherently required the use of vehicular travel to complete the offense. For example, while some crimes like burglary are facilitated by vehicular travel, the definition of street robbery used in this study requires that both the victim and assailant be on foot (Monk et al., 2010). Second, offender target searches rarely span long distances or involve ventures into unfamiliar areas (Ratcliffe, 2006; Rengert & Wasilchik, 1985; Wright & Decker, 1997), so a smaller bounding radius was selected to capture street block usage potential and offender awareness over a short distance.

Table 2. Descriptive Statistics

	Min	Max	Median	Mean	SD
Dependent Variable					
Robbery	0.000	9.000	0.000	0.084	0.373
Independent Variables					
Betweenness (1/4 mile radius)	-0.473	11.597	-0.350	0.002	1.003
Grocery Stores	0.000	1.000	0.000	0.002	0.047
Retail Stores	0.000	17.000	0.000	0.063	0.496
Everyday Stores	0.000	6.000	0.000	0.033	0.217
Restaurants	0.000	15.000	0.000	0.052	0.395
Bars/Clubs	0.000	4.000	0.000	0.014	0.141
Fringe Banking Facilities	0.000	2.000	0.000	0.002	0.045
Public Housing	0.000	1.000	0.000	0.009	0.092
High Schools	0.000	1.000	0.000	0.010	0.099
Higher Education	0.000	1.000	0.000	0.008	0.087
Parks	0.000	1.000	0.000	0.023	0.167
Bus Stops	0.000	1.000	0.000	0.289	0.453
Hotels	0.000	2.000	0.000	0.002	0.052
Entertainment Facilities	0.000	2.000	0.000	0.007	0.084
Facility Density	0.000	36.000	0.000	0.520	1.181
Spatial Lags					
SL Grocery Stores	0.000	2.000	0.000	0.011	0.106
SL Retail Stores	0.000	31.000	0.000	0.302	1.253
SL Everyday Stores	0.000	8.000	0.000	0.166	0.523
SL Restaurants	0.000	18.000	0.000	0.257	1.057
SL Bars/Clubs	0.000	7.000	0.000	0.070	0.346
SL Fringe Banking Facilities	0.000	3.000	0.000	0.010	0.100
SL Public Housing	0.000	1.000	0.000	0.012	0.104
SL High Schools	0.000	1.000	0.000	0.021	0.142
SL Higher Education	0.000	1.000	0.000	0.008	0.091
SL Parks	0.000	1.000	0.000	0.035	0.185
SL Bus Stops	0.000	1.000	0.000	0.259	0.438
SL Hotels	0.000	3.000	0.000	0.013	0.131
SL Entertainment Facilities	0.000	4.000	0.000	0.033	0.194
SL Facility Density	0.000	49.000	0.000	1.194	2.681
Socio-Demographics					
Disadvantage	0.000	93.836	28.674	30.857	20.115
Residential Mobility	0.000	78.344	19.966	22.095	12.710
Racial Heterogeneity	0.033	0.672	0.418	0.380	0.162
Residential Population	1.570	36.550	10.320	10.811	4.732
Street Block Length	12.630	18808.050	347.348	478.943	501.438

Notes: Units of analysis are street blocks (10,940); *SL* spatially lagged

Finally, it is noted that similar measures have been used to represent pedestrian trips in past research (Davies & Johnson, 2015; Hillier, 1993; Summers & Johnson, 2017; Yang & Diez-Roux, 2012). For instance, Summers and Johnson (2017) used an 800 meter (2,625 ft.) radius in their measure of betweenness to reflect more local pedestrian movement through the street network as opposed to a 3000 meter radius representing movement requiring vehicular travel.

Street Block Length

The length of each street block in feet was used to account for the fact that longer street blocks may have more crime than shorter street blocks simply because they are longer. Street block length was used as an offset variable in all count regression models, but as a control variable in all path models.

Facilities

Measures of facilities on street blocks in Cincinnati were provided by Dr. Cory Haberman and a team of graduate students who collected and manually cleaned data on business licenses from the Ohio Department of Taxation as well as several other sources. A total of 2,392 businesses in Cincinnati were identified after cleaning and geocoding all businesses. Additional facilities were identified using data from the Ohio Department of Education, the U.S. Department of Education's Office of Postsecondary Education, Cincinnati Area Geographic Information System (CAGIS), Cincinnati Parks and Recreation Department, the Cincinnati Metropolitan Housing Authority (CMHA), and the Southwest Ohio Regional Housing Authority. A total of 13 potentially criminogenic facilities were included in this study. Data on facilities were coded in one of two ways: 1) some facilities were summed per street block and 2) others were coded as dichotomous indicators reflecting their presence ("1") or absence ("0") from each street block. This coding depended on the nature of the facilities. Facilities represented as points at a single address (e.g., a bar) on a single street block were operationalized as counts; whereas facilities represented as polygons that span multiple street blocks (e.g., a park) were operationalized as indicators.

The first set of facilities included those which supply consumers with large quantities of goods: 1) grocery stores, 2) retail stores, and 3) everyday stores. Theoretically, these facilities may be associated with crime opportunities because they attract many cash carrying patrons, some who may walk and others who may drive and park at these facilities, providing likely offenders with suitable targets. Grocery stores included those facilities selling daily consumer products, food, and other household items. Retail stores were those facilities supplying clothing, household items, electronics, office supplies, jewelry, recreational equipment, florists, and thrift stores. Everyday stores included businesses at which consumers purchase items quickly, such as gas stations, convenience stores, bodegas, and pharmacies.

Next, facilities associated with risky behaviors, such as alcohol use and cash carrying, were included: 4) restaurants, 5) bars or clubs, and 6) fringe-banking facilities. Restaurants included establishments providing fast food and sit-down eating. Bars and clubs were those facilities selling alcohol for on-site consumption. Fringe banking establishments included pawnshops and check cashing businesses.

Additionally, several other facilities with empirical links to higher crime were included. 7) Public housing communities, identified apartments, single-, and multi-family homes, and high-rise communities, operated by the CMHA. 8) High schools included all public and private high schools teaching 9^{th} – 12^{th} grade students. 9) Higher education institutions were colleges and universities recognized by the U.S. Department of Education's Office of Postsecondary Education. An indicator of 10) parks captured street blocks that were adjacent to a city park.

Another indicator captured for 11) bus stops identified street blocks served by at least one public bus route. 12) Hotels included facilities renting rooms for short-term occupancy. Finally, 13) entertainment facilities, such as arcades, amusement parks, art galleries, bowling alleys, local landmarks and attractions, museums, sports arenas, theaters, and casinos, were also included.

Facility Density

The literature around facilities and crime reviewed in the second chapter focused primarily on how individual types of facilities directly impact crime. As articulated by Wilcox and Eck (2011), it is possible that these effects are the product of facility generated traffic rather than the specific routine activities associated with certain types of facilities. This suggests that the function of individual facilities should not play a role in determining whether they are criminogenic or not. Examining facilities as an agglomeration inherently masks their specific function, providing an avenue to investigate this argument. Moreover, Wilcox and Eck (2011) argue that areas with dense commercial activity should be associated with greater activity compared to areas with more sparsely arranged facilities. This suggests that streets with a greater density of facilities should be busier than those with a lower density of such businesses. Accordingly, a measure of street block facility density was created by taking the sum of facilities, regardless of whether a facility was originally measured as a sum or a dichotomous indicator, on each street block[3]. Higher street block densities correspond to a greater volume of facilities on each street block and potentially a greater amount of human activity.

Socio-demographics

In accordance with previous research in community criminology (Bursik & Grasmick,

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[3] Similar procedures were used to measure the density of facilities in census tracts or blocks (r & Pridemore, 2011; Roncek & Bell, 1981).

1993; Sampson et al., 1997), several items were included to capture neighborhood structural characteristics that can influence crime. Using the 2015 American Community Survey, estimates for each of the 4 items listed below at the census block group level were assigned to street blocks. Street blocks bordering multiple census blocks were assigned the average of the characteristics for each of the adjoining blocks. 1) Disadvantage included the percentage of residents living at or below the poverty line. 2) Residential mobility was measured by the percentage of residents residing in a different home than the prior year. 3) Racial heterogeneity was measured as the squared proportions of population of five race/ethnicity categories (White, Black, Hispanic, Asian, other) subtracted from one, where a value of zero indicates complete racial homogeneity and value of the mathematical maximum of .80 represents complete racial heterogeneity. A continuous measure of 4) the residential population was also included to provide an estimate of the risk-level in the area the street block is located in.

Spatial Effects

Due to the spatial structure of the data, it was necessary to account for any spatial effects, such as crime spillover effects from facilities to nearby areas (Haberman & Ratcliffe, 2015; Groff & Lockwood, 2014). More specifically, research has demonstrated how facilities such as alcohol establishments can influence crime levels beyond their immediate surrounds (Groff & Lockwood, 2014; Wheeler, 2016). For instance, if guardianship is high at certain facilities, offenders might follow patrons down a street block and rob them when potential witnesses or bystanders who may intervene are out of sight. To account for this possibility, spatially lagged independent variables were created for each measure of individual facilities. Using a queen-contiguity-first-order spatial weights matrix, which includes streets as neighbors if they intersect (Bellamy, 1996), lagged variables for each facility were created based upon their original coding scheme. More specifically, the lagged measures of facilities that were originally coded as a sum were also summed, while those represented by a dichotomous indicator remained as such in the lagged versions.[4] A spatially lagged version of facility density was also created using the same procedure.

Technically, when spatial effects are unaccounted for in regression models, it means the outcomes and model residuals will be correlated with each other across spatial units. This spatial autocorrelation in the residuals represents a violation of the assumption that the observations are independent from each other and could result in incorrect inferences. Including theoretically important spatially lagged predictor variables often accounts for the spatial structure of the data and eliminates spatially autocorrelated residuals. Nonetheless, spatial autocorrelation in the residuals of the study's regression models was also assessed using Moran's I tests (Anselin, 1988). The Moran's I results are available in Appendix A, but they suggest that spatial autocorrelation was not an issue for the data used in this study.

Analytic Plan

A number of analytical procedures were used to answer this study's research questions. Because each research question is addressed using separate analyses, the analytic plan described below is organized by research question. Table 1 summarizes the research questions and the analyses used to address them.

Research Question 1

Recall that the first research question asks: Are individual facilities or facility density the

[4]The potential for spatial autocorrelation was also assessed using Moran's I tests of model residuals (Anselin, 1988). The results of these tests, available in Appendix A, suggest that spatial autocorrelation is not an issue for the data used in this study.

more robust predictor of crime? This question aims to address Wilcox and Eck's (2011) hypothesis that the type of facility is less important than the traffic generated by facilities for shaping spatial crime patterns. As previously discussed, this study uses measures of individual facilities to represent facility specific routine activities while facility density reflects busyness. The analyses described below should yield an answer to this question by demonstrating whether the specific routine activities associated with types of individual facilities *or* busyness better explain spatial street robbery patterns. If facility density, or busyness, is observed to have the stronger relationship with street robberies, then this could be interpreted as support for the arguments of Wilcox and Eck (2011). If individual facilities exhibit the stronger relationship with street robberies, then this could be interpreted as supportive evidence for the importance of considering how specific types of facilities shape crime patterns.

To address the first research question, two count regression models will be estimated. Specifically, either negative binomial regression or Poisson regression, which are appropriate for discrete, non-negative count outcomes such as the dependent variable in this study (Cameron & Trivedi, 2013), will be estimated. Diagnostic tests, including a visual inspection of predicted and observed probabilities for each outcome as well as a comparison of model fit statistics, will be used to determine which model best fits the data. To assess whether the individual facilities or facility density is the more robust predictor of street robberies, a count regression model will be estimated where the dependent variable, street block robberies, is regressed upon the measures of individual facilities. Next, an additional count regression model will be estimated where street block robberies will be regressed on the measure of facility density. The only difference between these two models is that the first model includes the measures of individual facilities, while the second model includes the measure of facility density. Both models will include the sociodemographic variables described earlier.

Following the estimation of these models, each set of model fit statistics, including the Pseudo-R^2, model χ^2, and Bayesian information criterion (BIC) will be compared to determine which model does a better job of predicting robberies (Fox, 2015, p. 360; Land, McCall, & Nagin, 1996). Pseudo R^2 values, useful for comparing the fit of two or more models, are calculated by dividing the log likelihood of a fitted model by the log likelihood of a baseline or null model and subtracting this value from 1 (McFadden, 1974), The resulting value can then be compared to that of another model – in which the same data and outcome are used – to determine which model best fits the data. The model χ^2 , also used for determining model fit, is essentially a test of whether the parameters in a fitted model are actually equal to zero (Acock, 2013, p. 23). BIC statistics, commonly used to determine model fit, are computed by taking the natural log of the total sample size (N), multiplying this value by the number of free parameters in a fitted model, and adding this product to the model χ^2 (Fox, 2015, p. 673). Larger Pseudo-R^2 values, and smaller model χ^2 and BIC statistics suggest better model fit (Fox, 2015, p. 360; Land et al., 1996). When comparing BIC between models, differences larger than six provide strong evidence in support of using the model with the smaller BIC (Fox, 2015, p. 681).

Although Akaike Information Criteria (AIC) values are sometimes used to determine model fit, they are not reported in this study because they tend to favor more complex models (i.e., their values are smaller for models with more parameters) and BIC statistics provide a similar method for comparing model fit (Kline, 2016, pp. 287-289). Although BIC statistics come with their own limitations, such as favoring more parsimonious models over those that are more complex, they are preferred over AIC statistics by some scholars when it comes to determining the degree to which data support competing regression models (Fox, 2015, p. 696;

Kline, 2016, p. 287).

Research Question 2a

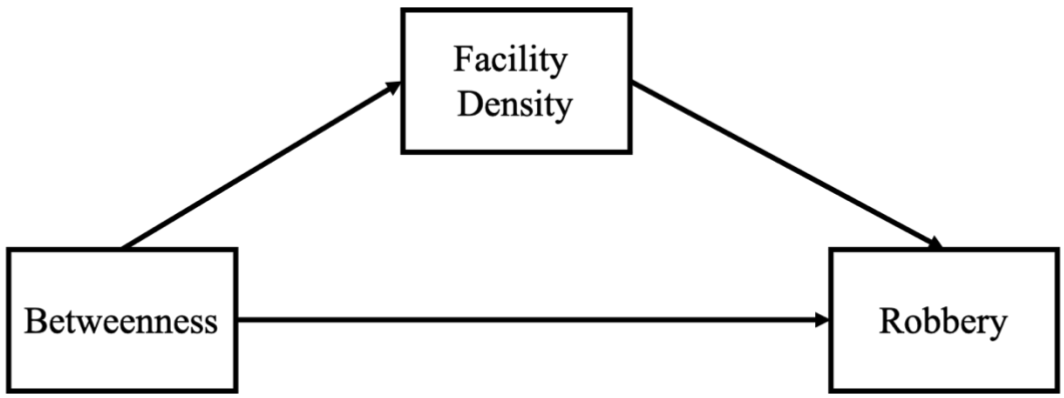
If the analyses used to address research question 1 suggest that the individual facilities model fit the data best, this study will attempt to answer research question 2a. Research question 2a asks: If individual facilities are the more robust predictor of crime, does street block betweenness confound the relationship between types of facilities and crime? To address this research question, a count regression model will be used to examine whether the inclusion of street block betweenness attenuates the relationship between facilities and street robberies. Recall that Wilcox and Eck (2011) charged that it is the traffic generated by specific facilities, rather than their type or function, that is responsible for their association with spatial crime patterns. As previously discussed, betweenness is considered a proxy measure for expected traffic on street blocks (Davies & Johnson, 2015), so streets with higher betweenness values should be associated with a higher volume of traffic (i.e., busier). Thus, accounting for street block traffic should – if Wilcox and Eck (2011) are correct – at least partially explain or attenuate the relationship between facilities and street robberies.

To test this argument, a count model will be estimated that includes measures of individual facilities, sociodemographic variables, and street block betweenness. If Wilcox and Eck (2011) are correct, the inclusion of betweenness in this model should attenuate the strength of the relationship between facilities and street robberies observed in the first count model used to address the first research question. This can be assessed by examining changes in statistical significance or magnitude of regression coefficients for measures of facilities (MacKinnon, Krull, & Lockwood, 2000). For example, if a particular facility is found to have a strong positive relationship with street robbery but is weakened once street block betweenness is added to the model, this provides some evidence that betweenness confounds the relationship between the facility and robberies (MacKinnon et al., 2000). In other words, the relationship between the facility and street robbery is explained by street block betweenness. If betweenness does appear to help explain the relationship between facilities and robberies, the significance of the change in the coefficients will be assessed. This process will include several steps. First, the regression coefficients for each facility in the original series of models used to answer the first research question will be subtracted from those in the models estimated to answer the second research question. Second, these values will be divided by the standard error of the difference. Last, these quotients will be compared to a normal distribution to determine statistical significance (MacKinnon et al., 2000).

Research Question 2b

If the analyses used to address research question 1 suggest that facility density is the stronger predictor of street robberies, the focus of this study will turn to answering research question 2b. Research question 2b asks: If facility density is the more robust predictor of crime, does street block betweenness influence the density of facilities and how do each of these proxy measures influence crime? To address this question, a path model will be used to disentangle the relationship between street block betweenness, facility density, and street robberies (see Figure 1 for a depiction of this hypothesized relationship). More specifically, path models are the most basic version of structural equation modelling (SEM) and do not require latent variables as traditional SEM does (Kline, 2016, p. 129). Path models allow for the estimation of direct and indirect effects of exogenous variables on endogenous outcomes while also offering an appropriate method for modelling mediation effects (Kline, 2016, p. 134). In the case of the current study, the empirical literature suggests that street block betweenness and facility density have direct effects on crime. However, it is also suspected that facility density is shaped by street block betweenness, since commercial activity is more highly concentrated on busier and more accessible streets. Assessing the relationships between variables in this recursive model (i.e., unidirectional), will help determine the extent to which the effects of facility density on crime are transmitted from betweenness.

Figure 1. The Hypothesized Relationship Between Betweenness, Facility Density, and Crime



The fit of the path model will be assessed using established diagnostics tests, including the Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and the root mean squared error of approximation (RMSEA) (Acock, 2013, p. 23-24). CFI values are computed by comparing an estimated model to a null or baseline model in which all variables are assumed to be unrelated to each other. TLI values are calculated in a manner similar to the CFI (i.e., a focal model is compared to a baseline model) but are not affected by sample size like the CFI. RMSEA statistics provide an estimate of the amount of error in a model for each degree of freedom while penalizing models with unnecessary complexity. Scholars suggest that CFI and TLI values above 0.95, and RMSEA values below 0.05 indicate good model fit (Acock, 2013, p. 23-24; Kline, 2016, p. 273-277).

The path model will be estimated in Stata 14 using the *sem* command where no variables are specified as latent (Stata Corp., 2017). It is important to note that scholars have expressed concerns about using the maximum likelihood (ML) method to generate estimates in structural equation or path models with ordinal or binary outcomes (DiStefano, 2002). Stata's *sem* command uses this method by default and does not allow for users to specify an alternative method (Stata Corp., 2017). The ML method of estimation assumes that the outcome measure is continuous, so it is possible that this method can produce inaccurate coefficients and standard errors if an outcome variable has few categories (Bernstein & Teng, 1989). However, this issue should not be a concern for the current study, since the outcome measure is continuous (i.e., street block robbery counts), has a range of 9, and the sample size in this study is large (N = 10,940). Statisticians have argued that outcomes with 6 to 7 categories and large samples produce accurate estimates using the ML estimator (Kline, 2016, pp. 257–258). Moreover, bootstrapped standard errors will be used to correct for the possibility that the original standard errors of coefficients may be too low given the large sample size (N = 10,940), and because the outcome variable is not normally distributed (Acock, 2013; p. 239). In some cases, small standard errors due to large sample sizes can result in an inflated probability of committing Type 1 error. To avoid this, maximum likelihood nonparametric bootstrapping will be used with 500 replications and a seed of 1, 2, 3.

Research Question 3

If proceeding from research question 2a, this study will attempt to address research question 3. This question asks: If the effects of individual facilities on crime are influenced by street block betweenness, are there interactions between types of facilities and betweenness? This question stems from the possibility that individual facilities may impact spatial crimes differentially based upon the busyness of the street block upon which it is located. In other words, the effects of specific facilities on crime may be conditional on the busyness of street blocks. To address this research question, this study will examine whether interactions between individual facility types and betweenness exist. Specifically, a negative binomial regression model will be estimated where street robberies will be regressed upon both the original individual facilities and betweenness variables, as well as the products of these variables (i.e., a street blocks' betweenness value multiplied by each facility indicator). Similar procedures have been used in previous studies to assess the conditional effects of land use on crime (Stucky & Ottensmann, 2009; Stucky & Smith, 2017; Wilcox, Quisenberry, & Jones, 2003). Any significant interaction terms observed in these models will provide support for the notion that the effects of individual facilities on street robberies are conditional upon street block characteristics. In addition, model fit statistics (e.g., Pseudo-R^2, model χ^2, and BIC) will be examined to determine whether the inclusion of the interaction terms improves model fit.

CHAPTER 4: RESULTS

Chapter 4 includes the results of the analyses used to address the research questions posed in the previous section. Prior to examining results of the multivariate analyses, an initial assessment of the descriptive statistics is warranted. Following this, the remainder of this section is organized by research question. More specifically, the analyses used to address the first research question are discussed first. Next, depending on the results of the analyses used to address research question 1, the results of the analyses used to answer research question 2a or 2b will be discussed. Contingent upon these findings, the results of the analyses used to address research question 3 may also be discussed.

Descriptive Statistics

As previously mentioned, descriptive statistics are available in Table 2. This includes minimum and maximum values, medians, means, and standard deviations for each variable. Recall that the unit of analysis for this study is street blocks, of which 10,940 were included in the analytical sample. At the top of Table 2, descriptive statistics for the dependent variable, robbery, are presented. Table 2 shows that the minimum count of robberies on street blocks was 0 while the largest count was 9. The median value for robberies was 0, while the average street block had fewer than 1 robbery ($\bar{x} = 0.084$). The standard deviation for robbery was 0.373. These descriptive statistics indicate that the distribution of robberies is positively skewed. In other words, most street blocks had no robberies and a fewer streets were associated with 1 or more robberies. To illustrate the distribution of robberies in Cincinnati, Figure 2 was included.

Figure 2. 2016 Robbery Density in Cincinnati

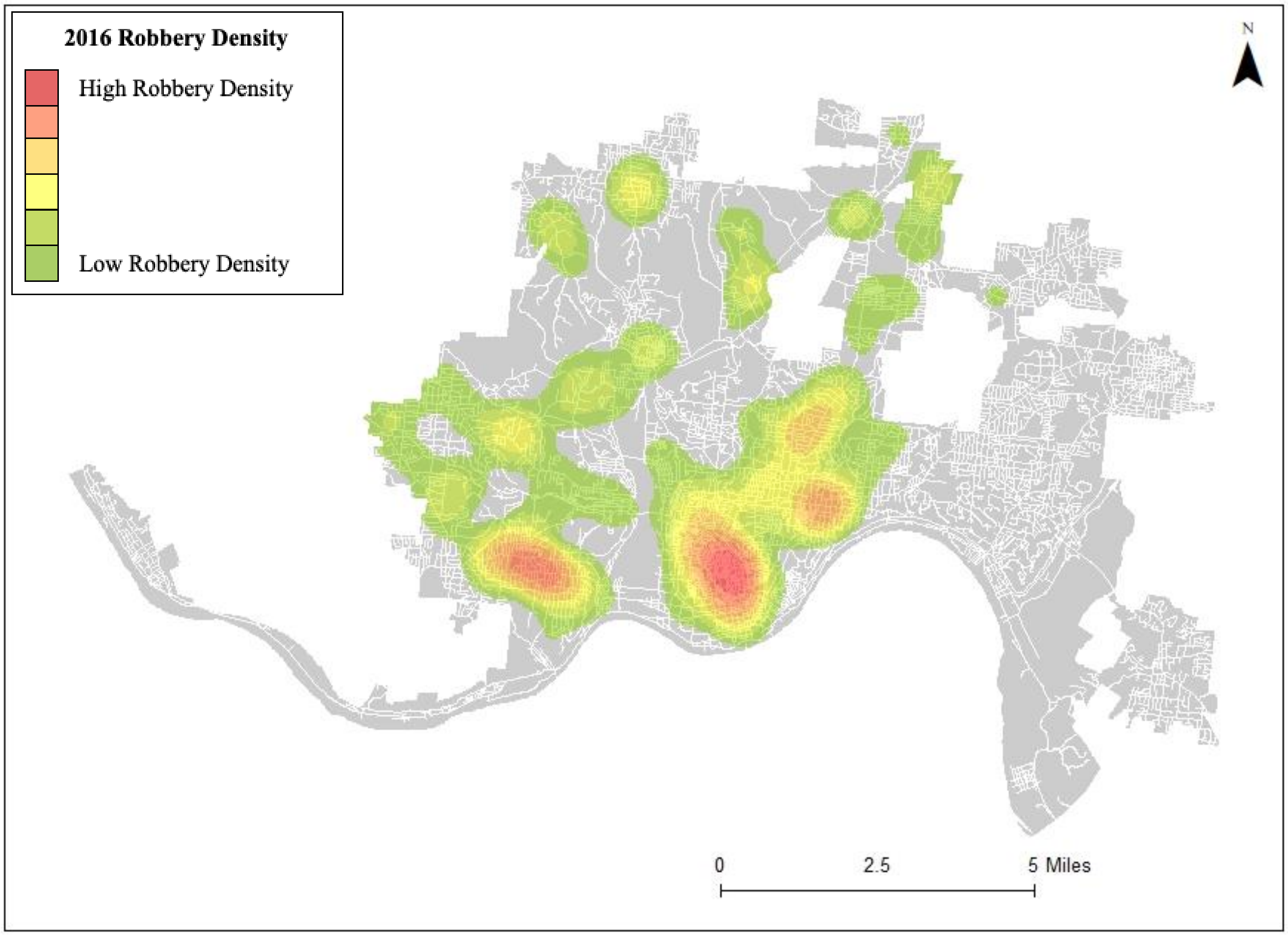


Figure 2 above reinforces the finding that robberies in Cincinnati are fairly concentrated. More specifically, it appears that the highest densities of robberies in Cincinnati, denoted by the dark red hue, were concentrated in four general locations. Moving from West to East, these neighborhoods with elevated robberies include East Price Hill, the downtown area, Avondale, and Walnut Hills. Much of the remainder of the city was subject to no robberies.

In addition to robbery, descriptive statistics are displayed in Table 2 for all remaining variables. These include street block betweenness, individual facility measures, facility density, the lagged versions of these facility variables, and sociodemographic items. Summary statistics for these measures should be interpreted similarly to those discussed for robbery.

Research Question 1

Before presenting the results, it was necessary to first determine which form of count regression was more appropriate for the data used in this study. Both negative binomial regression and Poisson regression are count regression models, which are appropriate for discrete, non-negative count outcomes (Cameron & Trivedi, 2013). Several diagnostic tests were used to determine which count regression model provides the best fit for this study's data. First, both Poisson and negative binomial regression models were estimated. Second, plots of the observed and predicted probabilities for both the Poisson and negative binomial regression models were created. These plots were visually examined to determine which of the two forms of regression provide the best fit for the data used in the current study by examining the normality of the distributed residuals (Long & Freese, 2014). Next, log-likelihood values and BIC values were compared between models to determine which of the two provided the best fit for the data (Fox, 2015, p. 360; Long & Freese, 2014). Smaller log likelihood and BIC values indicate better model fit (Long & Freese, 2014). Moreover, the overdispersion parameters for each negative binomial regression model was greater than 1, indicating that the negative binomial models fit the data better than the Poisson models. Each of these diagnostics confirmed that the negative binomial model fit the data better than the Poisson model.

In addition, variance inflation factors (VIF), used to detect collinearity, were computed for each measure included in both negative binomial models. VIF values provide an indication of the degree to which a regression coefficient is inflated because of multicollinearity in the model, where highly correlated predictors in regression models typically have a VIF value of 4 or greater (Thompson et al., 2017). The results of this diagnostic test suggest that collinearity is not an issue for the models included in this study, as the largest VIF value among the variables was 1.82.

Table 3 presents the results of the negative binomial regression models used to address the first research question. Model A in Table 3 includes the negative binomial regression model estimated with the individual facilities included, while model B includes the measure of facility density. As previously discussed, to address research question 1 the model fit statistics for each of these models will be compared to determine which of the two performs better at predicting robberies. Model fit statistics, including the Pseudo R^2, model χ^2, and BIC, are shown toward the bottom of table. Recall that larger Pseudo R^2 and smaller model χ^2 and BIC values indicate better model fit. For model A, the values for these fit statistics are 0.107, 657.540, and 5801.265, respectively. For model B, they are 0.083, 509.130, and 5726.470, respectively. A comparison of these indices appear to suggest that model B is a better fit for the data. Specifically, although the Pseudo R^2 value for model A is larger than that of model B, the model χ^2 and BIC values are smaller for model B. Moreover, the difference in the BIC between models A and B is 74.795, much larger than the threshold value of 6 which indicates superior model fit (Fox, 2015, p. 681). This suggests that the model including the measure of facility density is a better predictor of robberies than the model including individual measures of facilities.

Given the model fit statistics suggest that model B provides a better fit for the data, I now discuss the specific parameter estimates from this model. Starting at the top of model B, it appears that facility density is positively linked to street block robberies. The incident rate ratio (IRR) indicates that a 1 unit increase in facility density is associated with a 45% increase (i.e., 1.453 – 1 x 100 = 45%) in robberies per foot of street block length. A similar, but weaker, positive effect was observed for the spatially lagged measure of facility density. Specifically, a

Table 3. Negative Binomial Regression Models: Comparison of Individual Facilities and Facility Density Predicting Robbery

	Model A			**Model B**		
	Coef.	SE	IRR	Coef.	SE	IRR
Facilities						
Grocery Stores	0.203	0.513	1.225	--	--	--
Retail Stores	0.027	0.074	1.023	--	--	--
Everyday Stores	0.888***	0.136	2.430	--	--	--
Restaurants	0.059	0.095	1.060	--	--	--
Bars/Clubs	0.448*	0.221	1.566	--	--	--
Fringe Banking Facilities	0.722	0.554	2.059	--	--	--
Public Housing	0.839**	0.287	2.313	--	--	--
High Schools	-0.169	0.371	0.845	--	--	--
Higher Education	-1.372**	0.531	0.254	--	--	--
Parks	-0.143	0.241	0.866	--	--	--
Bus Stops	1.081***	0.113	2.948	--	--	--
Hotels	1.234*	0.549	3.435	--	--	--
Entertainment Facilities	0.001	0.409	1.001	--	--	--
Spatial Lags						
SL Grocery Stores	-0.373	0.329	0.688	--	--	--
SL Retail Stores	0.013	0.039	1.013	--	--	--
SL Everyday Stores	0.267***	0.070	1.306	--	--	--
SL Restaurants	0.003	0.042	1.003	--	--	--
SL Bars/Clubs	0.208	0.116	1.231	--	--	--
SL Fringe Banking Facilities	0.097	0.299	1.101	--	--	--
SL Public Housing	0.442	0.286	1.555	--	--	--
SL High Schools	0.129	0.251	1.138	--	--	--
SL Higher Education	-0.381	0.430	0.683	--	--	--
SL Parks	0.306	0.207	1.358	--	--	--
SL Bus Stops	0.421***	0.121	1.523	--	--	--
SL Hotels	0.180	0.285	1.198	--	--	--
SL Entertainment Facilities	0.014	0.197	1.014	--	--	--
Facility Density						
Facility Density	--	--	--	0.373***	0.035	1.453
SL Facility Density	--	--	--	0.058***	0.015	1.060
Socio-Demographics						
Disadvantage	0.034***	0.002	1.034	0.036***	0.002	1.037
Residential Mobility	-0.006	0.004	0.994	0.011**	0.004	0.989
Racial Heterogeneity	1.298***	0.289	3.663	1.272***	0.281	3.568
Residential Population	0.005	0.008	1.005	0.003	0.008	1.003
Constant	-11.079	0.197	--	-10.610	0.180	--
Ln(alpha)	1.063	0.103	--	1.322	0.095	--
Pseudo R^2	0.107	--	--	0.083	--	--
Model χ^2	657.540***	--	--	509.130***	--	--
BIC	5801.265	--	--	5726.470	--	--

Notes: *SL* spatially lagged; Street block length (feet) included as offset variable; $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

one unit increase in the density of facilities on a focal streets' adjoining neighbors is associated with 6% increase in street robberies per foot of street block length. Three of the sociodemographic variables included in this model were significantly associated with street block robbery counts. Disadvantage (3.7%) and racial heterogeneity (256.8%) were linked to higher street block robbery counts while residential mobility (-1.1%) was associated with fewer expected robbery counts.

Research Question 2a

Recall that the previously discussed analytical plan for this study was to address research question 1 and either 2a and 3 *or* 2b. However, the slight discordance in model fit statistics presented in Table 3 from the analyses used to address research question 1 reflect the need to address research question 2a in addition to research question 2b. More specifically, although the model χ^2, and BIC values indicate that Model B (i.e., the facility density model) was preferred over Model A (i.e., the individual facilities model) the Pseudo R^2 value was larger for Model A rather than Model B. This inconsistency led to the need to examine whether the inclusion of betweenness confounds the relationship between both individual facilities and robbery and facility density and robbery.

Table 4 presents the results of the two negative binomial regression models used to examine how the inclusion of street block betweenness influences the relationship between individual facilities and robberies as well as facility density and robberies. Model C in Table 4 presents the results of the negative binomial regression model estimated with individual facilities and betweenness, while Model D includes the measure of facility density and betweenness. Sociodemographic variables are included in both models. Aside from the inclusion of street block betweenness, Models C and D are identical to Models A and B, respectively.

Table 4. Negative Binomial Regression Models: Comparison of Individual Facilities and Facility Density Predicting Robbery Including Street Block Betweenness

	Model C			Model D		
	Coef.	SE	IRR	Coef.	SE	IRR
Betweenness (1/4 mile radius)	0.354***	0.034	1.425	0.343***	0.035	1.409
Facilities						
Grocery Stores	0.313	0.484	1.367	--	--	--
Retail Stores	0.299	0.070	1.030	--	--	--
Everyday Stores	0.877***	0.128	2.403	--	--	--
Restaurants	0.356	0.090	1.036	--	--	--
Bars/Clubs	0.219	0.222	1.245	--	--	--
Fringe Banking Facilities	0.735	0.527	2.085	--	--	--
Public Housing	0.856**	0.275	2.354	--	--	--
High Schools	-0.226	0.357	0.798	--	--	--
Higher Education	-1.240*	0.519	0.798	--	--	--
Parks	-0.121	0.229	0.886	--	--	--
Bus Stops	1.041***	0.111	2.831	--	--	--
Hotels	1.032*	0.509	2.806	--	--	--
Entertainment Facilities	-0.060	0.392	0.942	--	--	--
Spatial Lags						
SL Grocery Stores	-0.363	0.316	0.696	--	--	--
SL Retail Stores	0.027	0.037	1.027	--	--	--
SL Everyday Stores	0.271***	0.067	1.311	--	--	--
SL Restaurants	-0.008	0.040	0.992	--	--	--
SL Bars/Clubs	0.096	0.113	1.101	--	--	--
SL Fringe Banking Facilities	0.139	0.281	1.149	--	--	--
SL Public Housing	0.530	0.275	1.698	--	--	--
SL High Schools	-0.164	0.242	1.178	--	--	--
SL Higher Education	-0.343	0.410	0.710	--	--	--
SL Parks	0.287	0.199	1.346	--	--	--
SL Bus Stops	0.457***	0.119	1.579	--	--	--
SL Hotels	0.092	0.269	1.097	--	--	--
SL Entertainment Facilities	-0.031	0.186	0.970	--	--	--
Facility Density						
Facility Density	--	--	--	0.336***	0.034	1.400
SL Facility Density	--	--	--	0.053***	0.015	1.054
Socio-Demographics						
Disadvantage	0.031***	0.002	1.031	0.034***	0.002	1.034
Residential Mobility	-0.004	0.004	0.996	-0.009	0.004	0.991
Racial Heterogeneity	1.095***	0.285	2.989	1.113***	0.278	3.043
Residential Population	0.019*	0.008	1.020	0.018*	0.008	1.018
Constant	-11.083***	0.193	--	-10.633***	0.177	--
Ln(alpha)	0.911	0.109	--	1.209	0.098	--
Pseudo R^2	0.122	--	--	0.096	--	--
Model χ^2	752.01	--	--	594.820	--	--
BIC	5716.093	--	--	5591.682	--	--

Notes: *SL* spatially lagged; Street block length (feet) included as offset variable; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Model C in Table 4 indicates that betweenness is positively and significantly associated with robberies. Specifically, the incident rate ratio for betweenness suggests that a one standard deviation increase in street block betweenness is associated with a roughly 43% increase in robberies per foot of street block length. Comparing model C to Model A, where the only difference is the inclusion of betweenness, few differences are evident. Although some of the coefficients and IRR values have changed slightly, only one facility variable, the indicator for bars, is no longer statistically significant once betweenness is added to the model. Aside from this difference, Models A and C both suggest that convenience stores, public housing, bus stops, and hotels maintain significant and positive associations with robberies. Spatially lagged indicators for convenience stores and bus stops were also associated with elevated robberies. This suggests that focal streets with neighboring streets containing bus stops and convenience stores were subject to elevated robberies as well.

Similar findings are observed for Model D, which includes facility density rather than measures of individual facilities. Here, a one standard deviation increase in street block betweenness is associated with around a 41% increase in street robberies per foot of street block length. In addition, facility density and the spatially lagged version of facility density were both positively and significantly associated with robberies. Comparing Models B and D, which only differ by the inclusion of street block betweenness, suggests few substantive differences. Thus, it appears that betweenness only marginally attenuates the relationship between individual facilities, or facility density, and robberies.

Research Question 2b

Because the analyses used to address the first research question suggest that the measure of facility density was a better predictor of robberies than individual facilities, this study next addresses research question 2b. The aim of this research question is to disentangle the relationship between facility density, betweenness, and crime. Table 5 presents the results of the path model used to address this research question. The results shown in Model E of Table 5 include the unstandardized coefficients (*b*), bootstrap standard errors, and the standardized coefficients (*β*) from the path model. For purposes of clarity, only the results central to addressing research question 2b will be discussed, although the control variables included in the model below can be interpreted similarly to those discussed in the text.

Starting at the top of Table 5, the results of the path model suggest that betweenness is positively associated with facility density ($b = 0.089$; SE = 0.012; $\beta = 0.075$; $p < 0.001$). The standardized coefficient suggests that a one standard deviation increase in betweenness results in a 0.075 standard deviation increase in facility density. In addition, it appears that the spatially lagged facility density measure was positively associated with the density of facilities on focal street blocks ($b = 1.151$; SE = 0.015; $\beta = 0.343$; $p < 0.001$). The magnitude of the standardized coefficient suggests that it had a stronger influence on a focal block's density of facilities than betweenness. A one standard deviation increase in the facility density of neighboring street blocks is associated with a 0.343 standard deviation increase in the facility density of the focal block. This finding reinforces the notion that facilities tend to cluster together spatially.

Turning next to the direct effects of the key variables on robberies, Model E indicates that both facility density ($b = 0.057$; SE = 0.010; $\beta = 0.181$; $p < 0.001$) and betweenness ($b = 0.010$; SE = 0.005; $\beta = 0.026$; $p < 0.05$) were positively associated with robberies. A one standard deviation increase in facility density results in a 0.181 standard deviation increase in robberies while a one standard deviation increase in a street block's betweenness is associated with a 0.026 standard deviation increase in robberies.

Table 5. Path Model Examining the Relationships Among Betweenness, Facility Density, and Robbery

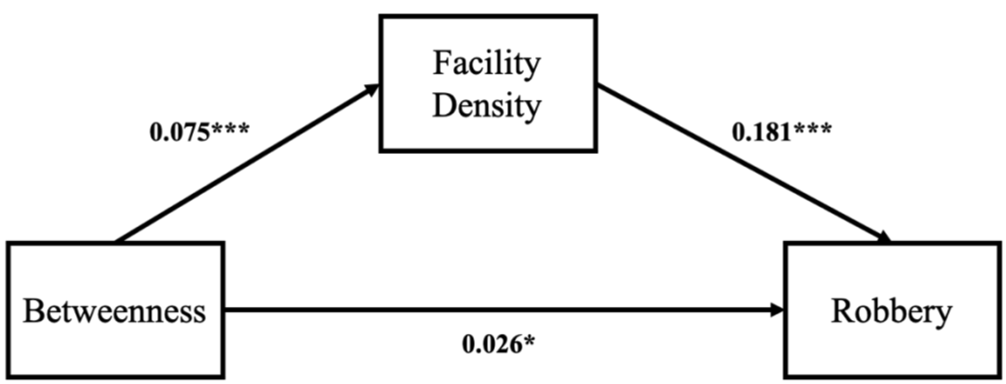
	Model E		
	b	Bootstrap SE	*B*
Facility Density ← Direct Effects			
Betweenness (1/4 mile radius)	0.089***	0.012	0.075
Control Variables			
SL Facility Density	0.151***	0.015	0.343
Disadvantage	-0.000	0.001	-0.000
Residential Mobility	0.004***	0.000	0.048
Racial Heterogeneity	0.010	0.051	0.001
Residential Population	0.005*	0.002	0.021
Street Block Length	0.000***	0.000	0.092
Robbery ← Direct Effects			
Facility Density	0.057***	0.010	0.181
Betweenness (1/4 mile radius)	0.010*	0.005	0.026
Control Variables			
SL Facility Density	0.003	0.002	0.025
Disadvantage	0.003***	0.000	0.154
Residential Mobility	-0.001**	0.000	-0.026
Racial Heterogeneity	0.029	0.023	0.125
Residential Population	0.005***	0.001	0.051
Street Block Length	0.000***	0.000	0.065
Robbery ← Indirect Effects			
Through Facility Density			
Betweenness (1/4 mile radius)	0.005***	0.001	0.014
Robbery ← Total Effects			
Betweenness (1/4 mile radius)	0.150**	0.005	0.040
R^2	0.163	--	--
Model χ^2	2375.545***	--	--
CFI	1.000	--	--
TLI	1.000	--	--
RMSEA	0.000	--	--

Note: N= 10,940; SL spatially lagged; *b* unstandardized coefficients; *β* standardized coefficients; CFI Comparative Fit index, TLI Tucker Lewis index, RMSEA root mean square error of approximation; **p* < 0.05; ***p* < 0.01; ****p* < 0.001

Comparing the magnitude of these coefficients, the effects of facility density on robberies are almost 7 times greater than the effects of betweenness (i.e., 0.181 / 0.026 = 6.962).

Model E also indicates that street block betweenness is indirectly and positively associated with robberies *through* facility density (b = 0.005; SE = 0.001; β = 0.014; p < 0.001). Moreover, the total effect of street block betweenness on robberies is 0.040 (i.e., direct and indirect association; b = 0.150; SE = 0.001; β = .0.040; p < .001). This suggests that 35% of the total effect of street block betweenness on robberies is indirectly transmitted through facility density (i.e., 0.014 / 0.040 = 0.35). Thus, it appears that betweenness shapes the density of facilities on street blocks, both of these features maintain positive direct associations with robberies, and a moderate portion of the effects of betweenness on robberies is indirect. These relationships are displayed in Figure 2.

Figure 3. The Effects of Betweenness and Facility Density on Robbery



Notes: This figure represents a focused version of the estimated path model – control variables are excluded in the diagram, but their associations are displayed in Model E of Table 4. The values shown are the standardized path coefficients.

Fit statistics for Model E are displayed at the bottom of Table 5. These include the R^2, Model χ^2, CFI, TLI, and RMSEA. The R^2 value (R^2 = 0.163) indicates that around 16% of the variance in robberies is explained by this model. The CFI (1.000), TLI (1.000), and RMSEA

(0.000), suggest that the model fit the data well. Specifically, scholars suggest that CFI and TLI values above 0.95, and RMSEA values below 0.05 indicate good model fit (Acock, 2013, pp. 23 -24).

Summary of Results

A handful of key findings are evident from the results presented above. First, the analyses presented in Table 3 indicate partial support for the notion that facility density was the more robust predictor of robbery. This support is only partial due to the inconsistency in fit statistics observed between regression models. Second, the negative binomial models presented in Table 4 suggest that betweenness did not attenuate the effects of individual facilities or facility density on robberies to any substantive degree. Comparing models with and without betweenness (i.e., Models A and B compared to Models C and D), only one facility, bars, was not significantly associated with robberies after betweenness was added to the model. Finally, the path model presented in Table 5 suggests that betweenness *and* facility density are positively associated with robberies, while betweenness was linked to a greater density of facilities. The results of Model E also indicate that a significant portion of the effects of betweenness on robberies is indirectly transmitted through facility density. The next section includes a contextualized and detailed discussion of these findings.

CHAPTER 5: DISCUSSION

Chapter 4 presented the results of the analyses used to address the conditional research questions posed in Chapter 3. Recall that, conditional upon the analysis used to answer research question 1, either research question 2a (and 3) *or* 2b would be addressed thereafter. However, because of the discrepancy in fit statistics for regression models used to address the first research question, the analytical plan was altered. The research questions addressed in Chapter 4 include: 1) Are individual facilities or facility density the more robust predictor of crime? 2a) If individual facilities are the more robust predictor of crime, does street block betweenness confound the relationship between types of facilities and crime, and 2b) If facility density is the more robust predictor of crime, does street block betweenness influence the density of facilities and how do each of these proxy measures influence crime? This chapter discusses the results presented in Chapter 4 in detail and contextualizes them within the literature reviewed in Chapter 2. In addition, it includes a discussion of the theoretical and practical implications of the findings in this study as well as its limitations.

Summary of the Results

Research Question 1

The aim of research question 1 was to determine whether a measure of individual facilities or facility density was the better predictor of robberies. Many past studies on potentially criminogenic facilities discuss the routine activities associated with types of facilities as the mechanism linking them to spatial crime patterns (Bernasco & Block, 2011; Groff & Lockwood, 2014; Kubrin & Hipp, 2016; McCord et al., 2007). Alternatively, others have suggested that the type of facility is not responsible for their observed association with crime, but the traffic they generate (Wilcox & Eck, 2011). Moreover, these scholars argue that areas with more dense commercial activity should be associated with higher traffic as well as crime levels. This study directly compares measures of individual facilities, which reflect the different routine activities associated with types of facilities, to a measure of facility density that masks facility types and serves as a proxy measure for busy places to address this critique.

The results from this study partially support the arguments raised by Wilcox and Eck (2011) which suggest that busyness, not the specific function or routine activities of facilities, is responsible for their relationship with crime. That is, the model including the measure of facility density was a marginally better fit for the data used in this study than the model including measures of individual facilities. The preference for the facility density measure was confirmed by comparing the fit statistics associated with both negative binomial regression models predicting street block robbery counts. Model fit statistics, including the model χ^2 and BIC values, appeared to support Model B in Table 3. Thus, facility density appears to be the more robust predictor of crime.

Research Question 2a

As previously mentioned, the fit statistics used to determine whether individual facilities or facility density was the more robust predictor of robberies were not in complete accordance. Although the model χ^2 and BIC for Model B were smaller than those of Model A, the Pseudo R^2 value for Model A was larger, which suggests that Model A is a better fit for the data than Model B. Due to this inconsistency, research question 2a was addressed. Recall that this question aimed to determine whether the effects of individual facilities on robberies were confounded or attenuated by street block betweenness. This question was developed based on the notion that the busyness of street blocks may partially explain the association between facilities and crime (Wilcox & Eck, 2011).

The results presented in the previous chapter indicate that betweenness was linked to elevated robberies but did not confound or attenuate the relationship between individual facilities, or facility density, and robberies to any substantive degree. More specifically, a comparison of Model A and Model C, which are identical models with the exception that Model C includes betweenness, suggests that betweenness only attenuated the effects of bars on robberies. All other individual facilities significantly associated with robberies in Model A maintained their significant associations with robberies in Model C, suggesting that certain facilities exhibit links to robberies that are independent of the busyness of the streets they are located on. This finding is inconsistent with the arguments made by Wilcox and Eck (2011) since individual facilities appear to influence robberies even after accounting for the busyness of street blocks. However, these results are supportive of previous studies linking betweenness (Davies & Johnson, 2015; Summers & Johnson, 2017) and individual facilities (Bernasco & Block, 2011; Groff & Lockwood, 2014; Kubrin et al., 2011) to elevated crime.

Research Question 2b

Research question 2b focused on disentangling the relationship between street block betweenness, facility density, and crime. The available literature assessing the relationship between features of the street network and crime indicates that busier and more accessible streets tend to be associated with higher crime (Beavon et al., 1994; Bevis & Nutter, 1977; Davies & Bowers, 2018; Davies & Johnson, 2015; Summers & Johnson, 2017; White, 1990). More recent work has focused on demonstrating how the street network measure of betweenness, a proxy measure for the expected traffic on street segments, is a salient factor predicting spatial crime patterns (e.g., Davies & Johnson, 2015). A separate body of literature has found that economic activity, including facilities, tends to be highly concentrated spatially (Ellison et al., 2010;

Krugman, 1991; Marshall, 1920; Saxenian, 1996; Shertzer et al., 2018; Twinam, 2017). Although zoning ordinances (Shertzer et al., 2018; Twinam, 2017) and the market principle of agglomeration (Ellison et al., 2010; Krugman, 1991; Ottaviano & Thisse, 2002) act to concentrate commercial places, studies have also observed that the density of commercial activities tend to follow the structure of the street network. More specifically, facilities tend to cluster together along busier and more accessible streets in urban areas (Omer & Goldblatt, 2016; Porta et al., 2009; Porta et al., 2012; Scoppa & Peponis, 2015; Wang et al., 2011). This finding suggests that while facilities and the street network can both influence spatial crime patterns, the street network also influences the location and density of facilities.

This study used a path model to assess the complex relationships among betweenness, facility density, and crime. The results of this path model reported in Chapter 4 indicate four key findings 1) betweenness and facility density both have direct positive influences on robberies, 2) facility density has a stronger effect on robberies than street block betweenness, 3) betweenness has a direct positive influence on facility density, and 4) a substantive portion of the effect of betweenness on robberies works through facility density. These results were observed while accounting for important sociodemographic variables drawn from community criminology (Bursik & Grasmick, 1993; Sampson et al., 1997).

The first of these findings is supportive of the past studies examining how features of the street network influence crime (Davies & Johnson, 2015; Frith et al., 2017; Summers & Johnson, 2017). Like the current study, most of this research has found that streets with higher betweenness values tends to be associated with higher crime levels (Davies & Bowers, 2018). This relationship is believed to be the result of greater traffic volume on streets with higher betweenness, which translates to more crime opportunities. More specifically, busier streets likely have a greater pool of potential targets and offenders are more likely to be aware of the available crime opportunities on busier streets (Davies & Johnson, 2015). However, many of these studies focused solely on burglaries (e.g., Davies & Johnson, 2015; Johnson & Bowers, 2010; but see Summers & Johnson, 2017 for a recent exception) and so this study supports the notion that street robberies may also be impacted by features of the street network, thereby improving the external validity of the relationship. Moreover, the finding that facility density is positively associated with robberies is unsurprising, given the extensive literature linking individual facilities to robbery patterns (Bernasco et al., 2011; 2013; 2017; Haberman & Ratcliffe, 2015; Haberman et al., 2018). This study adds an additional piece of evidence supporting the link between facilities and robberies.

Second, results from the current study suggest that the effect of facility density on robberies was stronger than the effect of betweenness. Specifically, the standardized path coefficients indicated that the effects of facility density on robberies were nearly 7 times greater than betweenness. This finding is particularly interesting, given that facility density is considered a proxy measure for busy places while betweenness represents busy streets. One potential interpretation of this result is that it represents an additional piece of evidence supporting the argument of Wilcox and Eck (2011). Observing that a measure of busy places is a salient predictor of crime, more so than the traffic facilitated by the street network, suggests that busy places may be more central to creating crime opportunities than the street network. In other words, a higher volume of facilities attracts people, perhaps walking, because there is something to do in the area.

Third, finding that betweenness is positively associated with facility density, supports the work of those who have also found that street network characteristics shape the distribution of economic activity in urban areas (Omer & Goldblatt, 2016; Porta et al., 2009; Porta et al., 2012; Scoppa & Peponis, 2015; Wang et al., 2011). The clustering of facilities along busier streets is largely due to the express desire of those responsible for selecting their sites to maximize exposure to potential customers and the accessibility of the facility (Damavandi et al., 2018; Kubis & Hartmann, 2007; Litz, 2014; Suarez-Vega et al., 2011). Thus, it appears that facilities tend to "self-select" onto busier streets. This indicates that the features of the urban environment are interrelated and may naturally coalesce to create hospitable locations for robberies.

Fourth, the path model used in this study suggests that a meaningful portion of the effects of betweenness on robberies is indirectly transmitted through facility density. Specifically, the results of the path model presented in Table 4 suggest that around 35% of the total effect of betweenness on crime is indirect through facility density. Although studies have found that facilities and characteristics of the street network influence crime levels independently, explicitly decomposing the effects of each of these features on crime provides greater insight into which features appear to be more important for shaping spatial crime patterns. As both facility density and betweenness constitute proxies for busyness, this finding can also be interpreted as support for the arguments of Wilcox and Eck (2011). Specifically, this finding suggests that busy streets may lead to busy places, and both can influence crime.

Implications

Understanding the role facilities play in shaping crime patterns has long been of interest to crime and place scholars who seek evidence-based solutions to crime problems (Brantingham & Brantingham, 1991; 1995; Eck & Weisburd, 1995; Sherman et al., 1989). Crime and place research is often framed by environmental criminology's theoretical perspectives, including crime pattern theory (Brantingham & Brantingham, 1991; 1993), routine activities theory (Cohen & Felson, 1979), and rational choice theory (Clarke & Cornish, 1985). Drawing upon these theoretical propositions and the existing crime and place research, this study sought to address one of the main critiques of this literature. Specifically, this study provides evidence to address the critique raised by Wilcox and Eck (2011) about the relationship between facilities and crime. The findings from this study have important implications for the theoretical perspectives used for understanding crime and place as well as practical implications for preventing crime associated with facilities and the street network.

Theoretical Implications

In Chapter 1, the following quote was included at the beginning of the introduction for the current study: *Environmental criminology can be advanced with a better understanding of how people shape the environment around them, and how law, policies, government actions, and the economy shape the environment in which we live (Brantingham & Brantingham, 1999;* p. 21). This study sought to realize this goal – to advance environmental criminology by developing a better understanding of the many factors that shape the physical environment. The current study has demonstrated how man-made features, including facilities and the street network, government actions, like zoning ordinances, and economic principles, such as agglomeration, shape our environment and facilitate crime patterns. In so doing, this study provides additional development of the theoretical perspectives couched within environmental criminology.

First, the finding that street blocks with a greater density of facilities, a proxy measure for busy places, is associated with elevated robberies is consistent with the idea that offenders make rational decisions about when and where to commit crime (Clarke & Cornish, 1985). Specifically, this finding suggests that offenders seeking to commit a robbery, on average, choose to do so where the potential rewards are greatest – at busier locations that are likely to have many potential suitable targets. Similarly, this finding is supportive of routine activities theory's assertion that crime opportunities exist where motivated offenders meet suitable targets (Cohen & Felson, 1979). More specifically, the results of this study indicate that active robbers tend to carry out these offenses near busier locations.

However, it is important to note that scholars have argued that busier places should also have elevated guardianship (Jacobs, 1961). For example, locations with higher guardianship should be subject to fewer crime opportunities because the likelihood of offenders being detected and thwarted by bystanders is greater. The findings from this study are more consistent with the views of Newman (1972), who argued that greater pedestrian and vehicular traffic should increase crime opportunities. That is, when places have higher foot and vehicle traffic, legitimate users and residents are less likely to exercise guardianship because other residents and legitimate patrons cannot be readily distinguished from those with a criminal purpose (Newman, 1972). In line with this finding, scholars have observed that the effectiveness of guardianship varies (Reynald, 2010). This suggests that the ability or willingness of bystanders to intervene during a crime, or their ability to recognize that a crime is occurring, is not assured (Reynald, 2010)[5]. For example, even at a busy location, potential bystanders may not necessarily be willing to intervene if a robbery is taking place. Similarly, potential guardians may not know that a robbery is unfolding nearby if visibility is poor.

Routine activities theory is partially supported by this study. Recall that many of the previous studies of crime and place linked facilities to spatial crime patterns by way of their specific routine activities (e.g., cash carrying or inebriated patrons at bars are suitable targets for offenders). Initially, this study observed that these facility specific routine activities were marginally less robust of predictors of robberies than the measure of facility density, a proxy for

[5] The current study did not include measures of guardianship on street blocks, which puts a complete test of these ideas out of reach. This constitutes a limitation which will be discussed in more detail in the next section.

busy places. However, in addressing research question 2a, this study found that the busyness of streets and individual facilities were linked to elevated robberies. Moreover, many individual facilities maintained their positive relationships with robbery even while accounting for the busyness of streets. This suggests that *both* street traffic and facility specific routine activities shape spatial crime patterns.

The results from this study also lend support to crime pattern theory. The idea that individual activity nodes, which include facilities, are associated with crime opportunities is well established in the theoretical and empirical literature (Bernasco & Block, 2011; Brantingham & Brantingham, 1993; 1995; Groff & Lockwood, 2014; McCord & Ratcliffe, 2009). However, the finding that high densities of facilities is associated with crime opportunities has been discussed but rarely examined in the past (Felson, 2006; Wilcox & Eck, 2011). For instance, Felson (2006, pp. 116 -122) discusses the idea of "thick crime habitats" where activity nodes cluster and increase crime opportunities. The current study provides empirical evidence that a concentration of activity generating features shapes spatial crime patterns. This suggests that areas with more activity nodes factor into the routines of many people, including potential offenders, which increases crime opportunities (Brantingham & Brantingham, 1993).

In addition, crime pattern theory's assertions about the ability of nodes and paths to create and facilitate crime opportunities through movement patterns is supported by the current study. Both features are expected to create crime opportunities by facilitating when and where offenders meet suitable targets (Brantingham & Brantingham, 1993). However, this study also observed the interrelationship between paths and nodes – that the characteristics of paths can influence where, and how many, nodes are situated at specific locations. This suggests that the ability of paths to shape crime patterns stems not only from its own characteristics, but the nodes that self-select onto it. Likewise, it is important to consider how the location of activity nodes is not random - they appear to be attracted to busy paths.

The findings from the current study also have potential implications for crime and place research, which often uses these theoretical perspectives to contextualize results. Specifically, the finding that facility density is a slightly more robust predictor of robberies than measures of individual facilities may open new avenues for exploration in this area of research. Studies of the relationship between facilities and crime have either focused on a single type of facility (Groff & Lockwood, 2014; Kubrin & Hipp, 2016; Roncek & Bell, 1981) or examined many individual facilities together (Barnum et al., 2017a; 2017b; Bernasco et al., 2013; 2017). That facility density appears to be a marginally better predictor of street robbery than its individual counterparts suggests that crime and place scholars may consider examining facilities as an agglomeration, since types of facilities may be less important than their busyness.

However, this study also demonstrates the importance of considering how facility specific routine activities shape crime patterns. Specifically, it was observed that some of the individual facilities maintained their positive associations with robberies even after accounting for the busyness of street blocks. This suggests that future research in this area may benefit from a comparative examination of how individual facilities influence crime before combining facilities into a summative measure of their density. Such a practice could involve an initial assessment of whether certain types of facilities are associated with elevated crime before summing or combining individual facilities to maximize model fit, as was the case in this study.

In addition, this study, like others (Davies & Bowers, 2018; Davies & Johnson, 2015), points to the importance of considering how the usage of streets influence street robberies directly, and through facilities. However, this study indicates that our understanding of the relationship between facilities and crime may be limited. Specifically, if past studies have examined the relationship between types of facilities and crime without accounting for the influence of the street network, their results may not be indicative of the true effects of the facility on crime. Future studies should continue to assess how both facilities and the street network shape crime opportunities in a manner that allows for their combined and separate effects to be estimated.

Practical Implications

There are also important practical implications that may be drawn from this study. Urban planners have a longstanding interest in designing communities in ways that discourage crime (Anderson, MacDonald, Bluthenthal, & Ashwood, 2013; Ziegler, 2007). Some of this research has led to the restriction of certain types of facilities to specific areas or at some specified distance from other types of land uses to prevent crime (Anderson et al., 2013; Tucker, 1997). For example, sexually oriented businesses are sometimes prohibited from being sited near residential areas (Tucker, 1997). This practice hinges on the notion that certain types of facilities are inherently criminogenic or immoral and nearby areas may be detrimentally impacted by their presence (Tucker, 1997). Others have focused on closing roads or limiting access to communities to reduce through-traffic and prevent non-residents and those with criminal purposes from using certain streets or entering communities (Armitage et al., 2011; Bevis & Nutter, 1977). This study provides some evidence to suggest that busyness, that might stem from dense commercial activity, not the specific type of facility may be responsible for their association with crime.

Urban planners and local municipalities interested in reducing crime might benefit from additional rules or approaches to urban planning that limit the number of facilities that can be co-located or diluting facilities that are densely packed into certain areas. Breaking up the concentration of facilities in certain areas may reduce the traffic or busyness of places leading to fewer opportunities for crime to occur. This could result from a lower likelihood of offenders and targets meeting at these locations or from the perception of offenders that areas with lower traffic do not provide a suitable pool of targets to choose from. Additional research is needed to determine whether this is an effective crime reduction strategy. Moreover, it may be necessary to examine threshold effects for facility density. Investigating the tipping point at which the density of facilities becomes high enough to increase crime patterns would allow for more formal rules designating the maximum number of facilities on streets.

Similarly, findings from this study indicate that busy streets should be assessed for their potential to influence crime. Changing traffic flow directions or closing streets to vehicular traffic have been offered as potential solutions to address busy, potentially criminogenic, streets (Bevis & Nutter, 1977; Wagner, 1997). This strategy hinges on the idea that decreasing the volume of traffic on streets associated with crime problems may result in fewer crime opportunities. However, this study examines street robberies which, by definition, involve offenders and victims who are on foot (Monk et al., 2010). This suggests that closing streets and reorienting traffic flows may not be an effective method for robbery prevention. Instead, it may be necessary for urban planners to use alternative methods for crime prevention such as increased street lighting or the installation of CCTV which are supported, at least partially, by empirical evidence (Farrington & Welsh, 2002; Ratcliffe, Taniguchi, & Taylor, 2009). These modifications to the physical design of streets may help prevent robberies of pedestrians from taking place or aid in the detection or apprehension of offenders.

Finally, there are practical implications for police strategy that could be drawn from the results of this study. One of the more effective methods for crime reduction involves a place-based focus of police resources (National Research Council, 2004). Place-based strategies, such as problem-oriented policing, focus on removing the opportunity structures associated with crime problems at specific places (Weisburd & Eck, 2004). Because this study observed that facility density was a more robust predictor of robberies than individual facilities, and busier streets tend to be associated with elevated robberies, it suggests that crime reduction efforts by police might benefit from additional resources (e.g., patrol) on busier streets, and especially those streets with a higher density of facilities. Crime analysts, who are already employed among most large police agencies in the U.S. (Piza & Feng, 2017), could develop a map of city streets with indicators of expected usage potential and facility density to help focus police resources. In other words, police strategies can be focused on routes with both high betweenness and facility density. Given that police resources are often spread thin due to budgetary constraints (Haberfeld, 2011), deploying resources to the areas of a jurisdiction with the most crime potential will likely result in a more cost-effective strategy compared to traditional methods (e.g., random patrol). Thus, incorporating specific streets into pre-existing patrol routes could potentially help reduce robberies with minimal effort (i.e., just re-allocating resources).

Limitations

Although this dissertation has provided evidence to address a major critique of the crime and place literature, and advanced knowledge in this area of research, like all studies, it is not without limitations. The limitations discussed below are primarily methodological in nature, and the findings of this study should be considered with these limitations in mind. Future studies will be needed to address these issues.

First, it was not possible to measure each component of the theoretical framework used in this study. Specifically, this study relies on the propositions of routine activities theory which asserts that crime opportunities exist when and where motivated offenders and suitable targets meet in the absence of capable guardianship (Cohen & Felson, 1979) but lacks a measure of guardianship. Scholars have suggested that some of the variation in crime among facilities of specific types (e.g., only bars) is due to poor place management or lax guardianship (Madensen & Eck, 2008). This study was unable to account for the potential protective factor of guardianship or place management at facilities or on street blocks. For instance, certain facilities or streets may have place managers or guardians who are more willing to intervene during a crime or take precautions to ensure that victimization does not occur on premises (Eck & Madensen, 2008; Reynald, 2010). Although this study did not explicitly seek to test routine activities theory, it is important to note that the observed results could have been affected by the absence of measures of guardianship. Future studies, perhaps qualitative or mixed methods in nature, will need to incorporate measures of guardianship to assess whether they influence results.

Second, the measure of facility density used in this study was created to approximate busy places – it is not an actual measure of facility generated traffic. This measure was included based on the arguments of Wilcox and Eck (2011), who suggested that areas with dense commercial activity should correspond to a higher volume of traffic. Despite being consistent with the arguments of these scholars, readers should note that this measure is a proxy for human activity and may not be reflective of actual movement patterns. Other researchers have also lamented the inaccessibility of data measuring the actual traffic at places (Epstein et al., 2016; Wang et al., 2017; Wilcox & Eck, 2011). Some have relied on geocoded cell phone and social media usage to measure traffic volume on streets (Dong et al., 2017), but even this method has its own limitations (Caceres et al., 2008). Despite the limitation of the measure used in this study, there is evidence to suggest that facility density is associated with greater (actual) pedestrian traffic (Hahm et al., 2017; 2019), alleviating some concern about its validity.

Third, this study does not account for the temporal dimensions of street robberies, the operating hours of facilities, or street traffic volume. Robberies primarily occur during the late night and early morning hours and are primarily driven by offenders' need to acquire cash or valuables (Monk et al., 2011; Wright & Decker, 1997). This means that offenders often choose areas near facilities as crime sites and target legitimate patrons of these facilities who may be carrying cash. However, facilities have differing hours of operation and street traffic volume may naturally vary in accordance with human routines, such as the need to sleep during the night. In other words, the busyness of facilities and streets is contingent upon the time of day. The availability of suitable targets near facilities and on busy streets likely varies in accordance with facility operating hours and human routines. For example, although fast food restaurants may be open during most hours of the day – which might provide a steady stream of opportunities for robberies – bars may only be open during the evening and nighttime. This could potentially restrict opportunities for robbery near bars to these late hours. Likewise, the busyness of streets is may also diminish during the late night hours when many people are at home sleeping.

The absence of control variables for these temporal characteristics have implications for the findings presented in this study. First, research indicates that certain facilities are associated with increased robberies during their operating hours, but not others (Haberman & Ratcliffe, 2015). This suggests that controlling for the time of day may have influenced the results presented here. For instance, it may be the case that certain facilities included in this study are linked to robberies during the hours they are open, but not during others. Examining facilities without considering this temporal dimension may have masked some of these effects. The same can be said for the observed effects of facility density on robberies presented in the previous chapter – areas with dense commercial activity may only be criminogenic during certain hours of the day. Additional research is needed to determine whether accounting for the operating hours of facilities influences the relationship between crime and the presence of facilities (but see Haberman & Ratcliffe, 2015). Second, although this study found that betweenness was positively associated with robberies, it does not consider how the busyness of streets may decrease during the night and early morning hours, when robberies are more likely to occur. Accounting for the natural variation in street block usage could have influenced the findings presented here. For example, busy streets may facilitate robbery opportunities during the night, but not during the day. This may be case if busier streets are perceived as too risky by offenders during the daytime hours when there are many potential bystanders who may intervene. However, by definition, street blocks with higher betweenness are more likely to have a greater volume of traffic. No available study has assessed whether betweenness provides an accurate assessment of traffic during different hours of the day. Without evidence to the contrary, it seems plausible that street blocks with higher betweenness values have elevated usage even during the nighttime hours when compared to those streets with lower betweenness. Still, readers should note that the results from this study may have differed if time of day was included as a covariate in this study.

Fourth, the data used in this study is cross sectional in nature, meaning that it was collected from one point in time. This means that it is not possible to establish temporal order between the key variables used. This unfortunate limitation in the data prohibits the specification of causal relationships between variables (Shadish, Cook, & Campbell, 2002). Specifically, it is not possible to state that betweenness, individual facilities, or facility density have a causal relationship with robberies, or that betweenness has a causal relationship with facility density.

Thus, the observed relationships between these variables are potentially spurious – or the result of some extraneous unmeasured variable.

However, it is important to note that there is very little reason to suspect that the betweenness of street blocks did not temporally precede the density of facilities. It is highly unlikely that facilities are constructed prior to the paving of streets, since facilities constructed prior to streets would not be accessible to their patrons or users, nor the workers tasked with building the establishment itself. In fact, municipal zoning ordinances, including that of Cincinnati, OH, explicitly require that commercial land uses be situated off of a street (City of Cincinnati, 2021; § 1409-17) This means that the chances that a facility is established prior to the street used to access it are very small. Thus, it can be said with reasonably high confidence that the structure of the street network existed prior to the siting of facilities.

Fifth, the data for the outcome variable used in this study is considered official crime data, which means that it is associated with a handful of limitations (Skogan, 1977). For example, the robbery incidents used in this study include only those offenses that were reported to the CPD – they do not include any offenses that went unreported by victims or undetected by police. Because many crimes go unreported (i.e., the dark figure of crime) it is possible that some robbery incidents were simply not captured by this measure. Additional research using alternative data sources that are not subject to this limitation is needed to establish the validity of the findings from this study.

Sixth, the measure of betweenness used in this study has limitations that are important to consider. Specifically, scholars have suggested that street block betweenness reflects a measure of 'through potential' (i.e., the likelihood that a street is used in a trip between destinations) rather than a measure of 'to potential' (i.e., the likelihood that a street is a destination in a trip)

(Summers & Johnson, 2017). Stated differently, betweenness provides a measure of the potential passersby on a street while *integration*, estimates the likelihood that a focal street was the destination of travelers (Summers & Johnson, 2017). Previous studies have used measures of integration and betweenness to reflect this difference (Summers & Johnson, 2017). Considering the difference between these measures, and the aim of the current study, it would be more appropriate to use a measure of street block integration as an estimate of the traffic generated by facilities. This is because the current study examines the traffic generated by facilities on street blocks. Unfortunately, it was not possible to incorporate a measure of street block integration into this study. The Network Analysis Toolbox used to calculate betweenness on the Cincinnati street network is not able to estimate a street's integration – only reach, gravity, closeness, straightness, and betweenness are possible to calculate using this tool (Sevtsuk & Mekonnen, 2002).[6] Alternative programs that are able to produce measure of street block integration are extremely costly or proprietary (Porta et al., 2006; Sevtsuk & Mekonnen, 2002) and so were unavailable for use. Nevertheless, betweenness offers a measure of the potential traffic on a street block, although it does not indicate the likelihood that pedestrians or vehicular travelers intended to end their trip on the block. Readers should consider the results of this study with this limitation in mind. Additional research is needed to determine whether similar results are obtained if street block integration is used rather than betweenness.

Similarly, although this study uses betweenness to approximate busyness on streets, scholars have also used betweenness to approximate offender awareness of crime opportunities on streets (Davies & Johnson, 2015; Summers & Johnson, 2017). For example, because betweenness measures the frequency of use of street blocks, it may also capture the degree to

[6] None of these alternative measures calculated by the Network Analysis Toolbox is similar to, or even an approximation of, integration.

which a street is familiar to offenders based on the likelihood that it is used during their routines (Davies & Johnson, 2015). Since busier streets are naturally likely to be incorporated into the routines of many offenders, this should translate into a greater familiarity of potential crime opportunities that are available on these streets. This idea is consistent with crime pattern theory's notion of "awareness spaces," or those areas that are familiar to potential offenders because they are visited more frequently during their routine activities (Brantingham & Brantingham, 1991). Thus, it is important to consider that the results of this study were interpreted from the perspective that betweenness reflects busyness rather than offender awareness. Because scholars have suggested that betweenness is a suitable proxy for both of these mechanisms (i.e., busyness and awareness), readers should keep in mind that the results presented here may be interpreted slightly differently depending on the mechanism betweenness is intended to approximate.

Finally, although this study has provided support for the relationship between street network features to a new crime type, street robbery, in a U.S. city, while most of the previous research on this relationship has been conducted in settings outside of the U.S., concerns around external validity remain. Only a handful of studies examining the role of the street networks in shaping spatial crime patterns exist (Davies & Bowers, 2018; Davies & Johnson, 2015; Frith et al., 2017; Summers & Johnson, 2017). This means that additional research in cities within and outside of the U.S. are needed to bolster the external validity of the findings from this area of inquiry.

Conclusions

The relationship between facilities and crime has occupied a great deal of scholars' attention over the last few decades. Studies of this relationship often assume that the criminogenic nature of facilities stems from the specific routine activities associated with their function. A major critique of this literature charged that labelling facilities as criminogenic is unfounded, and that facility traffic is to blame for their association with crime, has been largely overlooked. This study directly examined this issue finding that facility density, a proxy measure for busy places, is a somewhat better predictor of street robberies than measures of individual facilities, which reflect their unique functions and routine activities. However, additional analyses suggest that it is also important to consider how individual types of facilities influence crime, since some facilities linked to elevated robberies even after accounting for the busyness of streets. Moreover, consistent with research on facility site selection, this study observed that the betweenness of street blocks is positively associated with a higher density of facilities. Both facility density and betweenness were found to directly influence robberies, although part of the effects of betweenness on robberies was indirectly transmitted through facility density. These findings were observed while statistically controlling for important sociodemographic variables. Overall, this study indicates that it may be inappropriate to label certain facilities as criminogenic since the traffic they generate may be responsible for their association with crime, but certain facilities can maintain significant relationships with crime beyond busyness. Because interrelationships appear to exist between features of urban form, it may also be necessary to account for the traffic associated with facilities when examining their relationships with crime in the future.

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APPENDIX A

Because of the spatial structure of the data used in this study, the presence of spatial autocorrelation was assessed using Moran's *I* tests of model residuals (Anselin, 1988). Spatial autocorrelation occurs when values of variables at specific locations (e.g., crime) are dependent upon the values of the same variable at different locations (Anselin 2003). Moran's *I* tests are appropriate for continuous variables within polygons or displayed as points (Bernasco & Elffers, 2010), so they were computed for the model residuals to help detect spatial dependence or a lack of independence amongst the observations in the models. Distance based spatial weights matrices, including both 500- and 1,000-feet thresholds, were used in the computation of the Moran's *I* tests for each of the negative binomial regression models (Tita & Radil, 2010). Regardless of the selected distance threshold, and across both models, none of the Moran's I values suggest that spatial autocorrelation is a concern for the data used in this study. Specifically, Moran's I statistics range from -1 to +1, where a value of +1 indicates strong clustering of similar values, -1 indicates strong clustering of dissimilar values, and 0 indicates complete randomness. Because none of the Moran's I values displayed below for any of the models exceed 0.087, it appears that there was little clustering of model residuals across street blocks after the spatially lagged predictors were included in the models.

Table 6. Results of Moran's I Analysis of Residuals

	Moran's I (500ft)	Moran's I (1000ft)
Model A	0.087	0.075
Model B	0.071	0.044