RELEVANCE OF ROUTINE ACTIVITY VARIABLES FOR UNDERSTANDING THE SPATIAL DISTRIBUTION OF RESIDENTIAL BURGLARY AND GENERAL OUTDOOR ASSAULT IN DONGJAK DISTRICT IN SEOUL, SOUTH KOREA

by

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TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

ABSTRACT

There are few studies where researchers used South Korean spatial data to examine residential burglary and general outdoor assault. The current study examined the effects of routine activity variables on measures of residential burglary and general outdoor assault in South Korea using police data for these offenses that resulted in arrest from January 2015 to December 2016. The study (1) explored spatial patterns of these crimes, and (2) examined the applicability of routine activity theory, using various regression models. The results revealed that both crimes are spatially clustered. Distance to a subway station, the number of older residents, and the number of restaurants and adult entertainment places were all positively associated with residential burglary, whereas the number of preschool children and the number of high-rise apartments were negatively associated with it. The number of restaurants and adult entertainment places and population size were positively associated with general outdoor assault, while distance to a subway station and population density were negatively associated with it. While most of routine activity variables did not explain these crimes, restaurants and adult entertainment places were significant predictors for both residential burglary and general outdoor assault, meaning that police' and other interventions are necessary to address these crimes near restaurants and adult entertainment places. Unlike most previous studies that found young population as a significant predictor for burglary and assault, the current study found it to be a non-significant predictor; this may have been

due to teenagers in South Korea and the U.S. having different routine activities. Overall, the study found a weak support for routine activity theory, implying that researchers need to consider cultural differences between South Korea and western countries, especially the U.S.

I. INTRODUCTION

Purpose of Study

Previous studies of spatial patterns of residential burglary and general outdoor assault have been conducted in various contexts. Only a few studies, however, have been conducted with South Korean data, with or without census block data. Spatial analysis of census block data allows researchers to examine environmental factors more closely and how they are related to crime. Relying upon South Korean census block data and other data, this study (a) explored spatial patterns of residential burglary and general outdoor assault using the police-recorded data for crimes resulting in the arrest of a suspect, and (b) examined the applicability of routine activity theory to these crimes using (spatial) regression models. It was hypothesized that residential burglary and general outdoor assault would be spatially concentrated in particular areas—hotspot areas—where, as routine activity theory suggests, the three components necessary for crime (i.e., motivated offenders, suitable targets, and the absence of capable guardianship) would be present. To test these hypotheses, the study used crime data from Seoul Metropolitan Police Agency, census block data for Dongjak District in Seoul, South Korea, and several other data sources for January 1, 2015, to December 31, 2016. The crime data were limited to a single district because these were the only available data for this study. Use of data for crimes that resulted in an arrest is a limiting factor to the extent that clearance rates are low. The clearance rates for these crimes, however, were high during the period of this study.

The study examined two research questions: (1) Are there areas where residential burglaries and general outdoor assaults were concentrated in the study area?; and (2) If so, what accounts for the concentration? These are important questions to ask because the answers have policy implications for crime prevention in South Korea. Residential burglary and general outdoor assault are two of the most prevalent crimes in South Korea as they are in the U.S. Given their prevalence, the social costs of these crimes are enormous, and if they can be prevented by focusing on the right variables at less cost, this would be a major contribution of this study. Routine activity theory focuses on places and times to explain crime, and this makes the expected outcomes of crime prevention efforts more tangible than efforts to explain why some individuals commit crime. This study was the first to specifically use routine activity variables to account for the spatial distribution of crime in South Korea. The explanatory power of routine activity theory could have been affected by the different context of South Korea, but in the end the findings were largely consistent with findings in other (especially Western) countries.

Overview

In this chapter, it was noted that an examination of environmental and population correlates of residential burglaries and general outdoor assaults in the Dongjak District in Seoul, South Korea, warrants further inquiry. A review of the relevant literature is presented in Chapter II. This includes information from two critical areas of criminological theory, namely environmental criminology and especially routine activity theory, which is considered one of the major theories in environmental criminology. While the focus of this study is on residential burglary and general outdoor assault, most previous studies have focused on burglary and assault in general, not their subtypes.

Chapter III provides the details of the methods relied upon to carry out this study. Chapter III also defines the independent variables and the two dependent variables in the study (i.e., residential burglary and general outdoor assault) and another key concept: the hot spot. Several sources of data were relied upon, and each is described in detail. This is followed by a discussion of the analytical strategy, which includes several mapping techniques and regression models. Chapter IV presents the results of the hotspot analyses and analyses of the predictors of hotspot areas. It was found that residential burglary and general outdoor assault clustered but that there was a need to use spatial regression models for both residential burglary and general outdoor assault. A final model (a zero-inflated negative binomial regression model) for residential burglary reports that restaurants and adult entertainment places, subway stations, elderly, preschool children, and high-rise apartments are associated with the spatial distribution of residential burglary, while a final model for general outdoor assault reports that restaurants and adult entertainment places, subway stations, population density, and population size are associated with the spatial distribution of general outdoor assault. Chapter V includes a discussion of the present findings and their implications for theory, policy, and future research.

II. LITERATURE REVIEW

This research aimed to assess the level of spatial concentration of residential burglaries and general outdoor assaults (research question 1) and to determine whether any hot spots observed could be explained by routine activity theory (research question 2). Such goals called for an examination of environmental criminological theory, which assesses crime through the lens of how environmental factors affect crime (Brantingham & Brantingham, 1981). Routine activity theory, which posits that crime occurs when three factors converge in space and time—motivated offender, suitable target, and absence of a capable guardian (Cohen & Felson, 1979)—is one of the theories falling under the umbrella of environmental criminology.

Environmental Criminology

The roots of criminology before the emergence of environmental criminology can be found in cartographic criminology and social ecology. Research on the differential spatial distribution of crime began with cartographic criminology in the early 19th century. Cartographic criminology examined the relationship between crime and space. Crime distribution in urban areas was found to be correlated with urban environmental factors, such as structural patterns (e.g., roads, river networks, etc.), residential differentiation, and the macro processes of urban growth (e.g., planning and zoning of transport and infrastructure networks) (Evans, Fyfe, & Herbert, 1992).

The study of social ecology in the Chicago School in the U.S. in the 1920s and 1930s assessed the regional differences in crime and the relationship between urban areas' social mechanisms and crime. The social mechanisms in urban areas are generated not only by the areas themselves, but they also vary because of the interactions among people who reside in them. Social disorganization theory (Shaw & McKay, 1942), which is one of the social ecology theories, and subcultural theories (Fischer, 1975), have received considerable attention from criminologists and geographers by introducing a "regional factor" to explain crime (Herbert, 1989). Social ecologists employed quantitative analyses to explain crime ecologically and played an important role in finding relationships between crime and various socio-economic factors, such as economic deprivation, population turnover, and racial heterogeneity.

Since the 1970s, criminologists have examined the relationship between space and crime more closely than they did previously. Routine activity theory (Cohen & Felson, 1979) belongs to a theoretical tradition of social ecology, but the theory is more specific than other social ecology theories because it focuses on individuals' routine activities as structural background for crime occurrence. It explains how individuals' routine activities generate crime opportunities. According to Cohen and Felson (1979), traditional criminology had focused so much on offenders' motivation or criminality that it had ignored other important factors in crime. They suggested three necessary elements for crime: motivated offenders, suitable targets, and the absence of capable guardians (Cohen & Felson, 1979). Whether the three elements converge in the same time and space depends on individuals' routine activities. Such routine activities refer to activities that people perform regularly and frequently, including activities for the necessities of life, work and family, leisure activities, social activities, and so on. Although Cohen and Felson (1979) suggested that a motivated offender is one of the necessary elements for crime to occur, they pay little attention to it, believing that traditional criminological theories had focused too much on offender motivation. The concept of motivated offender had been assumed to be inherent in individuals or situationally stimulated due to suitable targets (Osgood, Wilson, O'Malley, Bachman, & Johnston, 1996). Thus, studies on routine activity theory have often focused on places that situationally motivate potential offenders.

Roncek and Maier (1991) explained how an area becomes a hot spot (i.e., geographical cluster of criminal activity) through routine activity theory. For example, adult entertainment places, such as bars and clubs, are places that can form hot spots because they are places where various individuals interact and where possibly the interactions can lead to criminal activities, such as public-order offenses and assaults. People may congregate outside of a bar during or after operation hours, perhaps to smoke cigarettes or get some fresh air. They may fight with other people while intoxicated. Such places have a high level of anonymity and weakened social control so that they attract potential offenders who are criminally motivated (Cohen & Felson, 1979).

Most criminological theories have focused on why individuals become criminals, or emphasize the etiology of criminal behavior, such as genetic factors, psychological and social interactions, family bonds, and so on. From the perspective of traditional theories, it has been thought that there is no advantage in explaining crime concentration in certain places (Weisburd & Braga, 2006). In contrast to most criminological theories, environmental criminology has focused on offenders, targets, and locations in crime occurrence, especially emphasizing its locations (Brantingham & Brantingham, 1981). Environmental criminology focuses on reducing crime opportunities by investigating criminal factors in particular places or environments. It focuses on offenses rather than offenders, attempting to understand why criminal events occur at particular times and places. The geographical characteristics of offenses can be analyzed, and the local environment around the crime can be used as sources of explanation (Herbert & Hyde, 1985). These sources may be the residential location of offenders, schools, workplaces, and entertainment areas among others. Brantingham and Brantingham (1982) emphasized that these various sources must be combined and analyzed.

Routine Activity Perspective

In this study, the three elements of routine activity theory (i.e., motivated offender, suitable target, and absence of capable guardian) are operationalized as follows. Three variables are taken as measures of motivated offenders: high-risk offenders, teenagers, and schools. There are four measures of suitable targets: high-level education, restaurants and adult entertainment places, subway stations, and shopping malls. And there are seven measures of absence of capable guardians: homeowners, the elderly, preschool children, high-rise apartments, CCTV cameras, police stations, and population density. Similar measures have been used in previous studies of routine activity theory, but they are spread out over diverse studies in different contexts. For residential burglary, the following variables were considered; high-risk offenders, teenagers, schools, high-level education, restaurants and adult entertainment places, subway stations, homeowners, the elderly, preschool children, high-rise apartments, CCTV cameras, police stations, population density, and households. For general outdoor assault, the variables include high-risk offenders, teenagers, schools, restaurants and adult entertainment places, subway stations, shopping malls, CCTV cameras, police stations, population density, and population.

Routine activity theory has drawn considerable attention from many researchers who have employed different datasets with different units of analysis (e.g., Clarke, Ekblom, Hough, & Mayhew, 1985; Cohen & Cantor, 1980, 1981; Cohen, 1981; Cohen, Kluegel, & Land, 1981; Gottfredson, 1984; Miethe, Stafford, & Long, 1987; Miethe, Hughes, & McDowall, 1991; Osgood, Wilson, O'Malley, Bachman, & Johnston, 1996; Riley, 1987; Sampson & Wooldredge, 1987; Widom & Maxfield, 1984). Clarke et al. (1985) found that people over the age of 60 were at lower risk of personal crime than were the young because the elderly have fewer chances of association with offenders or less attraction as victims. Riley (1987) found that teenagers' lifestyles, specifically their time spent away from home, were associated with their likelihood of victimization—the greater their time away from home, the greater their likelihood of victimization.

Other studies have focused on the core variables in the theory. Lynch (1987) reported that proximity is one of the strongest predictors of crime rates or victimization risk. This finding supports Zipf's Principle of Least Effort (Zipf, 1949), which states that people try to solve a problem in a way that minimizes the total work they need to spend. As Garofalo (1987) stated, however, physical proximity alone is not sufficient for a would-be offender. Many studies have considered that the "motivated offender" variable is assumed rather than treated as an empirical question (Garofalo, 1987). Another study reported target-hardening measures, such as locks, reduced crime rates (Feins, Peterson, & Rovetch, 1983).

Cohen et al. (1981) reported the effects of specific variables on crime incidence were moderated by crime type. Miethe et al. (1987) argued that the opportunity approach (i.e., lifestyle and routine activity theories) relied on an offender's rational choice, and, therefore, the spontaneous nature of violent crimes makes them difficult to predict. They also argued regarding violent crimes that activities outside the home increased guardianship, and, therefore, should decrease risks of violent crimes (Miethe et al., 1987).

There was an interesting cross-national study to assess routine activity theory. Bennett (1991) relied upon various data, involving crime, social, political, and economic variables covering the 25-year period from 1960 to 1984 for a diverse sample of 52 nations. The study relied upon crime data, especially personal and property crime as dependent variables. For the independent variables, the study first used a nation's gross domestic product (GDP) in order to measure the accessibility and availability of manufactured goods as targets of theft. For the second independent variable, the study used the GDP of a nation divided by its population size to measure target attractiveness. It assumed that the higher a nation's GDP, the more valuable the items that can be stolen. In addition, the study measured proximity by urbanization, or the yearly proportion of population residing in cities or towns, and it employed the status inequality as an indicator of the desire to steal, or offender motivation. Finally, the study used female labor-force participation to measure reduced informal guardianship. Even though the measured variables were not perfect indicators of the key variables, the study reported several noteworthy results. First, the theory was crime-specific; the theory was better supported for property crimes than personal crimes. Second, the guardianship variable explained only property crime. This result was already reported in other studies showing guardianship to be more strongly related to theft than to violent crimes (Cantor & Land, 1985; Cohen & Felson, 1979; Miethe et al., 1987).

Despite the study's general support for routine activity theory, Eck (1995) pointed out that when testing a micro-level theory using macro-level data, the study was susceptible to the ecological fallacy (i.e., the characteristics of an area at an aggregate level used to characterize individuals in the area) (Eck, 1995). Groff (2007, p. 78) stated that "routine activity theory is essentially a micro-level theory with macro-level implications." In this sense, Groff's (2007) simulation study was meaningful as an attempt not only to accommodate this issue, but also in its aim to address other issues, such as the spatio-temporal structure of routine activity theory and various measurement issues. The findings indicated that the more time individuals spent away from home, the greater the likelihood of street robberies (Groff, 2007).

Previous Studies

Empirical studies of burglary. Different neighborhoods have different patterns of burglary, and these patterns are not spatially random (Eck & Wartell, 1997; Farrell & Pease, 1993; Forrester, Chatterton, Pease, & Brown, 1988; Forrester, Frenz, O'Connell, & Pease, 1990; Polvi, Looman, Humphries, & Pease, 1991; Townsley, Homel, & Chaseling, 2000). For instance, Andresen (2006) investigated the spatial dimensions of different kinds of crimes using crime data for Vancouver, British Columbia, in 1996. He found the significant predictors of breaking and entering (i.e., burglary, though not just residential burglary) were the unemployment rate, percent of households headed by single parents, population size, population density, and percent of population ages 15 to 29. Bernasco and Luykx (2003) relied upon data in the city of the Hague, Netherlands, from 1996 to 2001 and found that proximity to the burglars' homes, proximity to the central business district, residential mobility, ethnic heterogeneity, the values of residential units, and home ownership had statistically significant effects on residential burglary. It suggests that burglars commit their crime in areas close to their homes (Rengert, Piquero, & Jones, 1999; Rossmo, 2000; Wiles & Costello, 2000). From the literature, it was found that residential burglary concentrates in space, and the spatial distribution of residential burglary is affected by single-parent households, population size, population density, young population, values of residential units, and home ownership, which can be used as proxies for the three elements of routine activity theory. For example, single-parent households can be treated as a proxy for absence of capable guardianship, and young population can be used as a proxy for motivated offender.

In South Korea, researchers employed police-recorded data to identify hot spots and examine the effects of socio-demographic variables on burglary. Hwang (2001) examined residential burglary in Seongbuk District, Seoul, and found that hot spot areas of residential burglary were located in concentrated low-income residential areas. The findings indicated that residential burglars do not necessarily commit their crimes in affluent areas for the high value of the items, but rather they burglarize in disadvantaged neighborhoods because of either the low level of security or the high level of accessibility. It is also possible that the burglary rate may be non-linearly associated with the level of affluence in a neighborhood; the burglary rate may increase with increasing affluence up to a point when increasing affluence becomes negatively associated with the burglary rate because of greater security.

Socio-demographic variables were also predictors of residential burglary in neighborhoods; these included the percent of the population comprised of children who were four years old and younger, the percent of households receiving social benefits, and the percent of the population in the neighborhood who wereages 14 to 19 (Hwang, 2001). These findings supported routine activity theory, although the author did not identify which theory was being tested. Regardless, the percent of children could be used to estimate guardianship in the home (Cohen & Felson, 1979). Children who stay at home most of the time can be considered as capable guardians protecting against a potential burglary because they spend most of the time with parents and caregivers who can actually be guardians against a potential burglary. The hot spot neighborhoods in the study had shabby houses on streets with narrow paths, which makes it difficult to watch over other neighbors. According to the study, the affluent areas which were not hot spot areas for burglary consisted of high-rise apartment residential areas with wide streets.

Another study in South Korea analyzed factors affecting different types of crime in a metropolitan city. According to Jeong, Moon, Jeong, and Heo (2009), hot spot areas of burglary (both residential and commercial) were in areas that had a large transient population due to an intercity bus terminal, a railway station, a large department store, and an industrial area in which a small number of people resided but was adjacent to residential areas. It was also found, for burglary, that the number of lodgings and restaurants, wholesale and retail sales, the amount of property tax paid, and the percentage of elderly (65 years and older) in the population were statistically significant predictors of burglary. These findings suggested that residential burglary was not only affected by physical environmental factors, such as lodgings and restaurants, but was also affected by sociodemographic characteristics of the population.

The two studies above conducted in South Korea, however, had some methodological limitations. Both studies employed data for census tracts, which are larger geographical units than the census blocks used here. Researchers have found that the aggregation level influences the results of a study. Bursik, Grasmick, and Chamlin (1990), for example, noted that the magnitude and the sign of the coefficients of variables might be very different depending on the aggregation level in a study. This is because, at the larger areal unit where the differences between individual units are aggregated, there would be some variance within the unit but relatively small variance between the units. The aggregating process from smaller units to larger units leads to homogenization in the measures due to small variance between units that can create some patterns, and, therefore, the model would have more explanatory power (Ouimet, 2000). Sometimes researchers have to aggregate units in order to draw meaningful results from their analysis (Sampson, Raudenbush, & Earls, 1997; Schuerman & Kobrin, 1986). For example, if there are only a few crimes and a few teenagers in a small unit, it would be difficult to create a pattern from such a small number of observations. In a study on the choice of level of aggregation, which compared census tracts and neighborhoods as units of analysis, Ouimet (2000) concluded that analyses with census tracts (i.e., smaller units) seemed to provide a better fit for studies that examined the role of opportunity variables, including routine activity variables than analyses of neighborhoods (i.e., larger units).

With regard to the two South Korean burglary studies, it was unclear to which theory or theories the variables were related. Both studies used socio-economic variables, such as the proportion of the population receiving social benefits, but neither of the studies explicitly tested theory-based variables. The current study seeks to address these gaps by employing spatial data at a census block level and include routine activity variables to examine their effects.

Although there were not many studies linking schools with residential burglary, a few studies found an association between the two variables. Most of studies focused on the school itself, not its effects on neighborhoods. Garofalo, Siegel, and Laub (1987) used National Criminal Victimization Survey (NCVS) data and found that more victimizations occurred on the way to school rather than within the school itself. Scott (2004) found that there was a strong correlation between daytime burglaries and truancy, and a greater number of household burglaries occurred near schools, as compared to away from schools.

There has been no empirical study that linked the elderly with residential burglary, though some studies on decision making by burglars found that burglars preferred houses with no signs of occupancy (Maguire, 1988; Nee & Meenaghan, 2006). This links with the elderly as a guardian against residential burglary because the elderly are retired and likely to be at home during the daytime when others are at work. Felson (1995) also stated that a retired person at home might prevent daytime burglary of his or her own home or even neighbors' homes.

There are only a few studies that found an association between high-rise residential buildings and residential burglaries. Newman (1972) compared two public housing units: one low-rise and the other high-rise. He found that crime rates were four times higher in high-rise units than low-rise units. While most studies have found that there were more burglaries and violent crimes in high-rise buildings than in low-rise buildings (Newman, 1972; Jacob, 1961), one study found the opposite (Bernard-Butcher, 1991). The studies that found an association between crimes and high-rise buildings asserted that high-rise buildings are impersonal; residents do not communicate and are indifferent with one another, whereas low-rise buildings are more humane in that they are more open to one another, and residents can easily watch other apartment units.

Empirical studies of assault. Violent crimes, such as assaults, have a pattern of clustering, especially associated with alcohol outlet density (Britt, Carlin, Toomey, & Wagenaar, 2005; Livingston, 2008; Nielsen & Martinez, 2003; Zhu, Gorman, & Horel, 2004). According to Cohen and Felson (1979), places such as bars/taverns have a high risk of violence for motivated offenders and potential victims because people, especially young males, congregate in these places. People in these places are often not self-conscious and they are hesitant to complain about others' behaviors. Individuals in these places may perceive that norms are weakened, and antisocial behavior is acceptable. Due to the weakened norms, individuals lose control over their behavior, increasing the risk of deviant behavior (Pernanen, 1991). These places provide the context where normative constraints are relaxed, and alcohol consumption may increase the risk of violence (Pridemore & Grubesic, 2013). It is not only these places that serve as criminogenic places, the surroundings may also be problematic. People tend to congregate outside of these places, perhaps just to smoke cigarettes or chat, even after closing (Graham, Tremblay, Wells, Pernanen, Purcell, & Jelley, 2006). In many places, convenience stores are also alcohol outlets. They not only sell alcohol but also provide places where people congregate for a variety of reasons. Some studies observed that the convenience stores served as taverns or attracted other criminals, such as drug dealers and prostitutes (Alaniz, Cartmill, & Parker, 1998; Block & Block, 1995).

Many researchers have examined the relationship between alcohol consumption and violent crime (e.g., Giancola, Saucier, & Gussler-Burkhardt, 2003; Gorman, Speer, Gruenewald, & Labouvie, 2001; Haines & Graham, 2005; Lipton & Gruenewald, 2002; Pihl & Lemarquand, 1998; Pridemore & Grubesic, 2013; Roncek & Maier, 1991; Scribner, MacKinnon & Dwyer, 1995; Stevenson, Lind, & Weatherburn, 1999). The research has tended to focus on individuals, either assault offenders or victims (Felson, Savolainen, Aaltonen, & Moustgaard, 2008) or criminal events (Felson, Burchfield, & Teasdale, 2007; Pridemore & Eckhardt, 2008). Most studies have reported that there is an association between alcohol outlets and violent crime, although some researchers have reported mixed results on the relationship between them. Gorman, Speer, Gruenewald, and Labouvie (2001), for example, found no association between alcohol outlets and assault or domestic violence in New Jersey. Block and Block (1995) also found no association between them in Chicago. Speer, Gorman, Labouvie, and Ontkush (1998), however, as a follow-up to the Gorman et al. study found an association between alcohol outlets and violence in Newark, New Jersey. Roman, Reid, Bhati, and Tereshchenko (2008), relying upon census block data, also found that on-premise outlets were significantly associated with assaults, and both on-premise and off-premise outlets were positively associated with disorder. Alcohol-related violence is likely to occur outdoors (Briscoe & Donnelly, 2001), which points to the importance of looking at general outdoor assaults in this study.

Other studies have found a positive association between density of alcohol outlets and violent crimes (Britt, Carlin, Toomey, & Wagenaar, 2005; Livingston, 2008; Nielson & Martinez, 2003; Zhu, Gorman, & Horel, 2004). The differences in the findings among these studies may be attributed to the measurement of their dependent variables and units of analysis. Some studies jointly measured different violent crimes, and others measured them separately, such as assaults v. public disorder crimes. Scribner, MacKinnon, and Dwyer (1995) found, in a study using cities as the unit of analysis, that large variation in violent crime was explained by sociodemographic variables, but only a small amount of variation in violent crime was explained by alcohol outlet density. In Speer et al.'s (1998) study using municipalities as the unit of analysis, there was no statistical association between alcohol outlet density and violent crime rates.

High-risk offenders are viewed versatile offenders in the current study; they commit other types of offenses other than sexual crimes. According to Soothill, Francis, Sanderson, and Ackerley (2000), rapists were two times likely to be reconvicted of a violent crime than a sexual crime. Teenagers are also a predictor of violent crime, especially assault. From the routine activity theory perspective, teenagers' routine activities often take place within schools. Their interactions with school participants, such as other students, teachers, and staff, influence the likelihood of violence especially when involved in extracurricular routine activities (Payne, 2008; Payne, Gottfredson, & Gottfredson, 2003).

Public transit, such as subway, can create opportunities for crime because large proportions of populations use it around the city along limited paths and stops (Brantingham, Brantingham, & Wong ,1991) Crime opportunities are framed not only within subways, but also above and around subway stations. Potential offenders hang around subway stations waiting for potential victims (Block & Davis, 1996); the transit stations can play as crime attractors. Recent studies found that assaults were significantly clustered around subway stations (Herrmann, 2015; Loukaitou-Sideris, Liggett, Iseki, 2002).

Shopping malls can also be crime attractors, which make them suitable targets for criminal opportunities. They attract many customers and potential offenders as well. Previous studies reported that shopping malls and their adjacent neighborhoods suffered from violent offenses against shoppers, employees, and security personnel (Stahura & Huff, 1981, Stahura & Sloan, 1988).

Although there are few studies on the deterrent effect of police stations on assault, one study found that police (sub)stations was found to have a negative and significant effect on violent crime (Levitt, 1995). Many studies used police patrol routes as the presence of police rather than the actual locations of police stations (Braga & Bond, 2008; McGarrell, Chermak, & Weiss, 2002; Sherman, Shaw, & Rogan, 1995; Weisburd & Braga, 2006). However, locations of police stations may have an impact on violent crime, especially on general assault because locations of police stations influence their response time to a crime location. There is a higher chance of intercepting and making an arrest as police response time reduces. Therefore, potential offenders are more likely to be deterred from committing crime because of the guardianship effect of nearby police stations.

In South Korea, Roh (2015) examined the predictive accuracy of crime forecasting models using spatio-temporal analysis and risk-terrain modeling. He found that a list of independent variables— community disorders (e.g., disturbance in public, juvenile delinquency, amusement business affecting public morals, illegal street vendors), the geographic concentration of liquor stores and accommodations, low-income, and proximity to bus stops—were predictors of the aggravated assault rate. Lee (1994) found that the number of adult entertainment places, inflow of population, and average education level increased the likelihood of general assault. In another study in South Korea, Kim, Jang, and Moon (2007) examined the spatial influences of criminogenic factors in larceny, assault, robbery, and rape, to identify the distribution of crime. They identified five factors related to crime occurrence and analyzed their effects on crime rates; these included the geographic locations of subway stations, shopping districts, police substations, arterial roads, and adult entertainment places. Only the geographic locations of adult entertainment places had a positive significant effect on general assault occurrence (the greater the number of adult entertainment places in an area, the greater the likelihood of general assault). Although the authors did not explain the results, it might have been the case that the geographical locations of adult entertainment places were more closely located near locations of crimes than the other types of locations. It might also have been the case that the effects of other variables were counteracted by the effect of the adult entertainment places considering that they are likely to be correlated with each other.

Studies of the police as formal social control. Routine activity theory has tended to focus on more than the police as capable guardians, but police presence may help to explain the spatial distribution of both residential burglary and general outdoor assault in this study. From the perspective of rational choice theory, it has been proffered that the presence of police will decrease crime (Becker, 1968). In the same sense, routine activity theory also suggests that formal social controls, such as police, will act as capable guardians against crime. There is an endogeneity problem, however, in looking at the relationship between police presence and crime. An endogeneity problem occurs in a situation where more police officers are hired when there are higher crime rates. This leads to the area having higher crime rates and more police officers than an area with lower crime rates. This effect has biased the police coefficient in extant studies (Cameron, 1988; Eck & Maguire, 2000; Marvell & Moody, 1996). Cameron (1988) found that in 18 out of 22 studies there was a positive association between police presence and crime or no relationship at all. Marvell and Moody (1996) also found that almost 80% of studies showed either no association or a positive association between police presence and crime. In order to respond to the endogeneity issue and in contrast to the other studies. Corman and Mocan (2000) employed high-frequency longitudinal data for New York City and found that the number of police officers is negatively associated with burglary.

Levitt (1995) used a different approach using instrumental variables. He used the timing of gubernatorial and mayoral elections as an instrument for police presence in 59 large U.S. cities and found that greater police presence reduced violent crime. But this negative relationship between the timing of election (i.e., police presence) and crime might be spurious, because other factors might have affected the reduction in violent crime, such as police effort and crime reporting might have changed with the elections. This is especially true if the police were used politically. The judges and prosecutors might also have behaved differently during the elections (Di Tella & Schargrodsky, 2004).

Summary of Theoretical Foundations and Empirical Research

This chapter shows how environmental criminology and routine activity theory serve as a foundation for assessing residential burglaries and general outdoor assaults and subsequently, to examine whether hot spot areas for those crimes can be explained by routine activity theory. Chapter III discusses how each of the elements of routine activity theory—motivated offenders, suitable targets, and absence of capable guardians are measured. Additionally, the analytical strategy is explicated.

III. METHODS

Background of Study

As shown in Figure 1, Dongjak District (also called Dongjak-gu; the area shaded on the map) is one of 25 administrative divisions in Seoul, the capital city of South Korea. Dongjak District had 412,774 people and 170,495 households in 2015. The average number of persons per households was 2.42. The land area is 6.4 square miles, which is 2.7% of the total land area of Seoul. Almost 84% of the district was residential, 2.2% of commercial, and 13.8% of greenbelt. In residential areas, there were about 23,600 households in detached single-family houses, 49,100 households in high-rise apartments, 6,000 households in town houses, and 24,600 households in multi-family houses. Dongjak District is located in the center of the Seoul city, which plays an important role as a traffic-center hub connecting all parts of the city. It also borders *Han* river on the north of the district, which divides the city into two main areas: *Gangbuk* and *Gangnam*. In general, the *Gangbuk* area is less affluent than the *Gangnam* area (*Gang* meaning “river”, *buk* meaning “north”, and *nam* meaning “south” in Korean language).

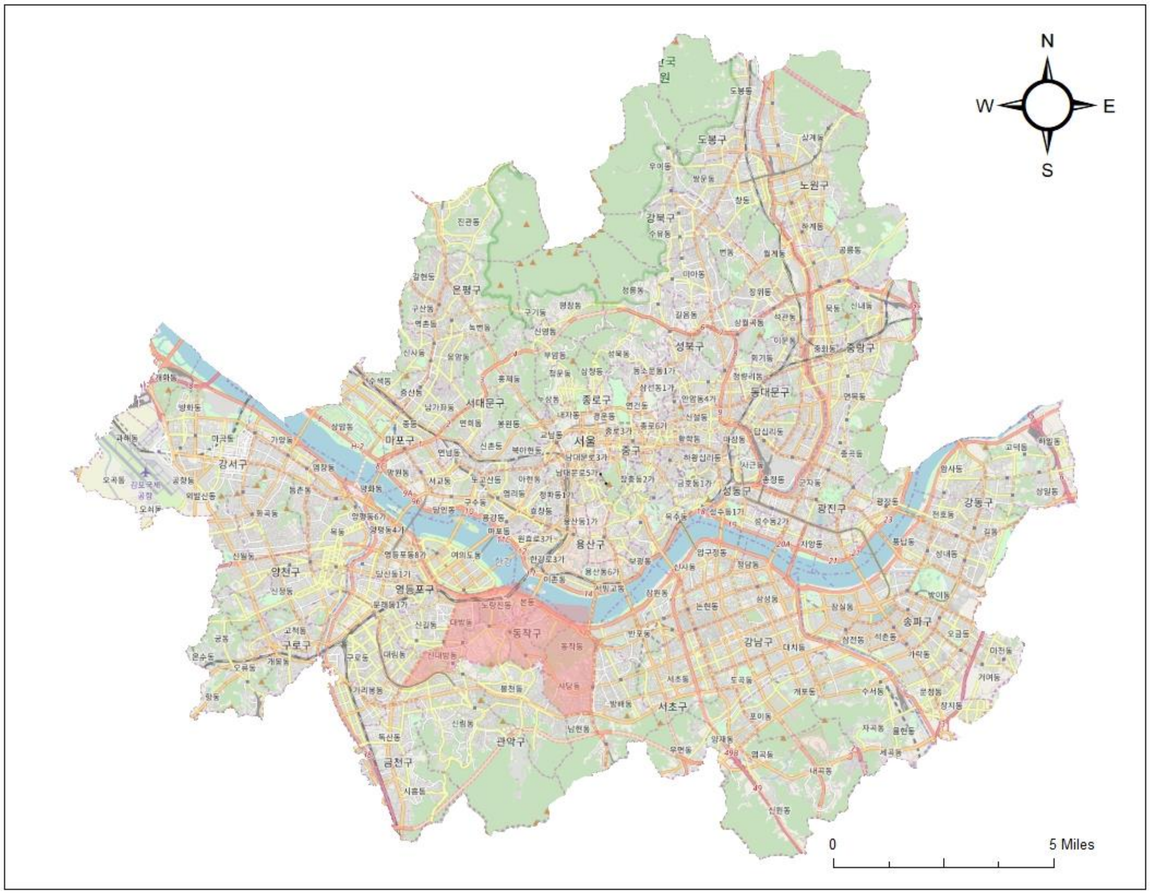

Figure 1. Dongjak district within Seoul city

As shown in Figure 2, Dongjak District is also home to Chongshin University, Chung-Ang University, and Soongsil University. Overall, there are 42 schools, including the three universities, elementary, middle, and high schools. There were also 16 subway stations located in the main downtown areas throughout the district. The residential and commercial areas are colored in grey on the map in Figure 2, and the greenbelt zones, which consist of public parks throughout the district and the National Cemetery located in the northeastern of Dongjak, are colored in green and light green in Figure 2.

Figure 2. Dongjak district with points of interest

South Korea conducts the *Population and Housing Census* of all South Koreans and foreign residents in the territory of the Republic of Korea and their places of residence every five years. The size of each census block varies by the number of households and people. Each census block has approximately 60 plus/minus 20 households. There are 794 census blocks in Dongjak District. The size of the census blocks also varies due to land use; some blocks are mainly used as residential areas, and others have mixed usage (82% of residential, 2.2% of commercial, and 15.8% of greenbelt).

Current study

This study has three main goals: (1) to explore spatial patterns of residential burglary and general outdoor assault in the Dongjak District in Seoul, South Korea; and (2) to examine the applicability of routine activity theory to those crimes using various regression models. The study timeframe included crimes that occurred from January 1, 2015 to December 31, 2016. Based on these goals, two research questions, utilizing descriptive (i.e., hotspot analyses) and deductive approaches (i.e., theory-testing), were addressed. These are: (1) Are there areas where residential burglaries and general outdoor assaults were concentrated in the study area?; and (2) Are the hot spot areas explained by routine activity theory?

It is important to define the two dependent variables: residential burglary and general outdoor assault, along with another key concept: a hot spot area. It is also important to describe several data sources: police-recorded data (including high-risk offender data), census block data, and other supplemental data sources. From these sources, the dependent variables (residential burglary and general outdoor assault) and all independent variables were extracted. The analytical strategies are also detailed in this chapter, including a series of techniques to map crime. The subsequent analyses, building upon the mapping techniques, include regression models and several spatial analysis techniques. The spatial analyses included a spatial lag model, a spatial error model, and a negative binomial model with spatially lagged term. The results of these analyses are presented in Chapter IV.

Definitions of Key Concepts

Burglary. There are substantial differences in how burglary is defined and recorded by the police in the U.S. and South Korea. According to the F.B.I.'s *Uniform Crime Reports* (UCR), a burglary occurs when someone breaks and enters into a structure (e.g., residence, commercial building) to commit a theft or other crime. An attempted forcible entry is also considered burglary for reporting purposes. The South Korean Penal Code does not define burglary—instead it defines "intrusion upon habitation, refusal to leave," which is more akin to breaking and entering in the U.S. because it includes no reference to intent to commit another crime. The following are the Korean definitions of the crimes similar to the U.S. definition of residential burglary.

> Article 319 (Intrusion upon Habitation, Refusal to Leave)
> (1) A person who intrudes upon someone's residence, guarded building, structure or ship or occupied room, shall be punished by imprisonment for not more than three years or by a fine not exceeding five million won (approximately five thousand dollars in U.S. dollars).
> (2) The preceding paragraph shall apply to a person who refuses to leave such a place upon demand as specified in the preceding paragraph.
>
> Article 320 (Special Intrusion upon Human Habitation)

> A person who commits the crimes of the preceding Article through the threat of collective force, or by carrying a dangerous weapon, shall be punished by imprisonment for not more than five years.
>
> Article 321 (Illegal Search of Human Habitation and Body)
> A person who illegally searches another's body or one's habitation, guarded building, structure, automobile, ship, aircraft or occupied room, shall be punished by imprisonment for not more than three years.
>
> Article 322 (Attempts)
> Attempts to commit the crimes of this Chapter shall be punished.
> (South Korean Criminal Act, 2013, n.p.)

According to the UCR, breaking and entering for the purpose of committing theft is recorded as burglary. In contrast, in South Korea, breaking and entering for the purpose of committing theft is recorded by police as theft, not burglary. This is because the police rely upon a principle of concurrent crimes—only the most serious crime is counted and recorded when multiple crimes occur in a single criminal incident. South Korean officials consider theft, and many other crimes, more serious when committed after breaking and entering. In the U.S., the F.B.I. uses a similar hierarchy rule that requires reporting of only the most serious crime in a multiple-crime incident. The hierarchy rule, however, is imposed infrequently by the F.B.I. and for only a few crimes, such as murder and rape.

South Korean burglary data involve mainly breaking and entering that was not followed by the commission of another crime. The most common crime committed after breaking and entering in South Korea is theft, and the theft data relied upon in this study allow for identification of thefts committed during residential burglaries. While there are other crimes, such as rape and murder, that can occur after an offender breaks and enters into a residence, they are excluded from the count of residential burglaries in this study.

Thus, for this study, these residential burglaries are defined here in accordance to South Korean law and are relied upon as one of the dependent variables, *residential burglaries.*

All residential burglaries resulting in arrest during the 2015-2016 timeframe were included in this study. Hence, the measure of residential burglaries is actually a measure of cleared residential burglaries. The gap between residential burglaries and cleared residential burglaries is problematic to the extent that a large number of the burglaries are not cleared by arrest. This is not the case with residential burglaries in the Dongjak District in South Korea where 100.8% in 2015 and 101.7% in 2016 of the burglaries are cleared by arrest (Moon, Choi, Lee, & Lee, 2017; South Korean Ministry of the Interior and Safety, 2016). The percentages exceed 100% because Korean National Police Agency counts clearance for crimes occurred in previous year as part of statistics in current year, while prior annual rates are not revised (South Korean Ministry of the Interior and Safety, 2016). This is often the case in FBI's UCR data, too.

Assault. The UCR divides assault into two subcategories: aggravated assault and other assaults (e.g., simple assault) (U.S. Department of Justice, 2016). Aggravated assault is defined as an unlawful attack by one person upon another for the purpose of inflicting severe or aggravated bodily injury. It usually is accompanied by the use of a weapon or by means likely to produce death or great bodily harm. Simple assault is excluded from the Part I index crimes (i.e., more serious crimes). In Part II crimes (i.e., less serious crimes) of the UCR, other assaults, which includes simple assault, are defined as assaults and attempted assaults where no weapon was used or there was no serious or aggravated injury to the victim. Stalking, intimidation, coercion, and hazing are included in this type of assault (U.S. Department of Justice, 2016).

The definition of assault in South Korea is similar to the one in the U.S. Assault is codified in the South Korean Penal Code as the following:

> Article 257 (Inflicting Bodily Injury on Other or on Lineal Ascendant)
> (1) A person who inflicts a bodily injury upon another shall be punished by imprisonment for not more than seven years or suspension of qualifications for not more than 10 years or by a fine not exceeding 10 million won (approximately 10 thousand dollars in U.S. dollars).
> (2) When the crime as referred in paragraph (1) is committed on a lineal ascendant of the offender or of his spouse, one shall be punished by imprisonment for not more than 10 years or a fine not exceeding 15 million won (approximately 15 thousand dollars in U.S. dollar).
> (3) Attempts to commit the crimes of the preceding two paragraphs shall be punished.
>
> Article 258 (Aggravated Bodily Injury on Other or on Lineal Ascendant)
> (1) A person who inflicts bodily injury upon another, thereby endangering one's life, shall be punished by imprisonment for not less than one year nor more than 10 years.
> (2) The preceding paragraph shall apply to a person who, in consequence of injuring another, causes one to be crippled or incurably or hopelessly diseased.
> (3) When the crimes of the preceding two paragraphs are committed on a lineal ascendant of the offender or of one's spouse, one shall be punished by limited imprisonment for not less than two years.
>
> Article 259 (Death Resulting from Bodily Injury)
> (1) A person who inflicts bodily injury upon another, thereby causing his death, shall be punished by limited imprisonment for not less than three years.
> (2) When the crime of the preceding paragraph is committed on a lineal ascendant of the offender or of his spouse, he shall be punished by imprisonment for life or not less than five years.
> (South Korean Criminal Act, 2013, n.p.)

The difference between Article 257 and 258 is that Article 257 defines simple assault and Article 258 defines aggravated assault. Regardless of the seriousness of an assault, any assault that victimizes one's lineal ascendants in South Korea, such as one's grandparents and parents, can be punished more severely. Lineal ascendants do not include spouses. It should be noted that simple and aggravated assault and not delineated by South Korean law as they are in the US. Simple and aggravated assault, therefore, are aggregated in this research and referred to as *general assaults.*

All general assaults during the 2015-2016 timeframe that resulted in an arrest were initially considered for this study. Like residential burglary, the measure of general outdoor assaults is really a measure of cleared general outdoor assaults. However, also like residential burglaries, this is less of a problem than it could be given that the clearance rate for general assault is 85.7% in 2015 and 87.6% in 2016 in South Korea (Moon et al., 2017; South Korean Ministry of the Interior and Safety, 2016).

Hot spot. A hot spot is defined as "an area that has a greater than average number of criminal or disorder events, or an area where people have a higher than average risk of victimization" (Eck, Chainey, Cameron, Leitner, & Wilson, 2005, p. 2). This indicates that hot spot areas can be divided into different categories by the extent to which they are above or below the average number of criminal incidents. It also suggests that there may be a "cold spot," where criminal incidents occur significantly less than in other areas. Harries (1999), however, notes that clustering of crime does not necessarily mean that the area where clustering appears is a hot spot, as environmental factors also can generate crime (i.e., crime generators or criminogenic factors). For example, Block and Block

(1995) suggest bars/taverns, and liquor stores generate clusters of criminal activity especially when time is considered as well. When bars/taverns close, yet liquor stores remain open, crimes are more likely to occur around the liquor stores. Thus, a clustering of crimes can occur temporally, yet the area, whether it is a neighborhood or census tract, does not necessarily meet the criteria of a hot spot.

Sherman (1995, p. 36) defined hot spots as "small places in which the occurrence of crime is so frequent that it is highly predictable, at least over a 1-year period." Buerger, Cohn, and Petrosino (1995) indicated that Sherman and Weisburd (1988) rely upon several criteria to determine what is a hot spot, as opposed to relying on a single criterion. These include: "(1) not more than one standard linear street block; (2) not more than half a block from an intersection; (3) no closer to another hot spot than one block" (Buerger et al., 1995, p. 240).

Prior researchers have relied upon complex definitions, processes, and software tools to identify hot spot areas (Block & Block, 1995; Buerger et al., 1995; Eck et al., 2005). Given this, the processes and software tools used for this research are described later in the Analytical Strategy section of this chapter.

Data Sources and Data Collection Processes

Police-recorded crime data. The police in South Korea collect crime data every time a crime is reported to the police. The police-recorded crime data include the following information for each criminal incident: date, time, location(s), including the X, Y coordinates (if it occurred at a specific address), location type, the patrol division that was dispatched, and the type of crime(s) that occurred. The data are automatically saved in a storage server once a dispatched police officer collects the information. This data source was accessed to obtain information regarding the two dependent variables in this study, residential burglary and general outdoor assault. The data only involve crimes that resulted in arrest.

Crime data were obtained from the Seoul Metropolitan Police Agency on residential burglary and general outdoor assault. All of the incidents occurred from January 1, 2015 to December 31, 2016 in the Dongjak District in Seoul, South Korea. There were 337 residential burglaries and 3,235 general outdoor assaults during the 2015-2016 timeframe[1]. With general outdoor assaults, every location of general assaults that took place outside and not inside a building, such as vacant lots, streets, parks, and outdoor markets, was designated as locations of general outdoor assaults.

Offender data. In addition to the police-recorded data described above, another separate data source for police-recorded data was included – high-risk offender data. High-risk offenders are defined by a law enacted in 2012, the "Collection of Information on High-Risk Offender Act.[2]" The purpose of this law was to collect and maintain information on released offenders and violent criminals for crime prevention and

[1] There were 2,714 of commercial burglaries and 776 indoor assaults during the 2015-2016 timeframe that were excluded from this study.

[2] Refer to Appendix A for the "Collection of Information on High-Risk Offender Act" written in English by the Ministry of Government Legislation. For the original Act written in Korean, refer to Appendix B).

investigation purposes. According to the law, a high-risk offender is someone who is a member of an organized violent gang or is likely to organize violent gangs based on the offense he/she committed. It can also be someone who is determined to be high-risk for reoffending, based on his/her background. This would include released offenders with prior records on murder, arson, robbery, larceny/theft, abduction/kidnapping, manufacture/use of illegal arms, bomb threat, and illegal drug use/sale. There were 187 high-risk offenders in the Dongjak District. Eighty-five of them were on the list for committing a sexual offense, 51 for larceny/theft, 18 for illegal drug offenses, 12 for robbery, 10 for murder, 9 for organized violence, and 2 for arson. This data source was accessed to obtain information regarding the independent variable, high-risk offender, which is relied upon to (partially) measure the motivated offender concept in routine activity theory.

The Chief of Police is notified of released prisoners in his/her jurisdictions by a chief of penitentiary facilities, such as a warden of a prison. The chief of police thoroughly examines the guidelines for high-risk offenders and transfers those who are likely to reoffend to the high-risk offender group after determination by review committees. In a situation where a high-risk offender is deceased or has not reoffended for any offense mentioned above for 10 years, it is determined that there is no risk of recidivism. The person is removed from the group through review committees.

The review committees consist of at least three, but no more than five committee members. A director of the criminal litigation division of the police station is appointed as chief of the committee, and he/she can have an assistant administrator. The committee holds a quarterly meeting (except under unavoidable circumstances) to make a decision on either the extension of term or removal from the list; thus, once a person is on the high-risk offender list, s/he can be removed. The chair of the committee reports the decisions to the Chief of Police. This research used the high-risk offender list from 2015-2016.

Census block data. South Korean officials conduct a census every five years. The most recent census was conducted in 2015, which is the same timeframe of the crime data used in this research. The unit of analysis is the census block, consisting of several blocks identified by Statistics Korea for the census. In the Dongjak District, there are 794 census blocks. A census block is smaller than a census tract. Although boundaries of blocks may be arbitrary, as the boundaries are established for the purpose of the census and have little meaning to residents; people in blocks are more representative of its local neighborhood than census tracts (Cohen, Spear, Scribner, Kissinger, Mason, & Wildgen, 2000). The census block also has advantages over smaller units of analysis, such as street segments, properties, and buildings. Among smaller units (i.e., streets, buildings), crime problems vary more by space and time (i.e., instability) than they do in larger units (i.e., census tracts, neighborhoods) (Leitner, 2013). Additionally, census data at the smallest units are not available. This data source was accessed to obtain information regarding several of the independent variables and exposure variables (number of households and population size) in the study, which are discussed later and presented in Table 1. The process to extract these variables and related measurement processes is discussed below.

Supplementary data. Additional sources of supplementary data were also used: The addresses of Seoul metropolitan subway stations were obtained from South Korea's Open Data Portal website[3]. The addresses for the schools were obtained from the Seoul Metropolitan Office of Education. The addresses of the shopping malls were identified by conducting a Google search. Additionally, the addresses of closed-circuit television (CCTV) cameras and number of police (sub)stations were obtained from the Seoul Metropolitan Police Agency.

Independent Variables

The variables were selected based on the key concepts of routine activity theory (see Table 1), and their availability from the available data sources. The key concepts include motivated offender, suitable target, and absence of a capable guardian. Most of the associated variables were the same for the models that included residential burglaries as the dependent variable and the models that included general outdoor assault as the dependent variable. General outdoor assault may be more likely to be explained, than residential burglary, by built environments around the facilities conducive to criminogenic activity, such as bars/taverns, shopping malls, and schools, because it is affected by surrounding environments where there are more dynamic changes of movement of population. In the discussion below, and as denoted in Table 1, the variables were relied upon differently for residential burglary and general outdoor assault.

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[3] https://www.data.go.kr/dataset/3045253/openapi.do

Motivated offender. Three variables, high-risk offenders, teenagers (i.e., those who ages 13-19), and schools were relied upon to measure motivated offender for both residential burglary and general outdoor assault. The high-risk offender variable was measured by the number of high-risk offenders who lived in each census block and dichotomized as a yes/no variable, indicating whether a high-risk offender lived in each census block. Although the high-risk offender group did not include those who specifically committed these two offenses, there are many researchers who have identified offenders are generalists (i.e., commit a wide variety of offense types). The specialization perspective describes an individual's tendency to repeat the same type of offense over time, and specialized offenders are those who become specialized in a particular crime and tend to commit that crime repeatedly and frequently (Reiss, 1986; Simon, 1997). Gottfredson and Hirschi (1990) noted that the specialist perspective has emerged likely due to the political currency in response to specific offenders, such as drug offenders, white-collar criminals, and child molesters. Although there is some evidence of specialization among sex offenders (Knight & Prentky, 1990; Soothill, Francis, Sanderson, & Ackerley, 2000), recent studies have indicated that sex offenders are similar to violent non-sexual offenders who commit diverse crimes with regard to the variety of crimes they have committed (Hanson, 2002; Hudson & Ward, 1997; Loehrer, 1992). One meta-analysis, however, revealed male adolescent sexual offenders do differ from non-sexual offenders in regard to their criminal histories. Sexual offenders had less extensive criminal histories than their other adolescent offenders who had not committed a sexual offense. The findings, therefore, are mixed. All 187 high-risk offenders in the current study, who had committed a variety of offenses, were therefore relied upon to measure motivated offenders.

The second variable, teenagers, were also included for both dependent variables. This variable was measured by the number of teenagers, those between ages 13-19, who lived in each census block. This variable was chosen based on its connection to the age-crime curve, which indicates that offending is most likely prevalent during mid- to late adolescence. A larger number of teenagers may reside in areas that are near schools. Felson (1987) noted that a likely offender, in the case of juveniles, must first be away from parents or handlers, and then find a suitable target for a crime. Teenagers who do not attend schools, run away from home, and are abandoned/neglected by their parents, and/or spend most of their time away from their parents may be motivated offenders.

Third, in regard to distance to schools, the residential areas close to schools are more likely to have young people, especially teenagers, who may be motivated to commit burglary. Researchers have found a positive association between the number of schools—especially high schools—and burglaries, including residential and commercial burglaries (Hwang, 2001; Kautt & Roncek, 2007; Roncek & LoBosco, 1983).

Suitable target. Various variables were relied upon to measure suitable targets for residential burglary and general outdoor assault: (distance to) restaurants and adult entertainment places and subway stations. Additionally, the number of single-person households and the number of persons with high-level of education were used to predict residential burglary as the dependent variable. Also, for general outdoor assault as the dependent variable, distance to shopping malls was also relied upon to measure suitability target.

Restaurants and adult entertainment places can increase the likelihood of a person becoming a victim; Davison and Smith (2001, p, 98) states that such places, ". . . bring people into the face block which significantly increases the likelihood of victimization for street robbery and residential burglary." He defines a face block as "the two sides of a block that face the street segment between intersection."

The distance to subway stations provides potential offenders with accessibility. Residential areas that are located near subway stations, therefore, would be suitable targets for burglars.

The number of persons with a high level of education (four-year college/university degree or more) per census block was also used as a measure of suitable targets, but only when residential burglary was the dependent variable. Also, unlike the other measures, it was hypothesized that the census blocks with more persons with a high level of education will have *less* criminal activity. A high level of education is a proxy measure of income. High-level education was used because income information was not available. Some researchers have found that residents' income is positively associated with residential burglary rates (Jeong et al., 2009). It is also possible that, as a previous study found (Cromwell & Olson, 2009), there is a curvilinear association between a high level of education and residential burglary. Burglars may not choose economically disadvantaged areas where there are no valuable targets. Burglaries may be most common in mid-affluent areas where there are many suitable targets with the low level or no presence of alarms or private security. They may not choose highly affluent areas because of a high level of security in the neighborhoods.

The distance to shopping malls was used to measure suitable targets, but only when general outdoor assault was the dependent variable. This was a direct measure of suitable targets because many people congregate in shopping malls, and therefore, there will be more likely to have a chance to involve in a fight. Also, if there is a likely offender of assault, he or she will be more likely to find a target where there are congregated people. It was not used when residential burglary was the dependent variable because there is no theoretical linkage or empirical findings of the effects of shopping malls on residential burglary.

Absence of a capable guardian. Several variables were relied upon to measure capable guardian for both dependent variables. These included (the number of) CCTV cameras, (distance to) police (sub)stations, and population density. The number of CCTV cameras per census block used as a proxy for a capable guardian and serves as a deterrent when in use. All of these are owned and managed by the police in South Korea. It was hypothesized, therefore, that the more CCTV cameras in a census block, the less likely it is that crimes will occur in that census block. Likewise, the distance to police (sub)stations was included to examine whether the geographic locations of police (sub)stations in a census block have an impact on residential burglary. Like CCTV cameras, the police (sub)stations are expected to have a preventive effect.

The number of single-person households per census block was used to measure the capable guardianship, but only when residential burglary was the dependent variable. From the victim's point of view, it could be an absence of capable guardians during those hours. Andresen (2006) found that a single-person household was a significant predictor of residential burglary.

Also, population density may play a role as a guardian. It has been debated for a long time whether population density is a crime generator or inhibitor (Harries, 2006). It could be a crime generator in the case of certain types of property crime. And it could also be a crime inhibitor to violent crimes. For some property crimes, a high population density may offer offenders more opportunities as targets. In contrast, for violent crimes, it may have a surveillance effect inhibiting crimes (Harries, 2006). In the current study, it was hypothesized that population density is positively related to residential burglary.

Several additional variables were relied upon when residential burglary was the dependent variable. These included: homeowners, elderly (65+ ages), preschool children, and high-rise apartments. The number of homeowners was taken into consideration for (residential) burglary, as prior researchers have made a clear connection between homeownership and guardianship (see Reynald, 2011, for a discussion). Previously, Newman (1972) proposed that home ownership and signs of home ownership (name plates, personalized decorations, etc.) indicated territoriality—a signal that the public space ended and a person's private space began; "it sends a clear message to the motivated offender to stay out" (Reynald, 2011, p. 117). Furthermore, both the number of elderly and preschool children variables work in the same way, as both occupy the home the majority of the time, creating guardianship.

The number of high-rise apartments was included as a measure of capable guardianship because high-rise apartments, compared to other types of housing, have better security systems, such as security guards and CCTV cameras. Also, the larger number of neighboring households in high-rise apartments can serve as guardians for other neighbors as well.

Exposure variables. When residential burglary was the dependent variable, the number of households per census block was used as the exposure variable. For general outdoor assault, population size was used as the exposure variable.

For general outdoor assault, it is difficult to measure the actual population at risk because the target of crime is people and they are frequently changing temporally and spatially. Andresen (2011) proposed using a calculation of the ambient population based on an alternative measure of the population at risk. He employed LandScan Global Population Database provided by Oak Ridge National Laboratory, estimating the expected population based on a 24-hour estimate. The database in this study computed the relative attractiveness of each square kilometer cell by assigning a certain value to each cell. This measure of relative attractiveness was calculated as a probability coefficient considering road proximity, slope, land cover, and nighttime lights. Road proximity was positively associated with population density. A slope is also a good measure because people tend to reside on relatively flat terrain. Land cover, whether it is desert, water, or wetlands, also gives a good estimate for places where people live. Nighttime lights are good indicators of where people concentrate and it is possible to roughly track the number of people in a particular area based on the amount of light emitted (Dobson, 2004). This method, however, has little utility for the current study due to the aggregation level.

Table 1. Dependent variables, routine activity theory concepts related independent variables, and data source

Dependent variables:	Description	Data source
Residential burglary (model 1)	Number of residential burglaries	Police-recorded crime data from Seoul Metropolitan Police Agency: 2015-2016
General outdoor assault (model 2)	Number of general outdoor assaults	Police-recorded crime data from Seoul Metropolitan Police Agency: 2015-2016
Routine activity theory concepts and related variables:		
Motivated offender		
High-risk offenders	Presence of a high-risk offender	High-risk offender data: 2015
Teenagers	Number of persons between the ages of 13 and 19	Census block data: 2015
Schools	Distance to nearest school	Supplementary data: Seoul Metropolitan Office of Education: 2015
Suitable target		
High-level of education*	Number of people with four-year university/college degrees or beyond	Census block data: 2015
Restaurants and entertainment places	Number of restaurants and adult entertainment places	Census block data: 2015
Subway stations	Distance to nearest subway station	Supplementary data: Open data portal website
Shopping malls**	Distance to shopping malls	Supplementary data: Google search
Absence of a Capable Guardian		
Single-person household*	Number of single-person households	Census block data: 2015
Homeowners*	Number of homeowners	Census block data: 2015
Elderly*	Number of people over the age of 65	Census block data: 2015
Preschool children*	Number of preschool children	Census block data: 2015
High-rise apartments*	Number of high-rise apartments	Census block data: 2015
CCTV cameras	Number of CCTV cameras	Police-recorded crime data from Seoul Metropolitan Police Agency: 2015-2016
Police	Distance to police (sub)station(s)	Police-recorded crime data from Seoul Metropolitan Police Agency: 2015-2016
Population density	Total population/Total administrative area	Census block data: 2015
Exposure Variables:		
Household*	Number of households	Census block data: 2015
Population**	Size of population	Census block data: 2015

*This variable is only included in the model with residential burglary as the dependent variable.

** This variable is only included in the model with general outdoor assault as the dependent variable.

Analytical Strategy

Mapping crimes. The locations of the residential burglaries, general outdoor assaults, residential addresses of high-risk offenders, and other key variables of interest, such as school and subway locations were mapped using ArcGIS software after geocoding the X, Y coordinates. To obtain the geographic coordinates, the Geocoding Tool (v17.11.10) was used. It was provided by a South Korean company (biz-gis.com) on spatial analysis and GIS applications for business and policy. With the addresses of crime locations in the police-recorded data written in Korean, the tool provided X, Y coordinates for longitude and latitude. The X, Y coordinates allowed locations to be recorded on the Dongjak District base map.

After the geocoding process, the X, Y coordinates from the police-recorded data were compared to the X, Y coordinates from the Geocoding Tool. About 92% of the X, Y coordinates were matched. For those X, Y coordinates that were not matched, police-recorded coordinates were used because there may be cases where general outdoor assaults occur in open spaces, such as on streets, in which X, Y coordinates cannot be accurately obtained from the tool. The X, Y coordinates provided by the police are arguably more accurate than those obtained independently, X, Y coordinates were automatically generated with the addresses police obtained when they were dispatched to the locations of crimes. There were no missing coordinate data for the crime data.

Kernel density estimation. Several methods were relied upon to identify hot spot areas. Kernel density estimation (KDE) calculates the magnitude per unit area from a specific point or polyline using a kernel function in GIS software. The kernel density fits a smooth curved surface over each point feature. The areas where many point features overlap would have the highest value of the surface, and the value diminishes (i.e., towards zero) as the distance from the point increases. The search radius is calculated using the following algorithm. First, the mean center of the point or polyline features input was calculated. Then the distance from the mean center for all features was calculated, and the median of the distances was computed. Finally, the distance for all features around the mean center was calculated, and all these calculated values are applied to the following formula to calculate the search radius:

[Eq. 1. The formula for the KDE search radius]

$$Search\ Radius = 0.9 * \min\left(SD, \sqrt{\frac{1}{\ln(2)}} * D_m\right) * n^{-0.2}$$

where, SD is the standard distance

D_m is the median distance

n is the number of points if no population field is used, or if a population field is supplied, n is he sum of the population field values

Note that the min part of the equation would equal whichever of the two options results in the smallest value.

KDE allowed the researcher to examine the areas where crime concentrated in the study area. With the results from the analysis, the areas were identified where residential burglaries and general outdoor assaults concentrated in the Dongjak District. This analysis addressed the first research question: Are there areas where residential burglaries and general outdoor assaults were concentrated in the study area?

Nearest neighbor index analysis. The nearest neighbor index analysis was to test the spatial randomness of data points on the map. For point features, the analysis calculates the distance from each point in a dataset to its nearest adjacent point. Then the distances between each feature are compared to the expected mean nearest neighbor distance for a random distribution of points. If the calculated average distance is less than the average distance for an expected random distribution (i.e., hypothetical random distribution), then the observed features are considered clustered. By contrast, if the calculated average distance is greater than a hypothetical random distribution, the features are considered dispersed. Figure 3 is a representation of the graphics obtained from *ArcGIS Desktop Help* in ArcGIS 10.3.1.

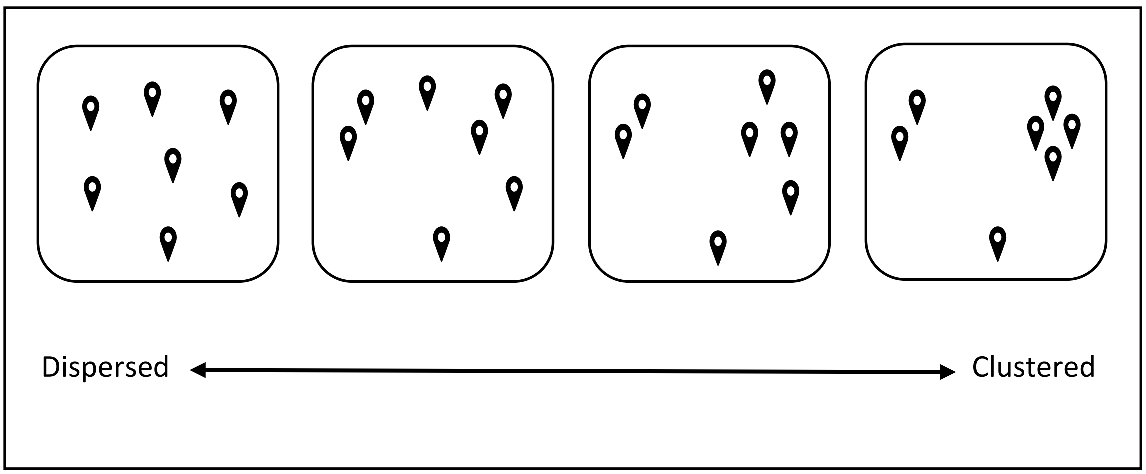


Figure 3. An example of nearest neighbor index

The nearest neighbor index analysis allowed the identification of whether residential burglary and general outdoor assault were clustered or dispersed over the study area. While the Kernel density analysis only visually demonstrated areas where crime concentrated, the nearest neighbor index analysis examined whether the spatial distribution of crime was randomly dispersed or clustered with a statistical test. Thus, this analysis addressed the first research question: Are there areas where residential burglaries and general outdoor assaults were concentrated in the study area?

The formula for the nearest neighbor index (NNI) is:

[Eq. 2. The formula for nearest neighbor index]

$$\text{NNI} = \frac{\overline{D}_O}{\overline{D}_E}$$

where $\overline{D}_O$ is the observed mean distance between each feature and its nearest neighbor:

$$\overline{D}_O = \frac{\sum_{i=1}^{n} d_i}{n}$$

and $\overline{D}_E$ is the expected mean distance for the features given in a random pattern:

$$\overline{D}_E = \frac{0.5}{\sqrt{n/A}}$$

where d_i equals the distance between feature *i* and its nearest neighboring feature, *n* corresponds to the total number of features, and *A* is the area of a minimum enclosing rectangle around all features, or it is a user-specified Area value.

The nearest neighbor z-score for the statistic is calculated as:

$$z = \frac{\overline{D}_O - \overline{D}_E}{SE}$$

where:

$$SE = \frac{0.26136}{\sqrt{n^2/A}}$$

The NNI measures the spatial distribution from 0 to 2.15. Rn values less than 1 mean that the pattern is clustered. Values greater than 1 mean that the pattern is randomly dispersed or regularly dispersed. The nearest neighbor index analysis also helps to examine the first research question in this study. Beyond identifying the patterns of crime locations, it allowed the researcher to examine how much the locations of crime were dispersed in the study area. The average nearest neighbor function from ArcGIS was relied upon to examine the NNI. Before examining the factors using regression models, it was important to examine whether there was a spatial autocorrelation issue when aggregating the crime data to the census block level. This issue is discussed next.

Spatial Autocorrelation Analysis. Through the analyses above, hot spot areas were identified. The next step was to examine whether there was spatial autocorrelation issue in the data, once the crime data had been aggregated to the census block level. Spatial autocorrelation is an issue where outcomes of the dependent variables (i.e., the number of residential burglaries and general outdoor assaults) can be dependent on whether neighboring areas have similar outcomes for the dependent variables.

Global Moran's I. The global Moran's I measures spatial autocorrelation based on both the locations and the attribute values of polygon features. It indicates whether the pattern identified is dispersed, clustered, or random considering a set of features and its attributes. It computes the global Moran's I index, expected index, variance, z-score, and p-value. When statistically significant, a positive value of the global Moran's I index indicates a tendency toward clustering, whereas a negative value for the global Moran's I index indicates a tendency toward dispersion. It examines the possibility of spatial autocorrelation in the data. When there is clustering, it may be necessary to run a spatial regression model to control for the spatial autocorrelation. The global Moran's I index is calculated using the following formulae:

[Eq. 3. The formula for global Moran's I]

$$Global\ Moran's\ I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{S_0 \sum_{i=1}^{n} z_i^2}$$

where, z_i is the deviation of an attribute for feature i from its mean (x_i - $\bar{x}$)

$w_{i,j}$ is the spatial weight between feature i and j (neighboring census blocks)

n is equal to the total number of features (all census blocks in the study)

S_0 is the aggregate of all the spatial weights:

$$S_0 = \sum_{i=1}^{\mathrm{n}} \sum_{j=1}^{n} w_{i,j}$$

The z_I-score for the statistic is computed as:

$$z_I = \frac{I - \mathrm{E}[I]}{\sqrt{\mathrm{V}[I]}}$$

where, $\mathrm{E}[I] = -1/(n-1)$

$\mathrm{V}[I] = \mathrm{E}[I^2] - \mathrm{E}[I]^2$

$$E[I^2] = \frac{A - B}{C}$$

where, $A = n[(n^2 - 3n + 3)S_1 - nS_2 + 3S_0^2]$

$B = D[(n^2 - n)S_1 - 2nS_2 + 6S_0^2]$

$C = (n-1)(n-2)(n-3)S_0^2$

$\mathrm{D} = \frac{\sum_{i=1}^{n} z_i^4}{(\sum_{i=0}^{n} z_i^2)^2}$

$S_1 = (\frac{1}{2}) \sum_{i=1}^{\mathrm{n}} \sum_{j=1}^{n} (w_{i,j} + w_{j,i})^2$

$S_2 = \sum_{i=1}^{\mathrm{n}} (\sum_{i=1}^{n} w_{i.i} + \sum_{i=1}^{n} w_{i.i})^2$

The global Moran’s I computes the mean and variance for the census blocks in the study. Then each feature value (i.e., census block) is subtracted from the mean, calculating a deviation score from the mean. The deviation values for all neighboring features are multiplied together to calculate a cross-product. The numerator for the global Moran's I statistic in the above formula includes these summed cross-products. For example, let us suppose that features A and B are neighbors and the mean for all feature values is five (e.g., five crime incidents). Let us further suppose we have the data shown in Table 2.

Table 2. An example of global Moran's I for a sample with a mean of 5 crimes

Number of crimes in a feature		Deviation score		Cross-product
A=20	B=15	15	10	150
A=3	B=2	-2	-3	6
A=10	B=2	5	-3	-15

When values (i.e., the number of crimes) for neighboring features are either both greater than the mean or both less than the mean, the cross-product is positive. When one value is less than the mean and the other is greater than the mean, the cross-product is negative. Regardless of the sign of deviation score, the greater the deviation score from the mean, the greater the cross-product. As seen in Table 2, if the number of crimes tends to cluster spatially, the global Moran's I index will be positive. For example, this might occur in a situation where high crime areas cluster near other high crime areas (low crime areas cluster near other low crime areas). On the other hand, when high crime areas are away from other high crime areas and adjacent to low crime areas, the global Moran's I index will be negative. If positive cross-product values balance negative cross-product values out, the global Moran's I index will be close to zero, which means no spatial autocorrelation. The numerator in the formula is normalized by the variance so that the global Moran's I index values fall between -1.0 and +1.0. After the global Moran's I index value is computed, the expected global Moran's I index was also computed. Next, the expected and observed index values are compared. Given the sample size (i.e., the number of features in a dataset) and the variance for the data values, a z-score and p-value were calculated to examine whether the difference between the expected and observed index values was statistically significant.

The global Moran's I also helped to answer the first research question: Are there areas where residential burglaries and general outdoor assaults were concentrated in the study area? Additionally, the global Moran's I provided information about whether there was spatial autocorrelation in the data. A value close to +1 means that census blocks with the similar number of crimes cluster together, which is to say there is spatial correlation. A value close to -1 means that census blocks with the dissimilar number of crimes cluster together. When the Moran's I value is computed, spatial weights are row standardized due to possible sample design or an imposed aggregation scheme; each weight is divided by the sum of the weights of all neighboring features (i.e., Queen's contiguity).

Although the Global Moran's I is an appropriate tool to identify the patterns of crimes and spatial associations, the patterns identified with the Global Moran's I may still differ from the local patterns of spatial association due to spatial heterogeneity (Anselin, 1995). While the global pattern indicates spatial association across the entire study region with an overall statistic, the local Moran's I provides a set of statistics for each polygon and examines whether the correlation between each polygon and those surrounding it is statistically significant. The local indicator of spatial association (LISA) will help to identify such local patterns of spatial relationship.

Local indicators of spatial association (LISA). Local indicators of spatial association (LISA), as the name suggests, identify spatial clusters of features with high or low values locally. The local Moran's I is one type of LISA that is often used to identify hot spot areas and cold spot areas. In the present study, the local Moran's I was used to identify hot spot areas more precisely. Like the global Moran's I, the local Moran's I calculates local Moran's I indexes, z-scores, p-values, and codes indicating four different types of clusters for each statistically significant feature.

The local Moran's I index was calculated using the following formulae:

[Eq. 4. The formula for local Moran's I]

$$Local\ Moran's\ I = \frac{x_i - \bar{x}}{S_i^2} \sum_{j=1, j \neq i}^{n} w_{i,j}(x_i - \bar{x})$$

where, x_i is an attribute for feature i (a particular census block)

$\bar{x}$ is the mean of the corresponding attribute

$w_{i,j}$ is the spatial weight between feature i and j (neighboring census blocks)

S_i^2 is:

$$S_i^2 = \frac{\sum_{j=1, j \neq i}^{n} (x_j - \bar{x})^2}{n-1}$$

where, n is the total number of features.

The z_I-score for the statistic is computed as:

$$z_{I_i} = \frac{I_i - \mathrm{E}[I_i]}{\sqrt{\mathrm{V}[I_i]}}$$

where, $\mathrm{E}[I_i] = -\frac{\sum_{j=1, j \neq i}^{n} w_{i,j}}{n-1}$

$\mathrm{V}[I_i] = \mathrm{E}[I_i{}^2] - \mathrm{E}[I_i]^2$

$\mathrm{E}\left[I_i{}^2\right] = A - B$

where, $A = \frac{(n - b_{2_i}) \sum_{j=1, j \neq i}^{n} w_{i,j}^2}{n-1}$

$B = \frac{(2b_{2_i} - n) \sum_{k=1, k \neq i}^{n} \sum_{h=1, h \neq i}^{n} w_{i,k} w_{i,h}}{n-1}$

$b_{2_i} = \frac{\sum_{i=1, i \neq j}^{n} (x_i - \bar{x})^4}{\left(\sum_{i=1, i \neq j}^{n} (x_i - \bar{x})^2\right)^2}$

A positive value for the local Moran's I indicates that a feature has neighboring features with similarly high or low attribute values, while a negative value indicates that a feature has neighboring features with dissimilar values. Thus, the features neighboring similar features (i.e., high-high; low-low) are part of a cluster, and the features neighboring dissimilar features (i.e., high-low; low-high) are outliers. In all cases, the p-value for the feature must be less than a significance level for the cluster or outlier to be considered statistically significant. Hot spot areas (i.e., areas where high-value features were surrounded by high-value features: high-high) were identified with those global and local Moran's Is and cold spot areas (i.e., areas where low-value features are surrounded by low-value features: low-low) as well.

The Global and Local Moran's Is were reported to examine whether there was spatial clustering, autocorrelation, or dependency with the data being aggregated at the Census block level. Controlling for any spatial association identified is an important process because classic regression models do not accommodate data with spatially correlated variables. The section below discusses the models employed for the current study.

Regression models. Once the hot spot areas were identified in the study area, all census blocks in the study area were examined to assess which routine activity variables contributed to the area becoming a hot spot. The regression models allowed the researcher to answer the second research question by including the routine activity variables in the regression analyses.

Before constructing regression models, there were some issues that had to be addressed. First, spatial regression is necessary when the data are spatially correlated. Classic statistical techniques, such as OLS, do not allow for spatial autocorrelation in data. For example, if there is a correlation among observations that are near to each other (i.e., spatial dependence), the standard error that is formulated from an OLS model will be larger for positive correlation coefficients and smaller for negative correlation coefficients; thus, it will yield inaccurate estimates. When spatially autocorrelated, a spatial error model (SEL) or spatial lag model (SLM) should be used.

Second, a dataset with spatial clustering may be over-dispersed in its distribution. That is, there are areas (i.e., census blocks in this study) with no crime, and there are some areas with high levels of crime. Since the crime is overly dispersed due to the clustering, regression models assuming a normal distribution or models assuming equal variance throughout the areas are inadequate. When the data are overdispersed, a negative binomial (NB) or zero-inflated negative binomial (ZINB) model may need to be used. More details about these models are discussed later.

Last, before including variables in the different models, it was necessary to consider possible collinearity among the independent variables. Multicollinearity is an issue when there are very high intercorrelations or interassociations among the independent variables. When it is present in the data, the statistical inference results are unreliable. It usually occurs when: dummy variables are used inaccurately; when a variable which can be computed from other variables in the data is included in the model; when the same variables are repeatedly included in the model; and when variables are highly correlated to each other. Specifically, it can cause several problems in the results, such as: imprecisely estimated partial regression coefficients; high standard errors; a change in the signs of the coefficients and the magnitudes of the coefficients; and, therefore, difficulty in assessing the relative importance of the independent variables in the model. Multicollinearity can be detected by estimating the variance inflation factor (VIF). If a value of VIF is 10 or above (Hair, Anderson, Tatham, & Black, 1995), then there is a multicollinearity issue in the model. To assess multicollinearity, VIFs were assessed before the regression model; none of the values exceeded 6.

Spatial lag model. A spatial lag model (SLM) is a statistical model that has a spatially lagged dependent variable in the regression equation in addition to independent variables. If the values of a dependent variable in an area are directly or spatially influenced by the values of a dependent variable in the area's neighbors, the SLM is the appropriate model rather than the OLS model. The SLM can be formulated with the following equation:

[Eq. 5. The spatial lag model equation]

$$y = (\rho)\mathrm{W}y + \mathrm{X}(\beta) + \varepsilon$$

where, $\mathrm{W}y$ is a spatially lagged dependent variable for weights matrix W

X is a matrix of observations on the independent variable

ε is a vector of error terms

ρ and β are parameters

Spatial error model. The spatial error model (SEM) is an alternative to the SLM. The difference between the two models is that the SLM views spatial dependence as a systematic component of the model, whereas the SEM treats spatial dependence as a nuisance, that is an error of the model, and therefore something to be eliminated from the model. The SEM can be formulated with the following equations:

[Eq. 6. The spatial error model equation]

$$y = X(\beta) + \varepsilon$$
$$\varepsilon = \lambda(W)\ \varepsilon\ +\ u$$

where, W is a spatial weights matrix

X is a matrix of observations on the independent variable

ε is a vector of spatially autocorrelated error terms

u is a vector of independent identically distributed errors

λ and β are parameters

Negative binomial model. With spatial crime counts, it is often the case that the locations of crime are overly distributed across the study area, which is called overdispersion. The overdispersion is often caused by spatial autocorrelation in a spatial dataset. The distribution of overdispersion follows the negative binomial distribution due to its flexibility in its mean and variance. Poisson, however, unlike the negative binomial, strictly assumes that the conditional mean and variance are equal in its distribution, which is often not a case in spatial crime data (Osgood, 2000). Although a negative binomial model does not control for spatial autocorrelation, the researcher can include a spatially lagged dependent variable in the model to control for potential neighboring or spillover effects. For the spatially lagged dependent variable, a spatial weigh matrix is created from GeoDa 1.12.1 using Queen's contiguity, which considers all census blocks neighboring around a census block, and the matrix is loaded in Stata 14. Then Stata generates a spatially lagged dependent variable using *splagvar* for each dependent variable.

For the negative binomial model to be used, the dependent variable should be an observed count that follows the negative binomial distribution, which is fitted with the data in the current study using the number of residential burglaries and general outdoor assaults in a census block.

Zero-inflated negative binomial model. A zero-inflated negative binomial model is used when there is an excess of zeros in the dependent variable and overdispersion in its distribution. It may be the case that there are many census blocks that have zero residential burglaries and general outdoor assaults in the study area, given that these crimes are often spatially clustered. In addition to the negative binomial model to control for overdispersion, the zero-inflated negative binomial model accommodates an excess of zeros in the data. Like the negative binomial model, a spatially lagged dependent variable in the model can be included to control for possible neighboring effects. This model also requires using a count as the dependent variable, which allowed the researcher to use the data in the current study using the number of residential burglaries and general outdoor assaults.

IV. RESULTS

The dependent variables, residential burglary and general outdoor assault, have different means and variances ($\bar{x}_{RB}$=.429, s_{RB}=.853, s^2_{RB}=.728; and $\bar{x}_{GA}$=2.526, s_{GA}=5.395, s^2_{GA}=29.106, respectively). Figure 4 and 5 also show that they are positively skewed. Hence, an ordinary least square model is not appropriate. There is also an overdispersion issue in the distributions, which required a negative binomial regression model instead of a Poisson regression model, since the Poisson distribution assumes equal means and variances. The overdispersion issue in the distribution will be examined with a likelihood ratio test for goodness-of-fit model.

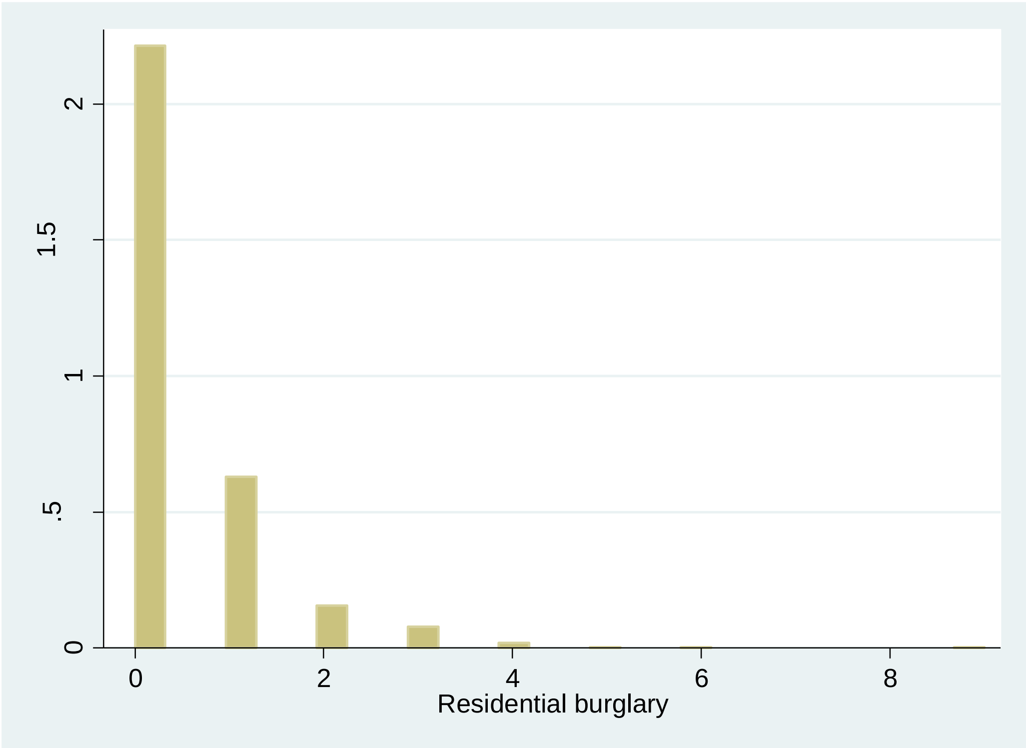


Figure 4. A histogram of residential burglary

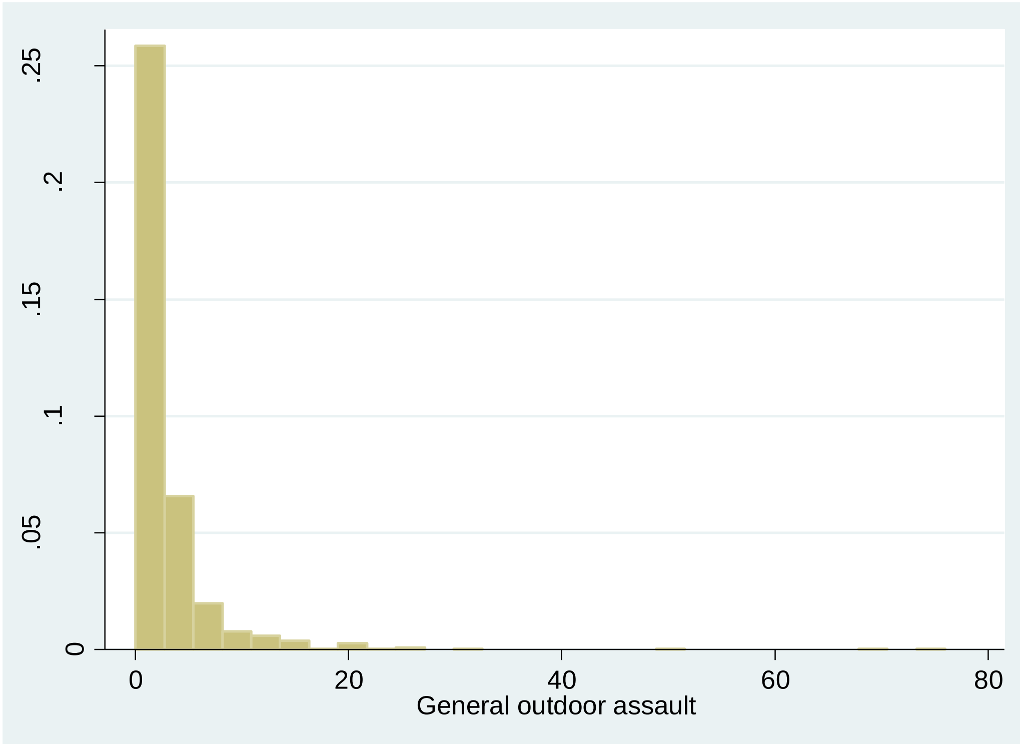


Figure 5. A histogram of general outdoor assault

Results of Kernel Density Estimation

The results of the Kernel Density Estimation (KDE) analysis of residential burglary and general outdoor assault are presented in Figures 6 and 7. As seen in the figures, there were several areas where residential burglaries and general outdoor assaults were more concentrated within Dongjak District. The concentrated areas that are shown in the figures are possible hotspot areas for those crimes. It is possible that there are boundary effects. Although they were not taken into account in the study, there might have been incidents just outside the boundary, which might have made some observed areas lower in density than it actually was. After hotspots were identified, it was necessary to run a statistical test to examine if the locations of those crimes are statistically clustered with the average nearest neighbor index.

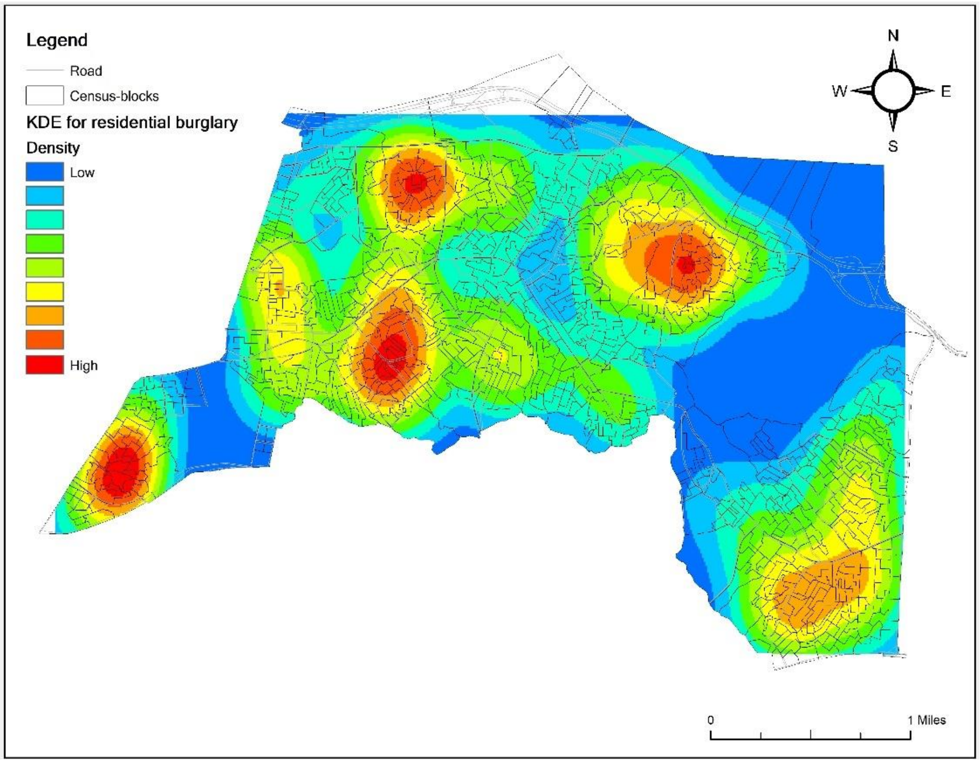


Figure 6. Kernel density estimation surface for residential burglary in Dongjak

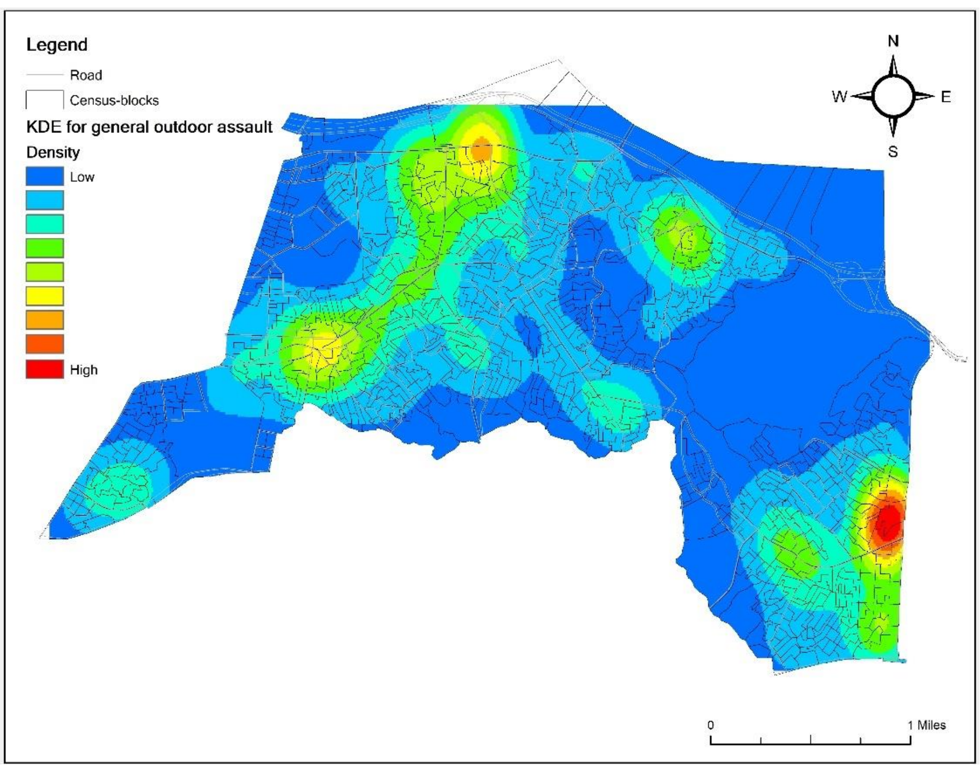


Figure 7. Kernel density estimation surface for general outdoor assault in Dongjak

Results of the Average Nearest Neighbor Index

The results of the Average Nearest Neighbor of residential burglary from ArcGIS are presented in Table 3. The analysis was conducted to determine whether the locations of residential burglaries in the study area were clustered or randomly dispersed. According to the results of the analysis, the pattern of residential burglary was significantly clustered. The nearest neighbor ratio of 0.537 is well below 1.0, which means a clustered pattern. There is little chance that this result is simply random—p-value less than 0.001.

Table 3. Results of average nearest neighbor of residential burglary in Dongjak

Observed mean distance:	74.473 meters
Expected mean distance:	138.739 meters
Nearest neighbor ratio:	0.537
z-score:	-16.340
p-value:	< 0.001

The results of Average Nearest Neighbor of general outdoor assault are presented in Table 4. According to the results of the Average Nearest Neighbor analysis, the pattern of general outdoor assault was significantly clustered. The nearest neighbor ratio of 0.401 is well below 1.0, which means a clustered pattern. There is also little chance that this result is simply random—p-value less than 0.001.

Table 4. Results of average nearest neighbor of general outdoor assault in Dongjak

Observed mean distance:	23.668 meters
Expected mean distance:	58.981 meters
Nearest neighbor ratio:	0.401
z-score:	-51.287
p-value:	< 0.001

Figure 8 presents the number of residential burglaries with points of interest in Dongjak district. The census blocks were gradually colored by the number of residential burglaries in a census block. There were 565 (71.19%) out of 794 census blocks with zero residential burglaries, which were controlled in a zero-inflated negative binomial regression model, discussed later in this chapter.

The number of general outdoor assaults with points of interest is presented in Figure 9. The census blocks were also gradually colored by the number of general outdoor assaults in a census block. There were 327 (41.18%) out of 794 census blocks with zero general outdoor assaults, which were also controlled in a zero-inflated negative binominal regression model.

The number of census blocks for residential burglary and general outdoor assaults is presented in Table 5. The crime counts in each category were calculated by the standard deviations for each crime (see Table 8). A small number of census blocks had a disproportionally large number of each crime.

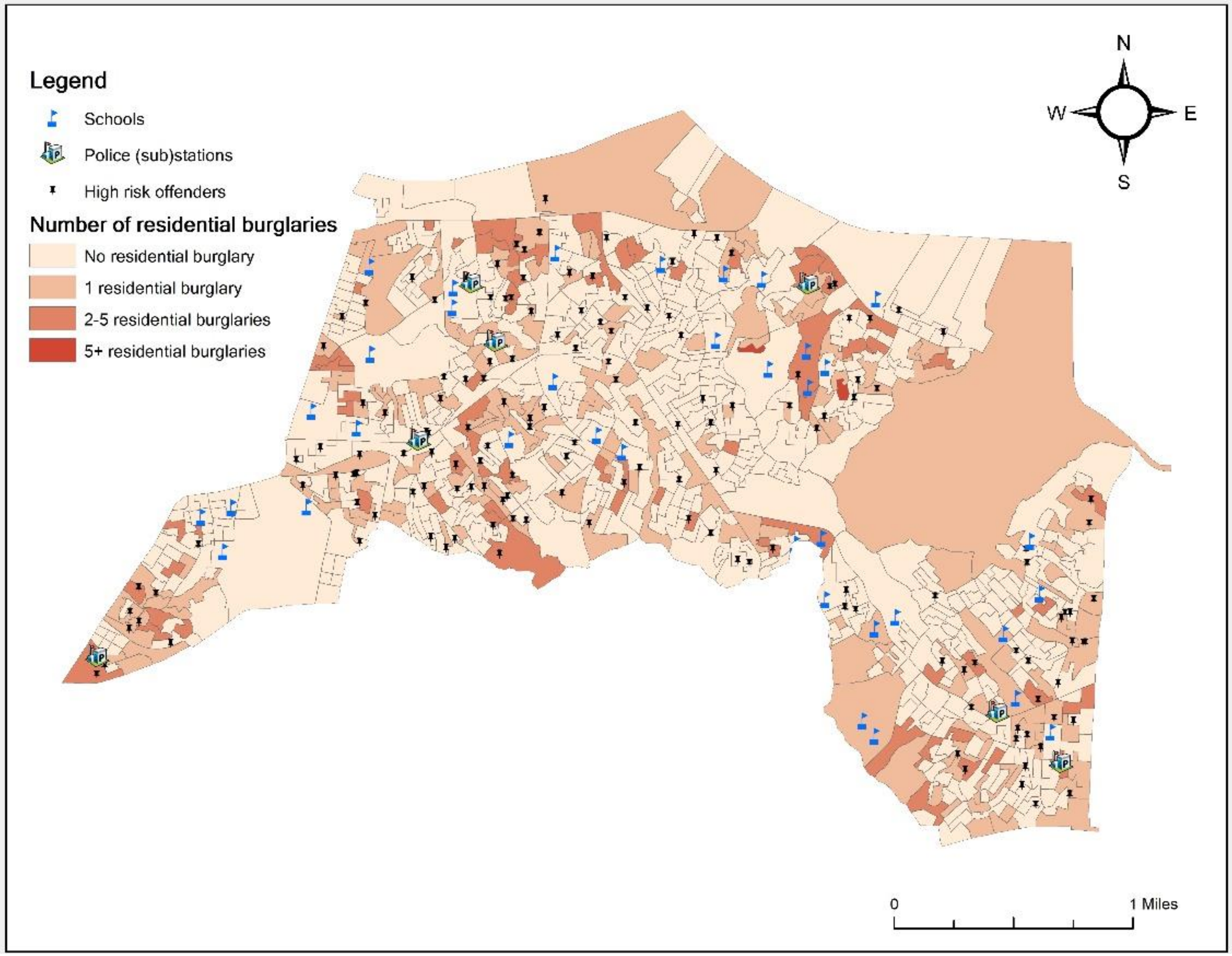


Figure 8. Number of residential burglaries with points of interest in Dongjak

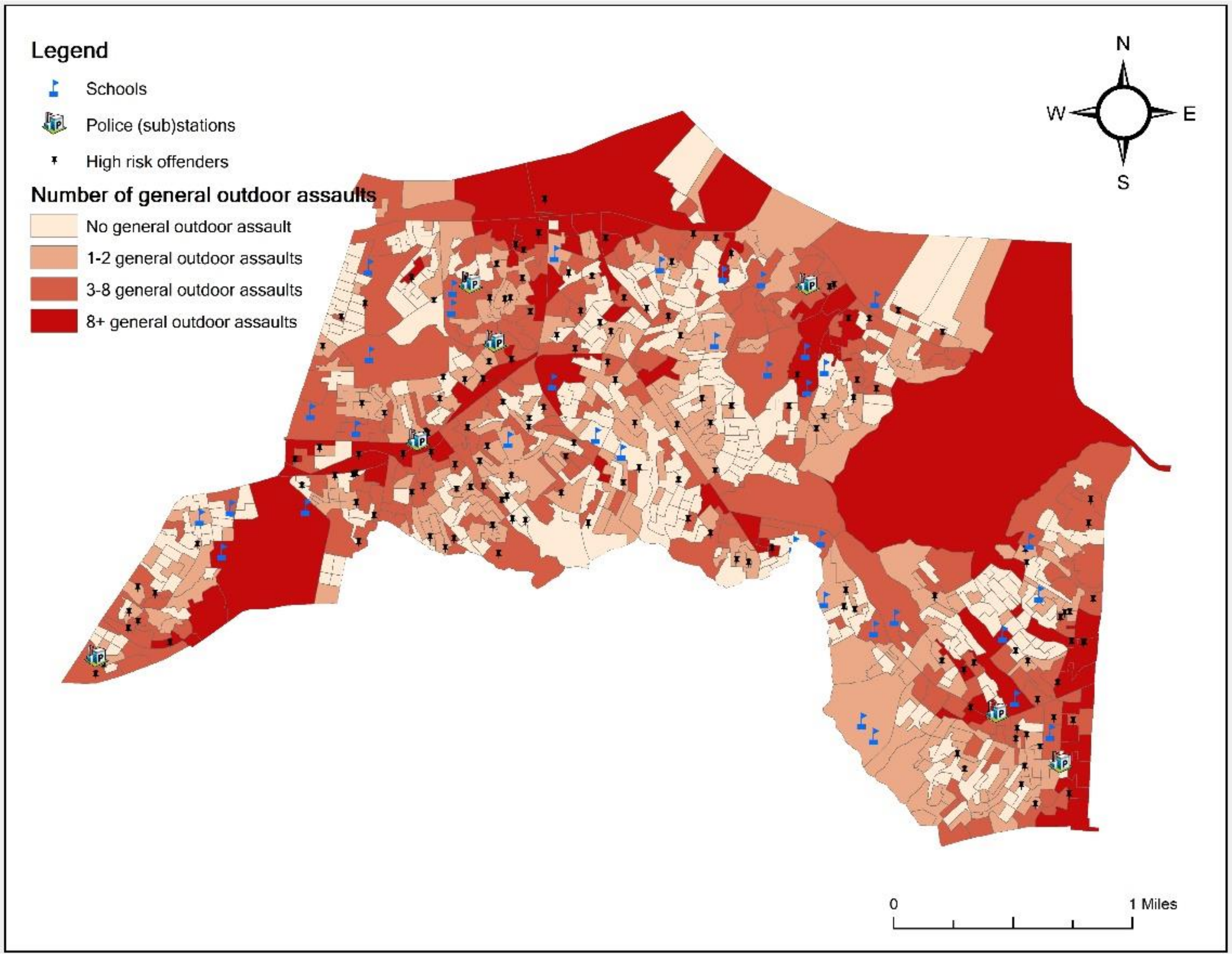


Figure 9. Number of general outdoor assaults with points of interest in Dongjak

Table 5. Number of census blocks for residential burglary and general outdoor assault

Residential burglary	**Number of census blocks (%)**	**General outdoor assault**	**Number of census blocks (%)**
No residential burglary	565 (71.19)	No general outdoor assault	327 (41.18)
1 residential burglary	161 (20.28)	1-2 general outdoor assaults	230 (28.97)
2-5 residential burglaries	66 (8.31)	3-8 general outdoor assaults	185 (23.30)
5+ residential burglaries	2 (0.25)	8+ general outdoor assaults	52 (6.55)
Total	794 (100.03)	Total	794 (100.00)

Results of Global Moran's I

The results of Global Moran's I for residential burglary are presented in Table 8. The Moran's I index value is .041 and is statistically significant at the .05 level, which means that census blocks with a similar number of residential burglaries clustered together. However, the index value of .041 is very low, given the possible range of Moran's I (from -1.0 to 1.0). Hence, although there was spatial dependence among residential burglaries in the study area, it was necessary to examine whether there is a need to use spatial regression models. This was done with diagnostics for spatial dependence with a spatial weight matrix that was created in the regression analysis discussed later in this chapter.

Table 6. Results of global Moran's I for residential burglary in Dongjak

Moran's Index:	0.041
Expected Index:	-0.001
Variance:	0.000
z-score:	2.007
p-value:	0.045

The results of Global Moran's I for general outdoor assault are presented in Table 9. The Moran's I value is 0.217 and statistically significant at the 0.001 level, which means that census blocks with the similar number of general outdoor assaults clustered together. Like residential burglaries, there was spatial dependence among general outdoor assaults in the study area, so the researcher needed to control for spatial dependence for general outdoor assault.

Table 7. Results of global Moran's I for general outdoor assault in Dongjak

Moran's Index:	0.217
Expected Index:	-0.001
Variance:	< 0.001
z-score:	10.775
p-value:	< 0.001

Results of Local Moran's I

The results of local Moran's I for residential burglary in the study area are presented in Figure 10. The areas in dark red and dark blue are census blocks clustering together with a similar number of residential burglaries (i.e., dark red for high-high and dark blue for low-low). The areas in light red and light blue are blocks that are outliers, which means that they had either unexpectedly high or unexpectedly low residential burglaries considering their neighboring blocks (i.e., light red for high-low and light blue for low-high).

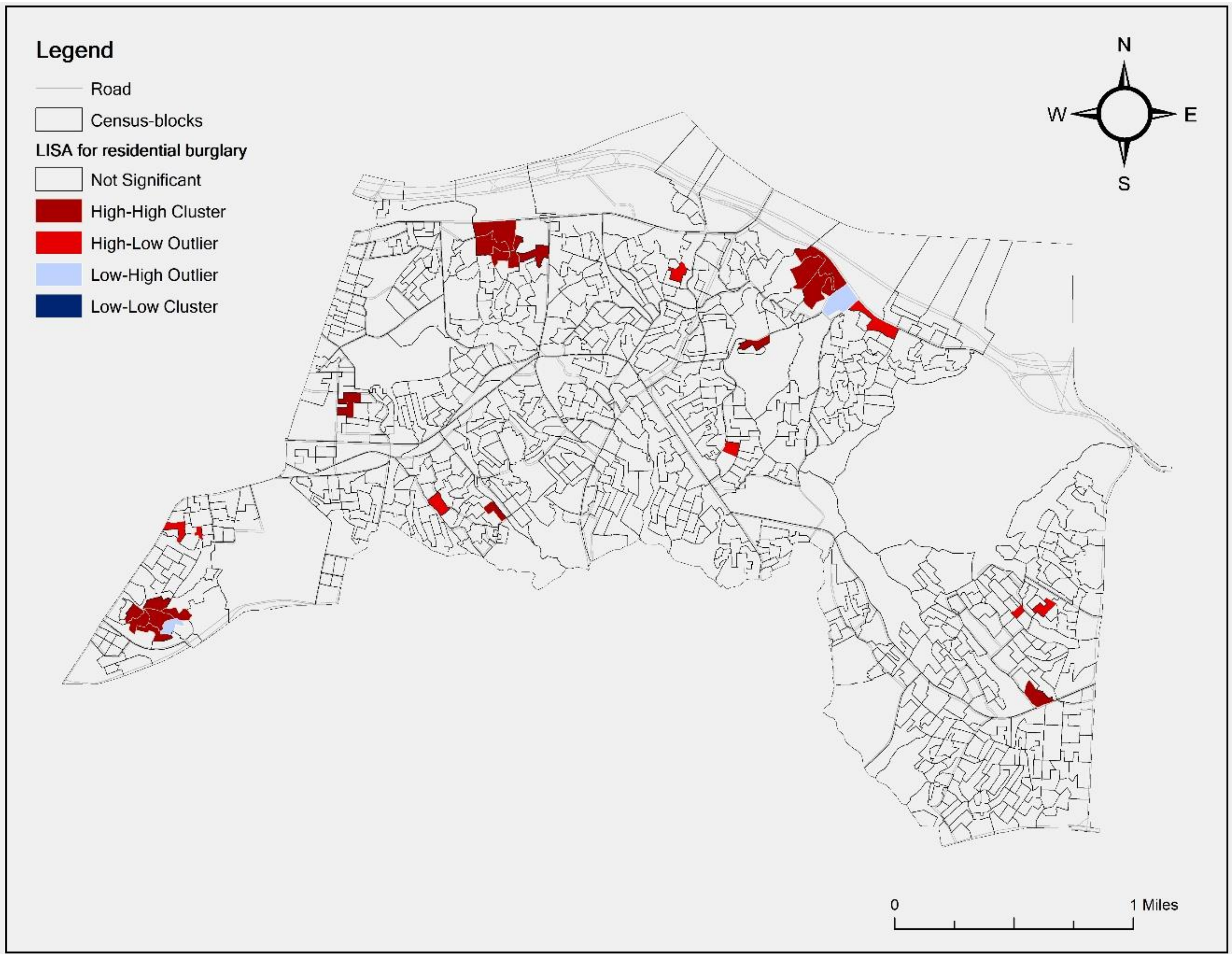


Figure 10. Local Moran's I for residential burglary in Dongjak

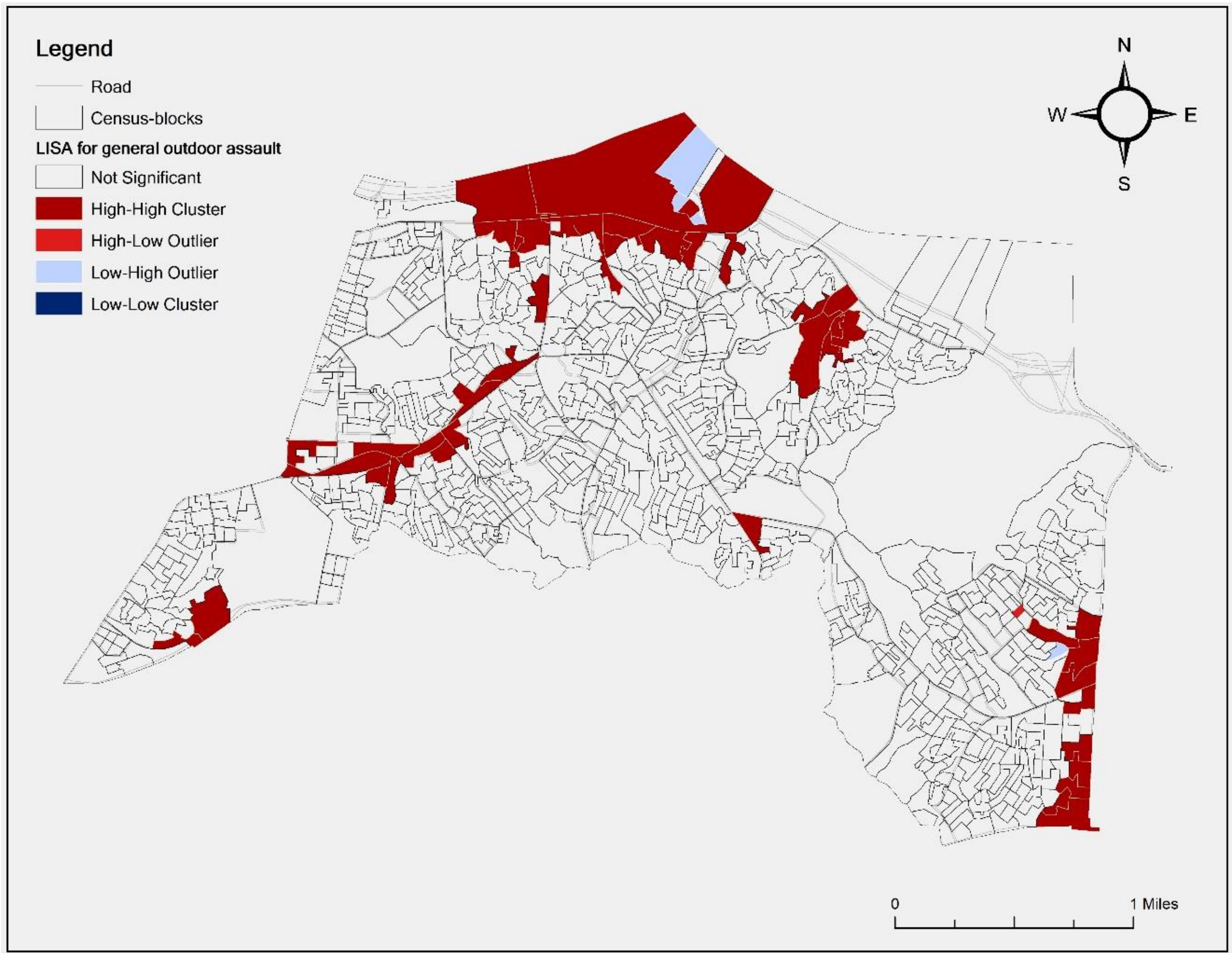


Figure 11. The result of local Moran's I for general outdoor assault in Dongjak

The result of local Moran's I for general outdoor assault are presented in Figure 10. For general outdoor assault, unlike residential burglary, there were many census blocks clustering together with a similar number of general outdoor assaults.

The bivariate analyses for residential burglary and general outdoor assault are presented in Table 8.

Table 8. Descriptive statistics for all variables

Variable	**Mean**	**Median**	**Std. Dev.**	**Min**	**Max**
Residential burglary[1]	.43	0	.85	0	9
General outdoor assault[1]	2.53	1	5.40	0	76
High-risk offender[2]	.18	0	.38	0	1
Teenagers[1]	38.13	35	37.68	0	672
High-level education[1]	210.98	201	168.85	0	1569
Restaurants and entertainments[1]	9.21	0	26.04	0	295
Subway stations[3]	578.88	511.59	316.99	57.33	2047.82
Schools[3]	318.74	292.36	166.88	4.53	851.39
Shopping malls[3]	819.21	732.08	469.19	23.31	1913.04
Single-person households[1]	64.63	46	80.79	0	772
Homeowners[1]	62.83	61	47.33	0	375
Elderly[1]	57.46	60	35.27	0	208
Preschool children[1]	16.83	15	13.80	0	110
High rise apartments[1]	52.19	0	84.75	0	480
CCTV cameras[1]	1.56	0	2.45	0	19
Police (sub)stations[3]	749.78	727.23	396.67	25.35	2026.50
Population density[4]	38.18	39.95	27.83	0	198.03
Population size[1]	435.04	470	235.04	0	2034
Households[1]	183.42	192	114.76	0	1113

Note: [1] Number in a census block
[2] Yes (dichotomous: 1=Yes, 0=No)
[3] Distance in meter from a point of interest to the centroid of the closest census block
[4] Population density per 1,000 residents

Table 9. Bivariate analysis between the dependent and independent variables

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
A. Res burg																	
B. Gen Assault	.17***																
C. Hi-risk off	.12**	.21***															
D. Teenager	.03	-.002	.03														
E. Hi level educ	.03	.07*	.04	.54***													
F. Rest enter	.12***	.74***	.18***	-.02	.07												
G. Subway station	.05	-.17***	-.03	.08*	-.07*	-.17***											
H. School	-.03	.04	.04	-.10**	-.07	-.02	.12***										
I. Shop mall	-.08*	-.03	-.03	.01	.07*	-.07*	-.06	-.07									
J. Homeowners	.01	-.05	-.01	.39***	.70***	-.06	.03	-.02	-.03								
K. Elderly	.10**	.09**	.09*	.27***	.59***	.09*	-.13***	.04	-.05	.62***							
L. Preschool	-.07	-.09*	-.04	.28***	.30***	-.10**	-.03	.13***	.05	.48***	.32***						
M. Hi-rise apart	-.14***	-.10**	-.17***	.23***	.29***	-.10**	-.02	-.01	.18***	.45***	.28***	.59***					
N. CCTV	.04	-.02	-.001	-.03	-.04	-.02	.01	.02	-.03	.01	-.02	.04	.06				
O. Police station	-.12***	-.09**	-.10**	.05	.01	-.16***	.02	-.11**	.45***	.04	-.08*	.15***	.25***	.02			
P. Pop density	-.05	-.11**	-.03	.29***	.28***	-.09**	.02	.04	-.002	.48***	.35***	-.08*	.15***	.25***	.02		
Q. Population	.07	.09*	.07*	.70***	.80***	.08*	-.11**	.01	.03	.65***	.76***	.57***	.38***	-.02	.02	.46***	
R. Households	.11**	.17***	.11**	.29***	.75***	.19***	-.17***	.02	.04	.48***	.74***	.36***	.16***	-.02	-.06	.29***	.83***

Regression Models

Previous analyses identified hot spots in the study area, and it was confirmed with Moran's I tests that there was a possibility of spatial dependence in the data. The next step would be to perform diagnostics for spatial dependence to check if it is necessary to conduct spatial regression models. Before this, it was necessary to check variance inflation factors (VIFs) to examine if there was any multicollinearity among the independent variables.

The VIFs of the variables in each model is presented in Tables 10 and 11. There appeared to be no multicollinearity issues with the outdoor general assault model (see Table 11). With residential burglary, however, there was a collinearity issue with the number of households and the number of single-person households (see Table 10). Since the number of households was an exposure variable which was necessary in models to control for variation among the census blocks, the number of single-person households was excluded from the regression models.

Table 10. Variance inflation factors among the independent variables for residential burglary

Variables	**VIF**
Household	41.55
Single-person household	28.53
High-level education	7.17
Elderly	5.26
Homeowner	4.90
Preschool children	3.65
High-rise apartment	2.17
Teenager	2.15
Population density	1.90
Restaurant and entertainment	1.16

Table 10. Continued

Police station	1.13
Subway station	1.12
School	1.10
High-risk offender	1.09
CCTV camera	1.01
Mean VIF	1.40

Table 11. Variance inflation factors among the independent variables for general outdoor assault

Variables	**VIF**
Population	2.54
Teenager	2.14
Population density	1.33
Police station	1.31
Shopping mall	1.27
Subway station	1.12
Restaurant and entertainment	1.12
School	1.06
High-risk offender	1.05
CCTV camera	1.01
Mean VIF	1.40

After excluding the number of single-person households from the model, new VIFs were calculated as shown in Table 12. The values of VIFs between the high-level education and the number of households were a little bit higher than the others. However, again, the number of households is an exposure variable, and it hardly gives redundant information as the high-level education. These variables, therefore, were retained in the regression models.

Table 12. Variance inflation factors excluding a problematic variable from the model

Variables	**VIF**
High-level education	5.75
Household	5.46
Elderly	3.65
Homeowner	3.29
Preschool children	2.32
High-rise apartment	2.11
Teenager	1.79
Population density	1.69
Restaurant and entertainment	1.16
Police station	1.13
Subway station	1.12
School	1.10
High-risk offender	1.09
CCTV camera	1.01
Mean VIF	2.33

To check for spatial autocorrelation, separate OLS models were run for residential burglary and general outdoor assault with all of the independent variables included in the models (Table 13 and 14). Coefficients are not interpreted here, because the models are not properly estimated. Instead, the focus is on the regression diagnostics, especially the diagnostics for spatial dependence. There are six tests performed to assess the spatial dependence of each model. First, for residential burglary, Moran's I is .49, which is not statistically significant, indicating no spatial autocorrelation of the residuals. The rest of the tests pertain to spatial dependence in linear models. The statistics are the simple and robust versions of the Lagrange Multiplier (LM) test for a missing spatially lagged dependent variable, the simple and robust versions of the LM test for error dependence, and the SARMA test, which combines the LM (error) and the LM (lag) tests. Both simple tests for a missing spatially lagged dependent variable and error dependence are not statistically significant, indicating no spatial dependence.

Table 13. Results of ordinary least square regression model for residential burglary

Variable	**Coef.**	**S.E.**	**t**
Constant	.278*	.124	2.242
Motivated offender			
High-risk offender[1]	.137	.080	1.713
Teenager	.001	.001	1.311
School[2]	> -.001	< .001	-1.446
Suitable target			
High-level education	-.001*	< .001	-1.994
Restaurant and Entertainment	.003*	.001	2.135
Subway station[2]	< .001*	< .001	2.293
Guardianship			
Homeowner	.001	.001	1.121
Elderly	.001	.002	.880
Preschool children	-.003	.003	-.952
High-rise apartment	-.001*	.001	-2.051
CCTV	.016	.012	1.363
Police[2]	> -.001	< .001	-1.682
Population density	-.001	.001	-.628
Household	.001*	< .001	2.147
AIC		1970.49	
Log-likelihood		-970.24	
Diagnostics for spatial dependence			
Moran's I (error)		.49	
Lagrange Multiplier (lag)		.19	
Robust LM (lag)		1.78	
Lagrange Multiplier (error)		.03	
Robust LM (error)		1.61	
Lagrange Multiplier (SARMA)		1.81	

Note: * p < .05; *** p < .001
[1] Dichotomous variable
[2] Distance in meter

The results of the OLS model for general outdoor assault are presented in Table 14. Like with residential burglary, the focus is on the diagnostics for spatial dependence. Moran’s I is -.73, which is not statistically significant, and neither are the LM (lag) or the LM (error) tests.

To summarize, the results suggested there was no need to control for spatial dependence in regression models for either residential burglary or general outdoor assault.

Table 14. Results of ordinary least square regression model for general outdoor assault

Variable	**Coef.**	**S.E.**	**t**
Constant	.426	.549	.776
Motivated offender			
High-risk offender[1]	1.114**	.341	3.267
Teenager	.002	.005	.338
School[2]	.002**	.001	2.723
Suitable target			
Restaurant and Entertainment	.147***	.005	28.381
Subway station[2]	-.001*	< .001	-2.025
Shopping mall[2]	< .001	< .001	.587
Guardianship			
CCTV	-.016	.052	-.308
Police[2]	< .001	< .001	1.053
Population density	-.012*	.005	-2.245
Population	< .001	< .001	.892
AIC		4300.24	
Log-likelihood		-2139.12	
Diagnostics for spatial dependence			
Moran's I (error)		-.73	
Lagrange Multiplier (lag)		.73	
Robust LM (lag)		5.41*	
Lagrange Multiplier (error)		1.06	
Robust LM (error)		5.74*	
Lagrange Multiplier (SARMA)		6.47*	

Note: * $p < .05$; *** $p < .001$
[1] Dichotomous variable
[2] Distance in meter

Predictors of residential burglary. In the current data, the sample mean and variance for residential burglary are .429 and .728, respectively (see Table 8). The variance is almost twice as large as the mean. Because there is no standard rule on how much larger the variance should be to indicate overdispersion, two models were compared: A Poisson model and a negative binomial model.

The Poisson regression model is compared to the negative binomial regression model for residential burglary in Table 15. As mentioned earlier, the purpose of the comparison is to examine which model is a better fit to the data.

First, the likelihood ratio test of alpha was examined after the negative binomial model. The chi-square value of 51.20 was statistically significant at the .001 level. This means that the dependent variable is overdispersed and the negative binomial model is a better alternative than the Poisson model. According to the log likelihood and Akaike Information Criterion (AIC), the negative binomial model is a better fit to the data than the Poisson model. This implies that the distribution of residential burglary is overdispersed, and it follows the negative binomial distribution.

There is another remaining issue with the model; there is a skewed distribution with many zeros in the dependent variable. In addition to the overdispersion issue, there is still a need to solve a positively skewed distribution with many zeros in the count of residential burglary. As seen in Table 8 in this chapter, there are 565 census blocks out of 794 (71.16%) that have zero residential burglaries. A zero-inflated negative binomial regression model (ZINB) was run to address the excessive number of zeros.

Table 15. Comparison of Poisson and negative binomial regression models for residential burglary

	Poisson			Negative binomial		
Variable	**Coef.**	**S.E.**	**Z**	**Coef.**	**S.E.**	**Z**
Constant	-1.138***	.232	-4.905	-1.200***	.285	-4.211
Motivated offender						
High-risk offender[1]	.260*	.128	2.031	.297	.160	1.856
Teenager	.003	.002	1.376	.003	.002	1.103
School[2]	> -.001	.0003	-1.751	-.001	< .001	-1.383
Suitable target						
High-level education	-.002*	.001	-2.521	-.002	.001	-1.932
Restaurant and Entertainment	.003*	.002	2.202	.004	.002	1.601
Subway station[2]	< .001**	.0002	2.984	< .001*	< .001	2.154
Guardianship						
Homeowner	.004	.002	1.553	.004	.003	1.322
Elderly	.004**	.003	1.364	.004*	.003	1.231
Preschool children	-.012	.007	-1.698	-.011	.008	-1.248
High-rise apartment	-.003**	.001	-3.227	-.004**	.001	-2.991
CCTV	.035	.020	1.750	.037	.026	1.423
Police[2]	> -.001*	.0002	-2.364	> -.001	< .001	-1.841
Population density	-.001	.003	-.289	-.001	.003	-.415
Household	.003**	.001	2.664	.003*	.001	2.020
Chi-square model fit	95.25***			64.42***		
Log likelihood	-685.21			-660.12		
Likelihood ratio test	-			50.17***		
AIC	1400.42			1352.25		
BIC	-3831.03			-3874.52		

Note: * $p < .05$; ** $p < .01$; *** $p < .001$
[1] Dichotomous variable
[2] Distance in meter

The results of a zero-inflated negative binomial regression model for residential burglary are presented in Table 16. First, the presence of high-risk offender was excluded from the logit model which predicts the odds of the area of being zero residential burglaries, because the goodness-of-fit of the model was non-significant, and it had an oddly large coefficient and standard error when it was included in the model. This is probably because there was a quasi-complete separation issue that occurs when an outcome variable separates a predictor variable or a combination of predictor variables to certain degree (Allison, 2008). Crosstabulation of the high-risk offender variable by the number of residential burglaries was not helpful in visual inspection of possible separation.

Table 16. Results of zero-inflated negative binomial regression model for residential burglary

Variable	Coef.	S.E.	Z
Count model			
Constant	-.605	.350	-1.728
Motivated offender			
High-risk offender[1]	.245	.153	1.601
Teenager	.003	.003	1.032
School[2]	-.001	< .001	-1.549
Suitable target			
High-level education	-.001	.001	-1.380
Restaurant and Entertainment	> -.001	.002	-.184
Subway station[2]	.001**	< .001	2.645
Guardianship			
Homeowner	.001	.003	.291
Elderly	.005*	.004	1.422
Preschool children	-.025*	.011	-2.384

Table 16. Continued

High-rise apartment	.001	.001	.983
CCTV	-.011	.028	-.379
Police[2]	> -.001	< .001	-1.142
Population density	-.001	.004	-.335
Household	.002	.001	1.359
Logit model			
Constant	.426	1.157	.368
Motivated offender			
Teenager	-.001	.007	-.082
School[2]	-.001	.002	-.662
Suitable target			
High-level education	.003	.003	.863
Restaurant and Entertainment	-.358*	.179	-1.999
Subway station[2]	.001	.001	.867
Guardianship			
Homeowner	-.013	.009	-1.421
Elderly	-.005	.012	-.401
Preschool children	-.054	.039	-1.414
High-rise apartment	.017**	.006	3.010
CCTV	-.333	.193	-1.725
Police[2]	< .001	.001	.587
Population density	-.006	.014	-.473
Household	< .001	.005	.061
Chi-square model fit	25.45*		
Log likelihood	-642.31		
AIC	1344.62		
BIC	-3816.67		

Note: * $p < .05$; ** $p < .01$
[1] Dichotomous variable
[2] Distance in meter

A Mann-Whitney test was conducted between the presence of high-risk offender and the number of residential burglaries. A Mann-Whitney test is appropriate rather than a t-test because residential burglary is not normally distributed. It was found that the difference between a census block with a high-risk offender(s) group and a census block without it was statistically significant at .001 level. A logistic regression model was employed using the presence of high-risk offender as a dependent variable regressed on the number of residential burglaries and one of the other independent variables. This was repeated for every combination of the high-risk offender variable and one of the independent variables. It was found that the number of residential burglaries was statistically significant, and the chi-square model fit was significant as well in every model. Finally, a contingency table was examined after recoding the number of residential burglaries to a dichotomous variable. A chi-square test reported that the two variables are statistically dependent on one another. The results of these quality tests are reported in Appendix C.

All these results suggest that there is a separation issue, although it is not clear what exactly causes the problem. Also, the fact that it was only an issue in the logit model for residential burglary suggests that there may be a separation issue (see Appendix C). The presence of high-risk offender, therefore, was excluded from the logit model for residential burglary. The AIC value of 1344.62 is also smaller than that of the negative binomial model in Table 15. Table 16 reports the results for the final model.

None of the motivated-offender variables in the count model is statistically significant for residential burglary. Among the suitable-target variables, only the subway-station variable is statistically significant at the .01 level. For the guardianship variables, the elderly and preschool children variables are statistically significant at the .05 level. For the interpretation of the coefficients in the count model, if the distance between a subway station and a census block increases by one meter, the expected number of residential burglaries in a census block would change by a factor of exp (.001) or 1.001, while controlling for all other variables in the model. Thus, against expectations, the farther a census block is located from a subway station, the greater the number of residential burglaries.

The elderly variable has a coefficient of .005. If the number of elderly in a census block increases by one, the expected number of residential burglaries in a census block would change by a factor of exp (.005) or 1.005, while controlling for all other variables in the model. In other words, the more elderly there are in a census block, the more residential burglaries.

The number of preschool children variable has a coefficient of -.025. If the number of preschool children in a census block increases by one, the expected number of residential burglaries would change by a factor of exp (-.025) or .975, while controlling for all other variables in the model. In other words, the more preschool children in a census block, the fewer residential burglaries, which is contrary to expectations.

In the logit model predicting the odds of the area having zero residential burglaries, none of the motivated-offender variables is statistically significant. Among the suitable-target variables, only the number of restaurants and adult entertainment places is statistically significant. For the guardianship variables, only the number of high-rise apartments is statistically significant. To interpret the coefficients in the logit model, if the number of restaurants and adult entertainment places, such as bars and pubs, in a census block increases by one, the odds that the census block will be in the "certain zero" group would change by a factor of exp (-.358); hence, there would be a decrease in the odds of the area having zero residential burglaries (by .699). In other words, the greater the number of restaurants and adult entertainment places in a census block, the more likely the census block would experience at least one residential burglary.

The coefficient for the number of high-rise apartments variable is .017. If the number of high-rise apartments in a census block increases by one, the odds that the census block would be in the "certain zero" group would change by a factor of exp (.017) or increase the odds of the area being zero residential burglaries by 1.017. In other words, the greater the number of high-rise apartments in a census block, the less likely it is the census block would experience at least one residential burglary.

Predictors of general outdoor assault. The Poisson regression model, negative binomial regression model, and zero-inflated regression model were examined first to find the best fitting model to the data for general outdoor assault. Like residential burglaries, general outdoor assaults in Dongjak also have a positively skewed distribution with many zeros. Zero-inflated regression models were used to address this issue.

As shown in Table 17, apart from interpreting the coefficients, the likelihood ratio test was examined after the negative binomial regression model. The chi-square value of 902.02 was statistically significant at the .001 level. This means that the Poisson model is inappropriate. The model fit to the data is better for the negative binomial model than for the Poisson model. Also, according to the results of the Poisson model, almost every variable (9 out of 11) is statistically significant due to the small values of the standard errors. This seems to be attributed to the heteroskedasticity caused by overdispersion in the dependent variable. The negative binomial model, therefore, provides a better fit to the data and was compared to a zero-inflated model to account for the excess zeros in the data.

Table 17. Comparison of Poisson and negative binomial regression models for general outdoor assault

	Poisson			Negative binomial		
Variable	**Coef.**	**S.E.**	**Z**	**Coef.**	**S.E.**	**Z**
Constant	.602***	.099	6.096	.362	.191	1.902
Motivated offender						
High-risk offender[1]	.433***	.052	8.278	.451***	.114	3.978
Teenager	.001	< .001	1.476	-.001	.002	-.712
School[2]	< .001***	< .001	3.723	< .001	< .001	1.603
Suitable target						
Restaurant and Entertainment	.011***	< .001	27.901	.023***	.002	10.114
Subway station[2]	> -.001***	< .001	-5.167	> -.001**	< .001	-3.152
Shopping mall[2]	< .001***	< .001	5.642	< .001	< .001	.865
Guardianship						
CCTV	.006	.010	.600	.019	.019	.997
Police[2]	> -.001***	< .001	-5.299	> -.001*	< .001	-2.064
Population density	-.008***	< .001	-6.902	-.011***	< .001	-4.993
Population	< .001*	< .001	2.204	.001***	< .001	3.976
Chi-square model fit	1892.46***			316.27***		
Log likelihood	-1882.12			-1447.30		
Likelihood ratio test	-			902.02***		
AIC	3788.24			2918.60		
BIC	-1457.24			-2326.88		

Note: * $p < .05$; ** $p < .01$; *** $p < .001$
[1] Dichotomous variable
[2] Distance in meter

Table 18 shows the results of the zero-inflated negative binomial regression model for general outdoor assault. First, for the model fit, the AIC value is well below 2809.37 from the negative binomial model. Thus, this model can be considered the final model for general outdoor assault in Dongjak.

Table 18. Results of zero-inflated negative binomial model for general outdoor assault

Variable	**Coef.**	**S.E.**	**Z**
Count model			
Constant	.722***	.184	3.921
Motivated offender			
High-risk offender[1]	.124	.097	1.283
Teenager	< .001	.001	.532
School[2]	< .001	< .001	1.001
Suitable target			
Restaurant and Entertainment	.018***	.002	11.378
Subway station[2]	> -.001*	< .001	-2.576
Shopping mall[2]	< .001	< .001	1.491
Guardianship			
CCTV	.013	.019	.683
Police[2]	> -.001	< .001	-.135
Population density	> -.001	< .001	-1.082
Population	< .001	< .001	.604
Logit model			
Constant	-.469	.612	-.0771
Motivated offender			
High-risk offender	-5.154	7.041	-.733
Teenager	.003	.010	.242
School[2]	> -.001	< .001	-.871
Suitable target			
Restaurant and Entertainment	-.581*	.225	-2.582
Subway station[2]	> -.001	< .001	< .156
Shopping mall[2]	< .001	< .001	1.207
Guardianship			
CCTV	.019	.062	.312
Police[2]	< .001	< .001	1.766

Table 18. Continued

Population density	.031***	.008	4.001
Population	-.004**	.001	-3.263
Chi-square model fit	447.50***		
Log likelihood	-1381.69		
AIC	2809.37		
BIC	-2384.66		

Note: * p < .05; ** p < .01; *** p < .001
[1] Dichotomous variable
[2] Distance in meter

In the logit model which predicts the odds of the area having zero general outdoor assaults, the number of restaurants and adult entertainment places, population density, and population are statistically significant. The number of restaurants of adult entertainment places has a coefficient of -.581, and it is statistically significant at the .05 level. If the number of restaurants and adult entertainment places in a census block increases by one, the odds that the census block would be in the “certain zero” group would change by a factor of exp (-.581) or decrease the odds of the area being zero general outdoor assault by .559. In other words, the greater the number of restaurants and adult entertainment places in a census block, the more likely the census block would have at least one general outdoor assault. As estimated in the count model, it was also found in the logit model that the number of restaurants and adult entertainment places had a positive, statistically significant effect on general outdoor assault.

The population density variable has a coefficient of .031, and it is statistically significant at the .001 level. If the population density in a census block increases by one, the odds that the census block would be in the “certain zero” group would change by a factor of exp (.031) or increase the odds of the area being zero general outdoor assaults by 1.031. That is, the denser the population in a census block, the less likely the census block would have at least one general outdoor assault.

In the count model, the number of restaurants and adult entertainment places and the distance to a subway station are statistically significant. For the interpretation of the coefficients in the count model, the number of restaurants and adult entertainment places has a coefficient of .018, and it is statistically significant at the .001 level. If the number of restaurants and adult entertainment places in a census block increases by one, the expected number of general outdoor assault in the census block would change by a factor of exp (.018) or 1.018, while controlling for all the other variables in the model. That is, the more restaurants and adult entertainment places in a census block, the more general outdoor assaults in the census block.

The distance to a subway station has a coefficient of -.0003, and it is statistically significant at the .05 level. If the distance to a subway station increases by one meter, the expected number of general outdoor assault in the census block would change by a factor of exp (-.0003) or .9997, while controlling for all the other variables in the model. The closer a subway station located to a census block, the more general outdoor assaults in the census block.

In summary, in the count model predicting the number of residential burglaries, the distance to a subway station and the number of the elderly were found to have positive, significant effects, whereas the number of preschool children was found to have a negative, significant effect. In the logit model predicting the odds of the area having zero residential burglaries, the number of restaurants and adult entertainment places was found to have positive, significant effects, whereas the number of high-rise apartments was found to have negative, significant effects. In the count model predicting the number of general outdoor assaults, the number of restaurants and adult entertainment places was found to have a positive, significant effect, whereas the distance to a subway station was found to be have a negative, significant effect. In the logit model predicting the odds of the area having zero general outdoor assaults, the population density was found to have a positive, significant effect, whereas the number of restaurants and adult entertainment places and population were found to have negative, significant effects.

V. DISCUSSION AND CONCLUSIONS

The current study examined the relevance of routine activity theory for assessing the spatial distribution of residential burglary and general outdoor assault in South Korea. While residential burglary and general outdoor assault are among the most commonly reported crimes in South Korea, they have never been examined from the perspective of routine activity theory with spatial data in South Korea. This study examined how well routine activity variables explain the spatial distribution of these crimes. Previous studies often tested the theory with data at the neighborhood level (Hwang, 2001; Jeong et al., 2009; Kim et al., 2007; Roh, 2015) and, therefore, ignored spatial effects within smaller localities, that is the possibility of spatial autocorrelation caused by spatial dependence. Like temporal autocorrelation in a longitudinal dataset, spatial autocorrelation violates the standard statistical assumption of independence among observations. Because standard regression models do not compensate for spatial dependence and result in unstable parameter estimates and yield unreliable significance tests, it is important to check spatial autocorrelation in the data with Moran's I to examine whether spatial models are necessary. Spatial regression models capture spatial dependence, and its results are more efficient and less biased than the results from standard regression models. Some researchers, however, are not inclined to correct for spatial dependence because it, in fact, provides them insights into what really happens in their focus areas (De Knegt et al., 2010). In the current study, for example, due to spatial dependence, it was possible to find that residential burglary and general outdoor assault were spatially clustered and to identify hot spots for those crimes in the study area.

Findings for Residential Burglary

This study found that distance to subway stations is positively associated with residential burglary in South Korea. This is somewhat an unexpected finding. It was hypothesized that if a subway station is located closer to a census block, the census block would have more residential burglaries because proximity to a subway station would make the premises more accessible to offenders (Felson & Poulsen, 2003). For further explanation, Figure 12 shows a land map around subway stations in the study area. In the map, pink colored areas indicate commercial areas, and beige colored areas show residential areas. As seen in the map, subway stations are directly surrounded by commercial areas, and residential areas are zoned as it gets farther from subway stations. This is probably the reason why distance to subway stations is positively associated with residential burglary. Given that the number of households in a census block was controlled in the model, however, the effect of zoning due to distance between a subway station and a census block was mitigated. Rather, it is possible that household density may be attractive to burglars because it gives them more to choose while they are in the area, which the current study was not able to examine.

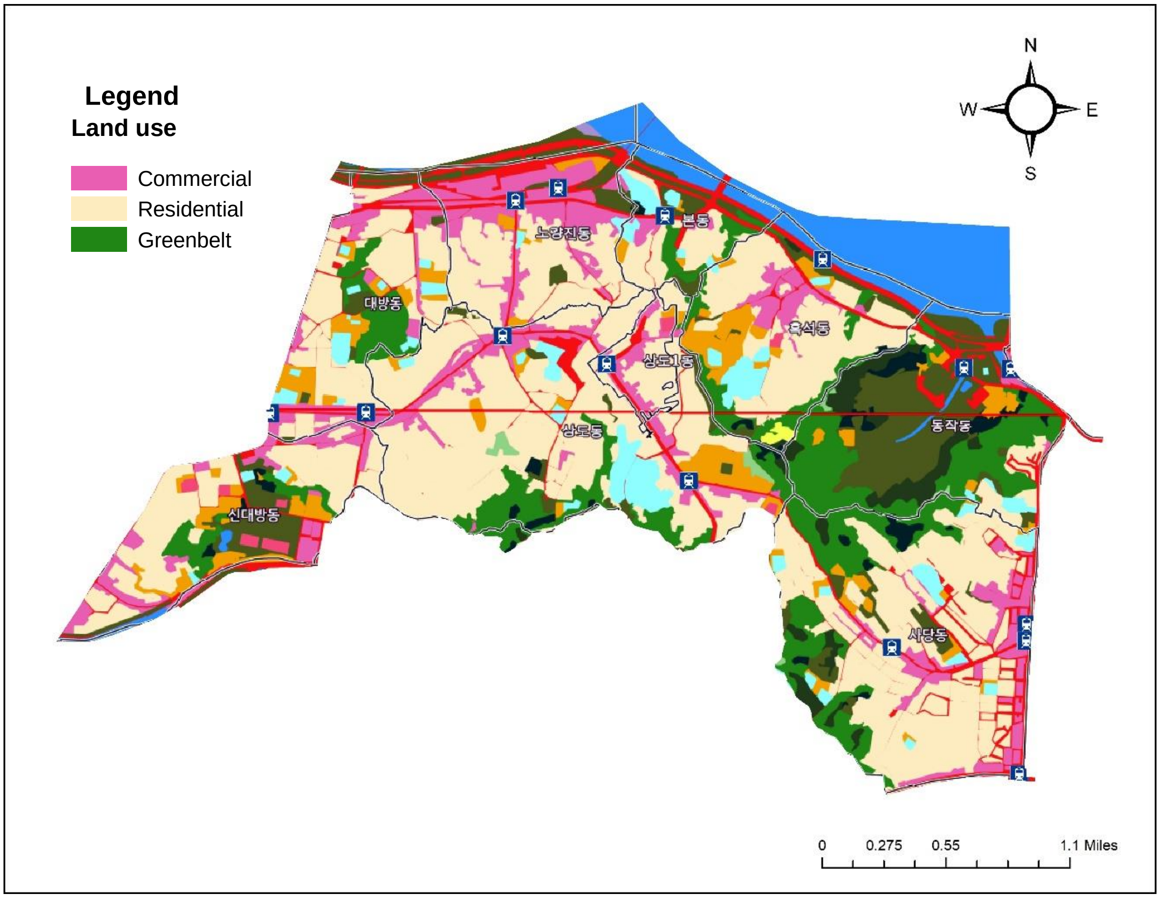


Figure 12. Land use around subway stations in Dongjak

The number of elderly persons was positively associated with residential burglaries. This finding is consistent with a finding from a previous study (Jeong et al., 2009). A possible explanation is that the number of elderlies is highly correlated with the number of households ($r = .74$, $p < .001$, see Table 4). Areas where there are many households would be suitable targets for residential burglary. Also, even though it was excluded from the model in the study due to multicollinearity, the number of single-person households was also correlated with the number of elderly ($r = .43$, $p < .001$, see Table 4). It is noteworthy that there could be moderating effects with the single-person household and the elderly, although it cannot be tested with the data in this study. If a single-person household is occupied by an old person, it will be protected against residential burglary. In contrast, if it is occupied by an occupationally active individual, it will be at higher risk for residential burglary, because this person is likely to be out at work. .

The negative relationship between the number of preschool children and residential burglary was statistically significant. It was anticipated that preschool children would play a role as capable guardians with their parent(s) or caregivers, because preschool children are more likely to be supervised as their parent(s) or caregivers stay with them at home (Cohen & Felson, 1979). It also is consistent with previous findings for South Korea (see Hwang, 2001). Despite sparse empirical evidence, it would be helpful for researchers and practitioners to use the information on preschool children in attempting to measure the risk of residential burglary in a neighborhood.

Restaurants and adult entertainment places had a negative relationship with the odds of the area having zero residential burglaries in the logit model. This finding is consistent with research by Davison and Smith (2001) and supports the effects of criminogenic facilities on residential burglary. The business/commercial areas located closest to residential areas are likely to attract potential criminals and victims. These criminogenic facilities, such as restaurants and adult entertainment places, such as bars and pubs, may increase the likelihood of a potential offender committing residential burglary or increase the number of residents outside their homes and increase opportunities for potential burglars when they are unoccupied.

The results showed that high-rise apartments are negatively associated with residential burglary. This finding is consistent with a previous study by Hwang (2001). A high-rise apartment may play a role as a capable guardian due to its high level of security by guards, CCTV cameras, and its density of residents.

Null results for residential burglary. Interestingly, none of the motivated-offender variables were statistically significant predictors of residential burglary. A previous study conducted in Canada found that the proportion of the population that was young was a significant predictor of breaking and entering (Andresen, 2006). The number of teenagers and distance to schools were also found to be a non-significant predictor of residential burglaries in this study. It was hypothesized that census blocks with the large number of teenagers and close to schools would have more residential burglaries. A plausible explanation for this unexpected finding in the current study is that teenagers in South Korea do not have enough time to commit residential burglary because they spend most of their time in schools and educational institutes until late at night (Lee & Larson, 2000). From a different perspective, this could be also explained by Confucianism. Confucian values, such as educational achievement and strict parenting, are emphasized in South Korea (Lee & Larson, 2000). In a previous study, it was found that delinquency (assaults, gang fighting, threatening others, collective bullying, sexual assaults, robbing, stealing, smoking, drinking, running away, and truancy) among South Korean youth was decreased by high standards of education, academic achievement, and increased parental supervision and discipline (Peterson, Lee, Henninger, & Cubellis., 2016).

The presence of high-risk offenders was not a significant predictor of the number of residential burglaries. This was probably because the effect of the presence of high-risk offenders on residential burglary was cancelled out by the effects of the number of restaurants and adult entertainment places. The KDE was estimated for both locations of high-risk offenders and restaurants and adult entertainment places and suggested they overlapped with each other. A t-test was conducted, and it was found that the average number of restaurants and adult entertainment places in census blocks with high-risk offenders and the average in census blocks without them was statistically different at the .001 level (t = -5.238). Census blocks with high-risk offender(s) had the mean of 19.415 restaurants and adult entertainment places and those without high-risk offender(s) had the mean of 6.988, on average.

The number of residents who had a four-year college degree or more was not significant in the residential burglary model. It was used as a proxy measure of income because an income variable was not available from South Korean census data, even though the level of education does not necessarily reflect income level. It might have been found to be significant if a direct measure of income had been used. In earlier analysis, the Kernel density estimation for residential burglary showed that those hotspot areas were highly concentrated in poor neighborhoods. Thus, the null finding was attributed to poor measurement of the variable.

The study hypothesized that homeowners would act as guardians because they are more likely to be interested in securing their properties. There was, however, a positive, non-significant effect of homeowners. Given that higher levels of education tend to increase income, though they do not necessarily reflect income level, and homeowners tend to have higher income than renters, the positive association with residential burglary is unexpected, although it is not statistically significant.

The number of CCTV cameras had a negative, non-significant effect on residential burglary in the count model. It was not statistically significant because the spatial distribution of the CCTV cameras did not overlap with that of residential burglary. Burglars might have avoided areas where there were many CCTV cameras. Given that the crime data in this study were detected crimes, the null results make sense. Although the current study did not examine the crime displacement effect, it is also possible that there was a displacement. This result suggests that they need to be relocated to hotspot areas in order to be more effective against residential burglaries.

Distance to police (sub)stations was found to be negative and non-significant in the model. Like the non-significant findings for CCTV cameras, the deterrent effect of police (sub)stations might have been counteracted by the higher-detection-rate effect embedded to the data in this study. Indoor crimes, such as residential burglary, would be less affected by distance to police stations than outdoor crimes, such as vehicle theft. In addition, the variable simply indicates distance between them to census blocks, and it does not necessarily measure the actual effects of the presence of police, such as police patrol routes.

Population density had negative, non-significant effect on residential burglaries. The effects were probably cancelled out by the number of homeowners and population that were highly correlated in the model. Although it was not statistically significant, the negative association with residential burglary, capturing the guardianship element, was supported by previous studies (Andresen, 2006).

Findings for General Outdoor Assault

The study found that restaurants and adult entertainment places were positively associated with general outdoor assaults. As hypothesized and as routine activity theory predicted, such criminogenic facilities play a significant role in attracting and generating general outdoor assaults (Cohen & Felson, 1979; Pernanen, 1991; Pridemore & Grubesic, 2013). Previous studies found that South Koreans go out to drink with friends and colleagues more often than drink alone at home (Ko & Sohn, 2018), and they were more likely to be injured intoxicated (Asante, Newell, Yun, Yun-Welch, & Chun, 2015).

The distance to a subway station was found to be negatively associated with general outdoor assaults. As the theory assumed, the closer a subway station is located to a census block, the census block would have more general outdoor assaults because proximity to a subway station would make the premises more accessible to offenders (Felson & Poulsen, 2003). Also, as shown in Figure 12, the locations of subway stations were close to commercial areas (areas in pink colored). These are areas where restaurants and adult entertainment places were located, giving a likely offender an opportunity to find suitable targets.

As assumed in the model, population density plays a role as capable guardians for general outdoor assault, unlike residential burglary. It is an expected finding because residential burglary, as an indoor crime, is hardly affected by population density and general outdoor assault is easily influenced by the concentration of people. It seems that densely congregated people can exercise effective surveillance.

Null results for general outdoor assault. None of the motivated offender variables were statistically significant for general outdoor assault in this study. The effect of the presence of high-risk offender was probably cancelled out by the number of restaurants and adult entertainment places, since the residential locations of high-risk offenders overlapped with these areas. Dunn-Bonferroni post hoc test for pairwise comparison was examined to compare the counts of general outdoor assaults among categorical groups of high-risk offenders. There were statistically significant differences between groups. Also, when only the motivated offender variables (i.e., high-risk offenders, teenagers, and schools) were included and the other variables were excluded from the model, the effects of high-risk offenders became positive and significant at the .001 level in the count model, and none is significant in the logit model (see Appendix D).

The number of teenagers had a positive, non-significant effect on general outdoor assault in the count model. Although the current study does not have empirical data on the age-violent crime relationship, the crime statistics from South Korea show the age group that commits the largest number of violent crimes is the 40s (Jeong, 2012), unlike in the U.S. where teenagers commit the largest number of violent crimes. This is attributed to cultural differences between the U.S. and South Korea. In South Korea, most teenagers have a hectic schedule almost every day for their studies.

Distance to schools had a positive, non-significant effect on general outdoor assault. Like the number of teenagers, the null effect of schools can be explained by the cultural characteristics of teenagers in South Korea.

The effects of shopping malls seem to also be cancelled by the effects of police stations (r = .45, p < .001). The locations of shopping malls and hotspot areas of general outdoor assaults overlapped (see Appendix E). These areas were also where the police stations were located. To examine the counteraction effect, the model was run excluding the police station variable. The distance to a shopping mall became positive and statistically significant in the logit model that predicts the odds of the area having zero general outdoor assault ($b = .001$, $p < .01$) (see Appendix E).

Similar to the case of residential burglary, the effect of the number of CCTV cameras on general outdoor assault was also non-significant. The null results can also be explained by the counteraction effect of the higher-detection-rate of general outdoor assault in South Korea. The relocation of CCTV cameras should be considered in the study area.

Limitations

The current study is not without its limitations. First, a notable limitation in the current study is the use of official records to measure residential burglary and general outdoor assault. Although these types of crimes have low under-reporting rates (Moon et al., 2017; South Korean Ministry of the Interior and Safety, 2016), the official data still are imperfect. Moreover, they provide only information on those offenses that resulted in an arrest. Crimes that the police did not identify suspects, therefore, were not included in this study. Cleared crimes are potentially biased to the extent that most crimes are not cleared with arrest. However, the clearance rates were 101.2% for burglary and 86.7% for general outdoor assault, on average for 2015-2016 periods in South Korea (Moon et al., 2017; South Korean Ministry of the Interior and Safety, 2016), and these high-detectionrates for both residential burglary and general outdoor assault counteracted the effects of capable-guardian variables (i.e., population density, police stations, and CCTV cameras) Future studies might combine official data and other data, such as victimization surveys to capture better measures of crime.

Second, the current study does not consider the ambient population, especially for general outdoor assault. People leave their homes (in a particular census block in the current study) during the day to work or to do something else. The best way to consider the ambient population may be to include the number of people using a cellphone through a cellular tower signal from a network carrier company. In the current study, however, it was not possible to obtain such a dataset because a South Korean network carrier did not want to share its customer's usage data. Johnson, Andresen, and Malleson (2018) pointed out that crime distribution over a study area changes after considering an ambient population. For future research, the effects of the ambient population should be further considered.

Third, the current study used a census block as a unit of analysis. Although it is the smallest unit available to South Korea, many researchers prefer a smaller unit than a census block, such as a street segment, in spatial analysis. Although the regression models were examined at the census block level, it was possible to show variation within the census blocks with the Kernel density estimations to identify hotspot areas for residential burglaries and general outdoor assaults. In this case, multi-level analyses keeping crime data at a smaller level and census data at a block level may be advantageous (see Weisburd et al., 2014).

Fourth, the effects of surrounding blocks outside of the district of study area that affect estimates for the blocks in the study area (i.e., boundary effect) could not be identified in this study. This problem could be minimized by examining data outside the boundary of the study area, but access to data outside the study area would be required.

Fifth, the high-risk offender variable was coded as dichotomous rather than the actual number of them. When the variable, as a continuous variable, was included in the regression model for residential burglary, the coefficient and standard error of the high-risk offender variable were oddly high, and consequently, the goodness-of-fit of the model became non-significant. This is probably because the continuous high-risk offender variable is extremely skewed (652 census blocks had zero high-risk offenders, 122 blocks had only one, 15 blocks had two, two blocks had three, other two blocks had four, and one block had 21 high-risk offenders). Accordingly, a dichotomous variable instead of a continuous variable was relied upon to obtain more efficient and less biased results. However, when dichotomizing a continuous variable, the variable loses much information, so the statistical power to detect an association between high-risk offender and crimes was reduced. It may also seriously underestimate the extent of variation in outcome, and variability may be subsumed within each category.

Sixth, although it was not mentioned in the police-recorded data when the data was obtained, it is possible that the addresses of where crimes occurred might not have been accurate, especially for general outdoor assault. The locations and X, Y coordinates for the locations of general outdoor assaults were automatically calculated and sent to the data server when police officers were dispatched to crime scenes. However, when there is no accurate address (e.g., on street, open vacant places), it might have been inaccurately calculated and recorded in the crime data. If the researcher were only given data for crimes where the exact locations were known, excluding those where the locations were unknown, the data would be biased. Although it was not clear if this was the case because they were secondary data, the biased data would have affected findings. For example, general outdoor assaults where those exact locations were unknown, and, therefore, excluded from the data, would have affected the results.

Conclusions

The purpose of this study was to examine the relevance of routine activity variables for understanding the spatial distribution of residential burglary and general outdoor assault in South Korea. To answer the first research question: *Are there areas where residential burglaries and general assaults were concentrated in the study area?*, the Kernel density estimation and nearest neighbor index analysis with data were used. Previous studies found that crimes, as comprehensive measures including various types of crimes, were concentrated in multiple small areas. The results of this study indicated that spatial distributions of residential burglary and general outdoor assault were significantly clustered in certain areas.

The second research question was: *If so, what makes the areas hot spot areas? Which routine activity variables matter most?* Various types of regression models were examined. To further explain the hotspot areas, this study employed regression models, including a linear regression model, a Poisson regression model, a negative binomial regression model, and a zero-inflated model. Spatial distribution was best explained by a zero-inflated negative binomial regression model since crimes were not randomly distributed and there were many areas where there were zero counts of crime. With regard to the result of each model, the directions of the coefficients were consistent across all the models, while the values and significance of them differed. This suggested the need to choose an appropriate model. Considering the AIC and BIC values for each model, the best fit model was the zero-inflated negative binomial regression model for both residential burglary and general outdoor assault. Predictors of residential burglary included the number of restaurants and adult entertainment places, the distance to subway stations, the number of elderlies, the number of preschool children, and the number of high-rise apartments.

Careful interpretations for subway stations and elderly were needed. As subway stations were closely located to commercial areas and located far from residential areas, the association was found to be negative. If they were bus stops which are closely located to residential areas, it would probably have produced the opposite result. Future studies may include such environmental factors and examine how these variables predict residential burglary. The number of elderlies in a census block was positively associated with residential burglary. This was probably because of the number of households which was somewhat highly correlated with the elderly variable.

Predictors of general outdoor assault included the number of restaurants and adult entertainment places, the distance to a subway station, and population density. Population density played a role as a capable guardian against general outdoor assault. However, this might have been affected by the measurement of population density. Population density in this study was measured as residential population rather than ambient population. In most cases, general outdoor assault occurs in non-residential areas where there are alcohol outlets.

The best predictors of residential burglary were distance to subway stations and the number of high-rise apartments, given that z-scores of these variables in the model. The positive coefficient for distance to subway stations in the count model does not support routine activity theory because the theory originally predicted that transportations, such as buses and subways would increase offender's mobility, which, in turn, would lead these census blocks close to subway stations would to be more suitable targets. The positive coefficient for the number of high-rise apartments in the logit model supports the theory. High-rise apartments usually have a high level of security due to their own security personnel and crime prevention means, such as CCTV cameras.

The best predictors of general outdoor assault were the number of restaurants and adult entertainment places and population density. The positive coefficient for the number of restaurants and adult entertainment places supports routine activity theory, because the theory predicted that those places would have weakened social norms, and potential offenders would view them as more suitable targets. The positive coefficient for population density in the logit model also supports the theory. The negative coefficient for population in the logit model also supports the theory.

Overall, the study found only weak support for routine activity theory. Many variables in the models were found to be non-significant. This might be due to poorly measured variables (e.g., the presence of high-risk offenders), but it actually might signal that routine activity theory does not apply as well in South Korea as in other places, such as the U.S. This may be because the theory was introduced in the U.S., and there is a distinct cultural difference between the U.S. and South Korea (e.g., routine activities of teenagers). This difference was clearly demonstrated in a previous study where the author compared the age-curve for violent crimes in the U.S. and in South Korea (Jeong, 2012). The previous study found that most violent crimes were committed by teenagers in the U.S., while they were committed by those in their 40s in South Korea. It can be explained by the differences in teenagers' life patterns between the two countries. South Korean teenagers spend most of their time in studying in educational institutions due to the university entrance examination (Lee & Larson, 2000). This nationwide examination is highly competitive and graduating from a high-ranked university is considered important to obtain a good job with high wages, high social status, and a good marriage (Bae & Lee, 1988). It goes even further by the social culture, such as Confucianism, which emphasizes educational achievement and strict parenting in South Korea.

Policy Implications

This study's findings provide some policy recommendations for practitioners, especially for law enforcement officers. Since restaurants and adult entertainment places are significant predictors of both residential burglary and general outdoor assault, the police may pay special attention to these places to prevent those crimes. This recommendation is supported from prior literature and the current study. When the police patrol a neighborhood, they need to focus on residential areas and other areas near restaurants and adult entertainment places in an effort to prevent not only general outdoor assault but also residential burglary. The police also need to focus on neighborhoods where there are few preschool children in order to prevent residential burglary. A large number of preschool children in a neighborhood seems to act as a guardian to prevent residential burglary. As the number of high-rise apartments is a significant factor in zero residential burglary areas, it is recommended that police increase patrols in a neighborhood where there are many types of residences other than a high-rise apartment. A potential burglar seems to be less likely to be deterred to commit residential burglary in such neighborhoods. Additionally, the areas with highly dense townhouses and narrow alleyways were common in hotspot areas of residential burglary.

In an effort to prevent general outdoor assault, the police need to pay close attention to places where restaurants and adult entertainment places are concentrated as general outdoor assaults are very closely related to alcohol consumption. Especially for alcohol outlets, there can be other interventions, such as adjusting their closing time in a block, so that patrons do not walk out simultaneously, and controlling crowding and lack of comfort by promoting patrons more comfortable environment. They also need to focus on surrounding areas of subway stations as most restaurants and adult entertainment places are located near subway stations. It seems that population density acts as a capable guardian against general outdoor assault. Therefore, the police need to pay special attention to less populated areas but close to restaurants and adult entertainment places. Although the police attention in these areas is more needed, a systematic analysis of the problem in hotspot areas would lead to the best strategies for general outdoor assaults.

APPENDIX SECTION

APPENDIX A. COLLECTION OF INFORMATION ON HIGH-RISK OFFENDER ACT WRITTEN IN ENGLISH.

Collection of Information on High-Risk Offender Act[4]

[Enforcement Date 1. Feb, 2017] [National Policy Agency General Rules, No. 520, 26. Jan, 2017 Amendment by Other Act]

Article 1 (Purpose) The purpose of this Act is to collect and keep information on prior convicts and members of organized violence in order to use as investigation data and ultimately to prevent their recidivism.

Article 2 (Definitions) A "high-risk offender" in this act is a person who corresponds to any of the following paragraphs:

1. A person who is a member of organized violence or is likely to organize violent organizations, given the criminal history he/she has.
2. A person who is at high risk to reoffend considering his/her propensity, recidivism, and background, among prior convicts who have prior records on murder, arson, robbery, larceny/theft, abduction/kidnapping, manufacture/use of illegal arms, bomb threat, and illegal drug use/sale.

Article 3 (Designation as a high-risk offender) ① A high-risk offender is designated among persons corresponding to either any of the following paragraphs, considering his/her propensity and risk of reoffending.

1. A person who corresponds to the Article 2, Paragraph 1.
2. A person who was released after punishment by imprisonment or higher punishment for murder, arson, abduction/kidnapping, or manufacture/use of illegal arms among the offenses listed in the Article 2, Paragraph 2.
3. A person who was released after punishment three or more times by imprisonment or higher punishment for robbery, larceny/theft, or illegal drug use/sale among the offenses listed in the Article 2, Paragraph 2.
4. A person who was punished three or more times by fine or a higher punishment for bomb threat among offenses listed in the Article 2, Paragraph 2.

[4] Because this Act is not provided in English by the Ministry of Government Legislation, the researcher translated it into English.

② After a high-risk offender is registered, data are recorded in the server and information is collected on crime-related activities.

Article 4 (Transfer and removal of a high-risk offender) ① A chief of police where released prisoners will reside, when the prisoners correspond to the Article 3, is notified of released prisoners by a chief of penitentiary facilities such as a warden of a prison. The chief of police will transfer the prisoners into the high-risk offender group and collect information on them. If it is determined that there is no risk of recidivism, the person is removed from the group through the review committee.

② In a situation where the high-risk offender's whereabouts unknown, the chief of police in the jurisdiction registers them as high-risk offenders and transmits investigation data to the police station where the offender registered as places of a residence. If they are still unknown in the police station where the offender is registered a resident, they are processed as missing.

③ In a situation where the high-risk offender is accounted for, but not in the local jurisdiction, the chief of police shall notify the police station where the offender's location is confirmed. The newly notified chief of police shall immediately confirm his/her location and register him/her as a high-risk offender.

④ In a situation where a high-risk offender is deceased or has not reoffended for any offense listed in the Article 2 for the period of time of the following paragraphs, and therefore it is determined that there is no risk of recidivism, the person is removed from the group through the review committee.

1. A person who is released and registered as a high-risk offender after three or more years of imprisonment: Five years

2. A person who is released and registered as a high-risk offender after less than three years of imprisonment: Three years

Article 5 (The review committee) ① The review committee consists of three or no more than five committee members. A director of criminal litigation division of the police station is appointed as a chair of the committee and he/she can have an assistant administrator.

② The committee holds a quarterly meeting for review except under inevitable circumstances.

③ In the meeting, they make a decision on either extension of term or removal from the list by reviewing the necessity for continued collection of information based on collected information on high-risk offenders.

④ The chair of the committee reports their decisions to the relevant chief of police.

Article 5-2 (The external committee members) The review committee can have no more than two external committee members appointed by the chief of police. The external committee member shall be one of the followings.

1. A professor of jurisprudence or an attorney

2. A professor of criminology/criminological psychology or a psychiatrist

3. A correctional/probation official

Article 6 (Collection of information) ① The chief of police shall appoint a coordinator of the high-risk offender group and a person in charge of each high-risk offender among criminal affair division (or criminal investigation division) personnel. The captain of patrol division (or the captain of the police substation) shall also appoint a person in charge of high-risk offenders.

② The coordinator of the police station shall quarterly report to the chief of police whether a high-risk offender is involved in crime-related activities for the first one year since registration.

③ The person in charge of high-risk offenders in the patrol division (or in the police substation) shall quarterly report to the chief of police whether a high-risk offender is involved in crime-related activities for the first one year since registration.

④ The coordinator or the person in charge of high-risk offenders shall be cautious in the process of collecting information about high-risk offenders by protecting their human rights and using an appropriate approach, and therefore not damaging high-risk offenders' reputation and credibility.

⑤ Collected information shall be entered into the high-risk offender information system.

Article 7 (Addressing a missing person) ① In a situation where a person who is registered as a high-risk offender is missing, the chief of police in the local jurisdiction shall immediately report after attempting to confirm his/her location and record it as a missing person in the system.

② In a situation where a missing person's location is confirmed, the chief of police shall immediately notify the local police station and notify the local police station (where the missing person is registered as a resident.

Article 8 (Entering and removal of a high-risk offender from the system) ① The coordinator in a police station shall print the record system form in the attached page and keep it on file after entering the information in the system.

② The chief of police shall send the original record system form to the local police station when it is confirmed that a high-risk offender has moved out to another jurisdiction.

③ With regard to a high-risk offender whose residential location is uncertain, the chief of police where the offender is registered as a resident shall take necessary actions.

④ A police officer shall check whether he/she is a registered high-risk offender and register him/her as a high-risk offender in the local police station when informed that a high-risk offender has moved into the jurisdiction.

Article 9 (Discarding the record system form) In accordance with the Article 4, Paragraph 4, the record system form shall be discarded when a high-risk offender is removed from the list of high-risk offender group.

Article 10 (Guidance and supervision) The commissioner of the National Police Agency and commissioners of district police agencies shall guide and supervise the system.

Article 11 (effective date) This act shall be effective until February 1st, 2020 when it would be required to review legislation or change in the present condition in accordance with “Code of enactment and management of directives and procedure.” (Presidential Directive No. 334).

Supplementary provisions <No. 520, 26. Jan, 2017>

This act shall be enforced from February 1st, 2017.

APPENDIX B. COLLECTION OF INFORMATION ON HIGH-RISK OFFENDER ACT WRITTEN IN KOREAN.

Source: http://www.law.go.kr/admRulLsInfoP.do?admRulSeq=2000000021070

우범자 첩보수집 등에 관한 규칙

[시행 2017.2.1] [경찰청예규 제 520 호, 2017.1.26, 일부개정]

제 1 조(목적) 이 규칙은 전과자 또는 조직폭력배들로서 그 성격 또는 환경으로 보아 죄를 범할 우려가 있는 사람에 대한 자료를 보관하고 범죄관련성 여부에 관한 첩보를 수집함으로써 재범의 위험을 방지하며, 수집된 첩보를 통해 수사자료로 활용함을 목적으로 한다.

제 2 조(정의) 이 규칙에서 '우범자'라 함은 다음 각 호의 어느 하나에 해당하는 사람을 말한다.

1. 범죄단체의 조직원 또는 불시에 조직화가 우려되는 조직성폭력배 중 범죄사실 등으로 보아 죄를 범할 우려가 있는 사람

2. 살인, 방화, 강도, 절도, 약취·유인, 총기 제조·이용 범죄, 폭파협박 범죄, 마약류사범의 범죄경력이 있는 자 중 그 성벽, 상습성, 환경 등으로 보아 죄를 범할 우려가 있는 고위험자

제 3 조(우범자 선정) ① 우범자는 다음 각 호의 어느 하나에 해당하는 사람 중 성벽, 재범의 위험성 등을 고려하여 선정한다.

1. 제 2 조제 1 호에 해당하는 사람

2. 제 2 조제 2 호중 살인, 방화, 약취유인, 총기 제조·이용 범죄로 금고형 이상의 실형을 받고 출소한 사람

3. 제 2 조제 2 호 중 강도·절도·마약류 관련 범죄로 3 회 이상 금고형 이상의 실형을 받고 출소한 사람

4. 제 2 조제 2 호 중 폭파협박 범죄로 3 회 이상 벌금형 이상의 형을 선고 받은 사람

② 우범자는 편입 후, 자료를 전산에 입력하고 범죄관련성 여부에 대해 첩보를 입수한다.

제 4 조(우범자의 편입 및 삭제) ① 출소예정자의 출소 후 실제 거주 예상지(이하 '귀주지'라 한다) 경찰서장은 교도소장 등 수형기관의 장으로부터 출소통보를 받은 출소예정자가 제 3 조에 해당하는 경우 우선 우범자로 편입하여 첩보 수집하고, 해당분기 내 심사위원회를 통해 죄를 범할 우려가 없다고 인정되는 경우 삭제하여야 한다.

② 우범자 편입 대상자가 소재불명일 경우 귀주지 경찰서장은 먼저 우범자로 편입한 후 주민등록지 경찰서로 이첩하고, 주민등록지 경찰서에서 소재확인 후 불명 시 행방불명 처리하여야 한다.

③ 우범자 편입 대상자가 관내 거주하지 않고 소재가 확인되었을 경우 관할 경찰서로 통보하고, 통보를 받은 경찰서장은 지체 없이 소재를 확인하여 우범자로 편입하여야 한다.

④ 우범자가 사망하였거나 우범자 편입 후 다음 각 호의 기간이 경과할 때까지 제 2 조의 죄를 범하지 않은 자 중 재범의 위험성이 없어 더 이상 관리가 필요하지 않다고 인정되는 자는 심사위원회의 의결을 거쳐 삭제한다.

1. 3 년을 초과하는 실형 후 출소하여 우범자에 편입된 사람 : 5 년

2. 3 년 이하의 실형 후 출소하여 우범자에 편입된 사람 : 3 년

제 5 조(심사위원회) ① 심사위원회의는 3 명 이상 5 명 이내의 위원으로 구성하고, 경찰서 형사(수사)과장을 위원장으로 하며, 간사 1 인을 둔다.

② 심사위원회는 특별한 사정이 없는 한 매분기별로 개최한다.

③ 심사위원회는 우범자에 대한 자료와 수집된 첩보 등을 기초로 재범위험성 등을 심사하여 우범자의 편입, 첩보수집 기간의 연장, 삭제에 대한 결정을 한다.

④ 심사위원장은 결정내용을 신속히 경찰서장에게 보고하여야 한다.

제 5 조의 2(외부 심사위원) 심사위원회에 경찰서장이 위촉하는 2 명 이내의 외부위원을 둘 수 있다. 외부위원은 다음 각 호에 해당하는 자로 한다.

1. 법학 교수, 변호사

2. 범죄학·범죄심리학 교수, 정신과 전문의

3. 교정기관·보호관찰소 공무원

제 6 조(첩보수집) ① 경찰서장은 형사(수사)과 직원 중 우범자 업무 담당자와 우범자별 담당자를 지정하고, 지구대장(파출소장)은 우범자별 담당자를 지정하여야 한다.

② 형사(수사)과 담당자는 우범자에 대해서 편입 후 1 년 동안 매 분기별 1 회 이상 범죄관련 여부에 대한 첩보를 수집하여 경찰서장에게 보고하여야 한다.

③ 지구대(파출소) 담당자는 우범자에 대해서 매 분기별 1 회 이상 범죄관련 여부에 대한 첩보를 수집하여 경찰서장에게 보고하여야 한다.

④ 우범자 담당자는 첩보를 수집하는 과정에서 우범자의 인권을 최대한 배려하여 적절한 방법을 사용하고 우범자의 명예나 신용을 부당하게 훼손하는 일이 없도록 각별히 주의하여야 한다.

⑤ 수집된 첩보는 우범자 첩보관리 시스템에 입력한다.

제 7 조(소재불명자의 처리) ① 우범자로 편입된 자가 소재가 불명일 경우 해당 경찰서장은 지체 없이 주소지 등에 대한 소재확인을 거친후 보고서를 작성하고, 전산에 행불자(行不者)로 입력하여야 한다.

② 경찰서장은 관내에서 소재불명 우범자를 발견하였을 경우에 즉시 해당 관서에 통보하고, 거주지를 확인하여 우범자로 편입하거나 거주지 관할 경찰서로 통보하여야 한다.

제 8 조(우범자 전산 입력 및 전출) ① 우범자로 편입하는 자에 대해서는 경찰서 우범자 담당자가 전산입력 후 별지 제 2 호 우범자 전산입력카드 서식을 출력, 보관하여야 한다.

② 경찰서장은 우범자가 타 관할로 전출한 것을 확인하였을 때는 우범자 전산입력카드 원본을 송부하여야 한다.

③ 주거지가 불확실한 우범자에 대하여는 주민등록 등재지 관할 경찰서장이 필요한 조치를 하여야 한다.

④ 경찰관은 직무수행 중 관내에 우범자로 인정되는 자가 전입한 사실을 인지하였을 때에는 우범자 여부를 조회하여 우범자일 경우 우범자로 편입하여야 한다.

제 9 조(우범자 전산입력카드의 폐기) 제 4 조제 4 항에 의하여 우범자가 삭제된 때에는 전산입력카드를 폐기한다.

제 10 조(지도·감독) 경찰청장과 지방경찰청장은 우범자 관리의 적절성 여부를 확인하는 등 지도·감독하여야 한다.

제 11 조(유효기간) 이 규칙은「훈령·예규 등의 발령 및 관리에 관한 규정」(대통령훈령 제 334 호)에 따라 이 규칙을 발령한 후의 법령이나 현실 여건의 변화 등을 검토하여야 하는 2020 년 2 월 1 일까지 효력을 가진다.

부칙 <제 520 호,2017.1.26>

이 규칙은 2017 년 2 월 1 일부터 시행한다.

APPENDIX C. TESTS TO EXAMINE THE POSSIBILITY OF QUASI-COMPLETE SEPARATION

Result of Two-sample Wilcoxon rank-sum (Mann-Whitney) test

High-risk offenders	N	Rank sum	Expected
No	652	250415.5	259170
Yes	142	65199.5	56445
Combined	794	315615	315615

z = -4.449***

Results of logistic regression models for high-risk offender (Note: * p <.05; ** p < .01; and *** p < .001)

	Coef.	S.E.	z
Residential burglary	.292**	.095	3.070
Teenager	.002	.002	.841
cons	-1.740***	.137	-12.700
Chi-square of model fit	9.86**		

	Coef.	S.E.	z
Residential burglary	.292**	.095	3.070
High-level education	<.001	.002	.941
cons	-1.774***	.156	-11.345
Chi-square of model fit	10.05**		

	Coef.	S.E.	z
Residential burglary	.250**	.096	2.592
Restaurants and entertainment	.013***	.003	4.009
Cons	-1.796***	.114	-15.789
Chi-square of model fit	26.92***		

	Coef.	S.E.	z
Residential burglary	.300**	.096	3.142
Subway	>-.001	<.001	-1.079
Cons	-1.486***	.199	-7.453
Chi-square of model fit	10.39**		

	Coef.	S.E.	z
Residential burglary	.299**	.095	3.143
School	<.001	<.001	1.145

cons	-1.874***	.213	-8.822
Chi-square of model fit	10.48**		

	Coef.	S.E.	z
Residential burglary	.294**	.095	3.091
Homeowner	>-.001	.002	-.293
cons	-1.633***	.163	-10.021
Chi-square of model fit	9.30**		

	Coef.	S.E.	z
Residential burglary	.275**	.095	2.897
Elderly	.006*	.003	2.281
cons	-2.024***	.195	-10.409
Chi-square of model fit	14.40***		

	Coef.	S.E.	z
Residential burglary	.287**	.096	3.001
Preschool children	-.007	.007	-.993
Cons	-1.548***	.160	-9.698
Chi-square of model fit	10.23**		

	Coef.	S.E.	z
Residential burglary	.235*	.097	2.423
High-rise apartment	-.007***	.002	-4.249
Cons	-1.382***	.118	-11.692
Chi-square of model fit	33.29***		

	Coef.	S.E.	z
Residential burglary	.295**	.095	3.092
CCTV cameras	-.006	.038	-.167
Cons	-1.661***	.121	-13.721
Chi-square of model fit	9.23**		

	Coef.	S.E.	z
Residential burglary	.266**	.096	2.781
Police	>-.001*	<.001	-2.357
Cons	-1.232***	.208	-5.912
Chi-square of model fit	14.97***		

	Coef.	S.E.	z
Residential burglary	.291**	.095	3.061
Population density	>-.001	<.001	-.606

Cons	-1.590***	.168	-9.463
Chi-square of model fit	9.58**		

	Coef.	S.E.	z
Residential burglary	.270**	.096	2.825
Household	.002**	<.001	2.631
Cons	-2.047***	.185	-11.098
Chi-square of model fit	16.01***		

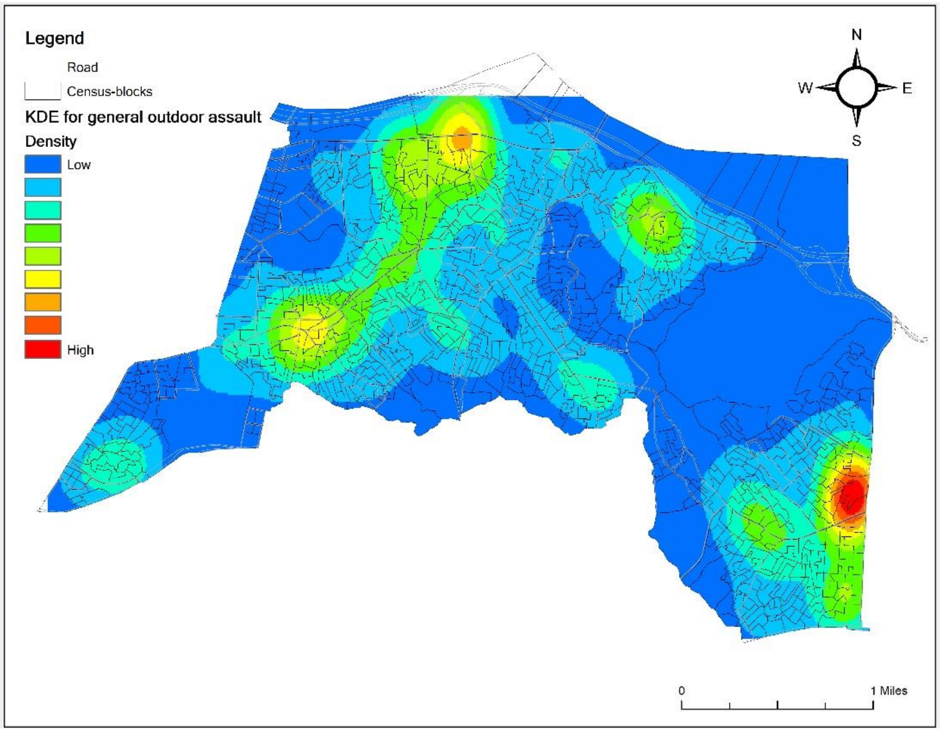
Result of a chi-square test

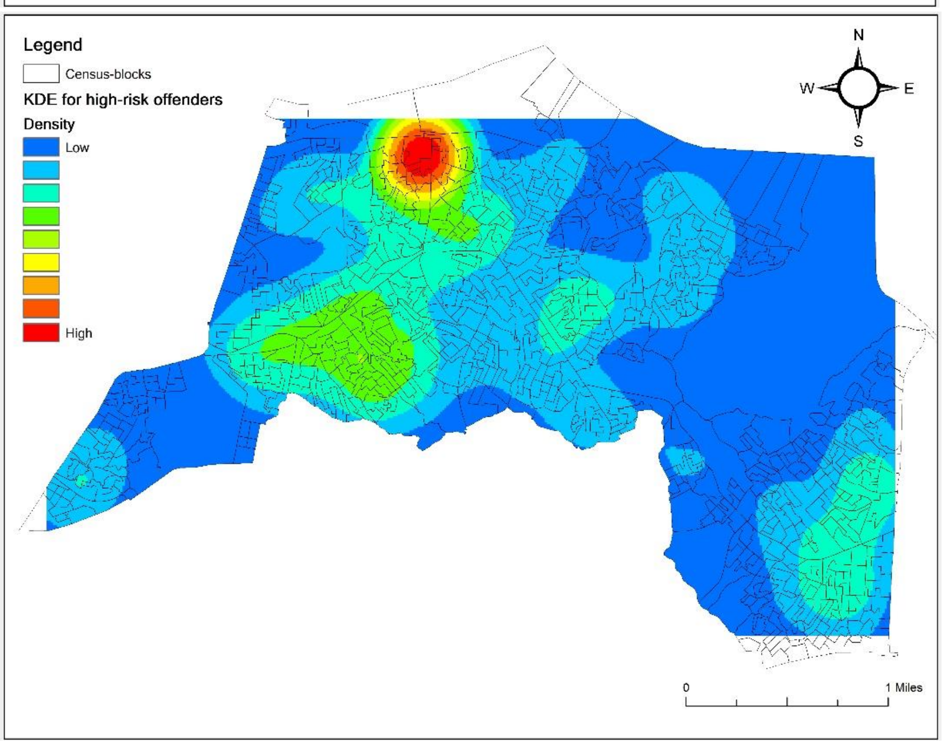
High-risk offender	Residential burglary		
	No	Yes	Total
No	486	166	652
Yes	79	63	142
Total	565	229	794

Pearson chi2(1) = 20.3084 $p < 0.001$

APPENDIX D. KERNEL DENSITY ESTIMATIONS FOR HIGH-RISK OFFENDERS AND GENERAL OUTDOOR ASSAULTS AND A MANN-WHITNEY TEST

Results of kernel density estimations for comparison





Results of a Mann-Whitney test between high-risk offender and restaurants and adult entertainment places

High-risk offenders	N	Rank sum	Expected
No	652	248203.5	259170
Yes	142	67411.5	56445
Combined	794	315615	315615

z = -4.879***

Summary for general outdoor assault by categories of the counts of high-risk offenders

Number of High-risk offenders	**N**	**Mean**	**S.D.**
No high-risk offender[1]	652	1.99	3.48
1 high-risk offender[2]	122	4.30	8.71
2+ high-risk offenders[3]	20	9.35	15.43
Total	794	2.53	5.40

Note: [1] Group 1; [2] Group 2; and [3] Group 3 in Tukey HSD pairwise comparison

Results of one-way ANOVA between general outdoor assaults and high-risk offenders

Groups	**N**	**Rank Sum**
No high-risk offender	652	242186.50
1 high-risk offender	122	61566.00
2+ high-risk offenders	20	11862.50

Chi-square = 49.58***

Results of Dunn-Bonferroni post hoc test for pairwise comparison

Group comparison	**Difference**
1 vs 2	-6.129***
1 vs 3	-4.433***
2 vs 3	-1.665*

Note: *p < .05 and *** p < .001

Results of zero-inflated negative binomial regression including only the motivated offender variables

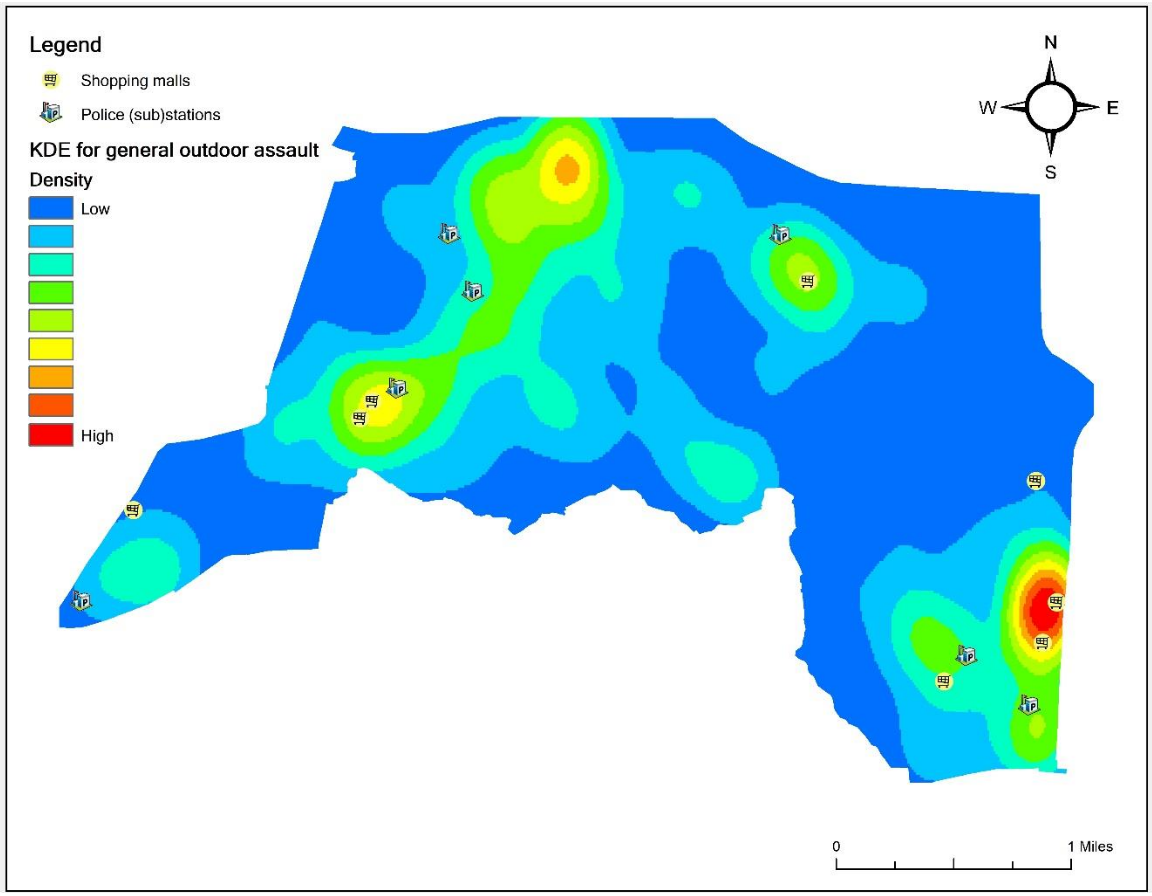
Variables	**Coef.**	**S.E.**	**z**
Count model			
High-risk offender	.834***	.134	6.221
Teenager	> -.001	.001	-.773
School	< .001	< .001	.587
Cons	.738***	.141	5.252

Logit model			
High-risk offender	-35.039	1.36e+07	> -.001
Teenager	-1.893	113.436	-.021
School	< .001	.002	.325
Cons	-.426	.645	-.663
Chi-square	51.15***		

Note: *** $p < .001$

APPENDIX E. KERNEL DENSITY ESTIMATIONS FOR GENERAL OUTDOOR ASSAULT AND LOCATIONS OF SHOPPING MALLS AND POLICE STATIONS

Locations of shopping malls and police stations on hotspots of general outdoor assault



Results of zero-inflated negative binomial for general outdoor assault excluding the police station variable

Variables	**Coef.**	**S.E.**	**z**
Count model			
High-risk offender	.128	.096	1.342
Teenager	< .001	.001	.525
School	< .001	< .001	1.051
Restaurants and entertainment	.018***	.002	11.497
Subway	> -.001**	< .001	-2.603
Shopping mall	< .001	< .001	1.770
CCTV	.013	.018	.713
Population density	-.002	.002	-1.079

Population	< .001	< .001	.581
Cons	.705***	.178	3.973
Logit model			
High-risk offender	-4.178	2.336	-1.793
Teenager	.002	.011	.205
School	> -.001	< .001	-1.002
Restaurants and entertainment	-.603**	.230	-2.621
Subway	> -.001	< .001	-.153
Shopping mall	< .001**	< .001	2.594
CCTV	.024	.060	.405
Population density	.033***	.008	4.239
Population	-.004**	.001	-3.352
Cons	-.150	.579	-.260
Chi-square	264.55***		

Note: ** p < .01; and *** p < .001

REFERENCES

Alaniz, M. L., Cartmill, R. S., & Parker, R. N. (1998). Immigrants and violence: The importance of neighborhood context. *Hispanic Journal of Behavioral Sciences*, *20*(2), 155-174.

Allison, P. D. (2008). Convergence failures in logistic regression. In *SAS Global Forum, 360*, 1-11.

Andresen, M. A. (2006). A spatial analysis of crime in Vancouver, British Columbia: A synthesis of social disorganization and routine activity theory. *The Canadian Geographer/Le Géographe Canadien*, *50*(4), 487-502.

Andresen, M. A. (2011). The ambient population and crime analysis. *The Professional Geographer, 63*(2), 193-212.

Anselin, L. (1995). Local indicators of spatial association—LISA. *Geographical Analysis*, *27*(2), 93-115.

Asante, L. S., Newell, M., Yun, M., Yun-Welch, S., & Chun, S. (2015). Comparative study of the impact of intoxication on injuries in China and Korea. *Osong public health and research perspectives*, *6*(1), 27-33.

Bae, J. K., & Lee, M. N. (1988). *Substance of Korean education: How Korean people think education*. Seoul, South Korea: Kyoyouk KwaHak.

Becker, G. S. (1968). Crime and punishment: An economic approach. *Journal of Political Economy, 76*(2), 169-217.

Bennett, R. R. (1991). Routine activities: A cross-national assessment of a criminological perspective. *Social Forces*, *70*(1), 147-163.

Bernard-Butcher, D. (1991). *Crime in the third dimension: A study of burglary patterns in a high density residential area* (Master's thesis). Simon Fraser University: Burnaby, BC.

Bernasco, W., & Luykx, F. (2003). Effects of attractiveness, opportunity and accessibility to burglars on residential burglary rates of urban neighborhoods. *Criminology*, *41*(3), 981-1002.

Block, R. L., & Block, C. R. (1995). Space, place and crime: Hot spot areas and hot places of liquor-related crime. *Crime and Place, 4*(2), 145-184.

Braga, A. A., & Bond, B. J. (2008). Policing crime and disorder hot spots: A randomized controlled trial. *Criminology*, *46*(3), 577-607.

Brantingham, P. J., & Brantingham, P. L. (Eds.). (1981). *Environmental criminology*. Beverly Hills, CA: Sage Publications.

Brantingham, P. L., & Brantingham, P. J. (1982). Mobility, notoriety, and crime: A study in the crime patterns of urban nodal points. *Journal of Environmental Systems, 11*(1), 89-99.

Brantingham, P. J., Brantingham, P. J., & Wong, P. S. (1991). How public transit feeds private crime: notes on the Vancouver 'Skytrain' experience. *Security Journal*, *2*(2), 91-95.

Briscoe, S., & Donnelly, N. (2001). Temporal and regional aspects of alcohol-related violence and disorder. *BOCSAR NSW Alcohol Studies Bulletins*, 16.

Britt, H. R., Carlin, B. P., Toomey, T. L., & Wagenaar, A. C. (2005). Neighborhood level spatial analysis of the relationship between alcohol outlet density and criminal violence. *Environmental and Ecological Statistics*, *12*(4), 411-426.

Buerger, M. E., Cohn, E. G., & Petrosino, A. J. (1995). Defining the "hot spots of crime": Operationalizing theoretical concepts for field research. In Eck, J. and Weisburd, D. (Eds) *Crime and Place*, Monsey, NY: Willow Tree Press.

Bursik, R. J., Grasmick, H. G., & Chamlin, M. B. (1990). The effect of longitudinal arrest patterns on the development of robbery trends at the neighborhood level. *Criminology, 28*(3), 431-450.

Cameron, S. (1988). The economics of crime deterrence: A survey of theory and evidence. *Kyklos*, *41*(2), 301-323.

Cantor, D., & Land, K. C. (1985). Unemployment and crime rates in the post-World War II United States: A theoretical and empirical analysis. *American Sociological Review*, *50*(3) 317-332.

Clarke, R. V. G., Ekblom, P., Hough, M., & Mayhew, P. (1985). Elderly victims of crime and exposure to risk. *Howard Journal of Criminal Justice, 24*(1), 81-89.

Cohen, L. E. (1981). Modeling crime trends: A criminal opportunity perspective. *Journal of Research in Crime and Delinquency, 18*(1), 138-164.

Cohen, L. E., & Cantor, D. (1980). The determinants of larceny: An empirical and theoretical study. *Journal of Research in Crime Delinquency*, *17*(2), 140-159.

Cohen, L. E., & Cantor, D. (1981). Residual burglary in the United States: Life-style and demographic factors associated with the probability of victimization. *Journal of Research in Crime Delinquency*, *18*(1), 113-127.

Cohen, L. E., & Felson, M. (1979). Social change and crime rate trends: A routine activity approach. *American Sociological Review, 44*(4), 588-608.

Cohen, L. E., Kluegel, J. R., & Land, K. C. (1981). Social inequality and predatory criminal victimization: An exposition and test of a formal theory. *American Sociological Review, 46*(5), 505-524.

Cohen, D., Spear, S., Scribner, R., Kissinger, P., Mason, K., & Wildgen, J. (2000). "Broken windows" and the risk of gonorrhea. *American Journal of Public Health, 90*(2), 230-236.

Corman, H., & Mocan, H. N. (2000). A time-series analysis of crime, deterrence, and drug abuse in New York City. *American Economic Review, 90*(3), 584-604.

Cromwell, P. and Olson, J.N. (2009) The reasoning burglar: Motives and decision-making strategies. In: P. Cromwell (Eds.) *In their own Words: Criminals on Crime*, 5th Ed. Oxford: Oxford University Press.

Davison, E. L., & Smith, W. R. (2001). Informing community policing initiatives with GIS assisted multi-source data and micro-level analysis. *Journal of Crime and Justice, 24*(1), 85-108.

De Knegt, H. J., van Langevelde, F. V., Coughenour, M. B., Skidmore, A. K., De Boer, W. F., Heitkönig, Knox, N. M., Slotow, R., Van Der Waal C., & Prins, H. H. T. (2010). Spatial autocorrelation and the scaling of species–environment relationships. *Ecology, 91*(8), 2455-2465.

Di Tella, R., & Schargrodsky, E. (2004). Do police reduce crime? Estimates using the allocation of police forces after a terrorist attack. *American Economic Review*, *94*(1), 115-133.

Dobson, J. E. (2004). The GIS revolution in science and society. In S. D. Brunn, S. L., Cutter, & J. W. Harrington (Eds.), *Geography and technology*, (pp. 573-587). Dordrecht, The Netherlands: Kluwer Academic.

Eck, J. E. (1995). Examining routine activity theory: A review of two books. *Justice Quarterly, 12*(4): 783-797.

Eck, J. E., Chainey, S. P., Cameron, J. G., Leitner, M., & Wilson, R. E. (2005) *Mapping crime: Understanding hot spots*. Washington, D.C: Government Printing Office.

Eck, J. E., & Maguire, E. R. (2000). Have changes in policing reduced violent crime? An assessment of the evidence. In A. Blumstein & J. Wallman. (Eds.), *The crime drop in America*, (pp. 207-228). Cambridge, UK: Cambridge University Press.

Eck, J. E., & Wartell, J. (1997). *Reducing crime and drug dealing by improving place management: A randomized experiment*. Washington, DC: Government Printing Office.

Evans, D. J., Fyfe, N. R., & Herbert, D. T. (1992). *Crime, policing and place: Essays in environmental criminology*. New York, NY: Routledge.

Farrell, G., & Pease, K. (1993). *Once bitten, twice bitten: Repeat victimisation and its implications for crime prevention*. (Crime Prevention Unit Series Paper No. 46). London, UK: Police Research Group, Home Office Police Department.

Feins, J. D., Peterson, J., & Rovetch, E. (1983). *Partnerships for neighborhood crime prevention*. Washington DC: Government Printing Office.

Felson, M. (1987). Routine activities and crime prevention in the developing metropolis. *Criminology*, *25*(4), 911-932.

Felson, M. (1995). Those who discourage crime. *Crime and place*, *4*, 53-66.

Felson, M., & Poulsen, E. (2003). Simple indicators of crime by time of day. *International Journal of Forecasting*, *19*(4), 595-601.

Felson, R. B., Burchfield, K. B., & Teasdale, B. (2007). The impact of alcohol on different types of violent incidents. *Criminal Justice and Behavior*, *34*(8), 1057-1068.

Felson, R., Savolainen, J., Aaltonen, M., & Moustgaard, H. (2008). Is the association between alcohol use and delinquency causal or spurious? *Criminology*, *46*(3), 785-808.

Fischer, C. S. (1975). Toward a subcultural theory of urbanism. *American Journal of Sociology*, *80*(6), 1319-1341.

Forrester, D., Chatterton, M., Pease, K., & Brown, R. (1988). *The Kirkholt burglary prevention project, Rochdale*. London, UK: Home Office.

Forrester, D., Frenz, S., O'Connell, M., & Pease, K. (1990). *The Kirkholt burglary prevention project: Phase II*. London, UK: Home Office.

Garofalo, J. (1987). Reassessing the lifestyle model of criminal victimization. In M. Gottfredson & T. Hirschi, (Eds.), *Positive criminology: Essays in honor of Michael J. Hindelang* (pp. 23-43). Beverly Hills, CA: Sage.

Giancola, P. R., Saucier, D. A., & Gussler-Burkhardt, N. L. (2003). The effects of affective, behavioral, and cognitive components of trait anger on the alcohol-aggression relation. *Alcoholism: Clinical and Experimental Research, 27*(12), 1944-1954.

Gorman, D. M., Speer, P. W., Gruenewald, P. J., & Labouvie, E. W. (2001). Spatial dynamics of alcohol availability, neighborhood structure and violent crime. *Journal of Studies on Alcohol*, *62*(5), 628-636.

Gottfredson, M. R. (1984). *Victims of crime: The dimensions of risk*, Home Office Research Study No. 81, London: Her Majesty's Stationery Office.

Gottfredson, M. R., & Hirschi, T. (1990). *A general theory of crime*. Redwood City, CA: Stanford University Press.

Graham, K., Tremblay, P. F., Wells, S., Pernanen, K., Purcell, J., & Jelley, J. (2006). Harm, intent, and the nature of aggressive behavior: Measuring naturally occurring aggression in barroom settings. *Assessment*, *13*(3), 280-296.

Groff, E. R. (2007). Simulation for theory testing and experimentation: An example using routine activity theory and street robbery. *Journal of Quantitative Criminology*, *23*(2), 75-103.

Haines, B., & Graham, K. (2005). Violence prevention in licensed premises. In T. Stockwell, P. Gruenewald, J. Toumbourou, & W. Loxley (Eds.), *Preventing harmful substance use: The evidence base for policy and practice* (pp. 163-176). New York, NY: Wiley.

Hair, J. F. Jr., Anderson, R. E., Tatham, R. L. & Black, W. C. (1995). *Multivariate data analysis (3rd Ed)*. New York: Macmillan.

Hanson, R. K. (2002). Recidivism and age. *Journal of Interpersonal Violence*, *17*(10), 1046-1062.

Harries, K. (1999). *Mapping crime: Principles and practice*. United States National Institute of Justice. Washington DC: Government Printing Office.

Harries, K. (2006). Property crimes and violence in United States: An analysis of the influence of population density. *International Journal of Criminal Justice Sciences*, *1*(2), 24-34.

Herbert, D. T. (1989). Crime and place: An introduction. In Herbert, D. T. (Eds.), *The Geography of Crime* (pp. 1-15). New York, NY: Routledge.

Herbert, D. T., & Hyde, S. W. (1985). Environmental criminology: Testing some area hypotheses. *Transactions of the Institute of British Geographers, 10(2)*, 259-274.

Herrmann, C. R. (2015). The dynamics of robbery and violence hot spots. *Crime Science*, *4*(1), 33.

Hudson, S. M., & Ward, T. (1997). Intimacy, loneliness, and attachment style in sexual offenders. *Journal of Interpersonal Violence*, *12*(3), 323-339.

Hwang, S. (2001). *The spatial pattern analysis of crime using GIS: The case of residential burglary* (Doctoral dissertation). Kyung Hee University, Seoul, South Korea.

Jacobs, J. (1961). *The death and life of great American cities*. New York: Random House

Jeong, E. (2012). A study on Korean crime rates according to ages. *Korean Criminological Review, 23*(3), 267-291.

Jeong, K., Moon, T., Jeong, J., & Heo, S. (2009). Analysis of spatio-temporal pattern of urban crime and its influencing factors. *Journal of the Korean Association of Geographic Information Studies, 12*(1), 12-25.

Johnson, P. J., Andresen, M., & Malleson, N. (2018). *Mobile cellular data as a population at risk*. Paper presented at the American Society of Criminology, Atlanta, GA.

Kautt, P. M., & Roncek, D. W. (2007). Schools as criminal "hot spots" primary, secondary, and beyond. *Criminal Justice Review, 32*(4), 339-357.

Kim, Y., Jang, D., & Moon, J. (2007). Study on the distribution of crime in urban space: Gwangju metropolitan city from the perspective of the environmental criminology. *Journal of the Korea Society of Computer and Information, 12*(5), 235-241.

Knight, R. A., & Prentky, R. A. (1990). Classifying sexual offenders: The development and corroboration of taxonomic models. In W. L. Marshall, D. R. Laws, & H. E. Barbaree (Eds.), *Handbook of sexual assault* (pp. 23-52). New York, NY: Plenum Press.

Ko, S., & Sohn, A. (2018). Behaviors and culture of drinking among Korean people. *Iranian journal of public health*, *47*(1), 47.

Korean Criminal Act (Act No. 11731, 2013) (R. O. Korea).

Lee, H. (1994). *A study on the differences in crime rates from place to place* (Doctoral dissertation). Ewha Womans University, Seoul, Republic of Korea.

Lee, M., & Larson, R. (2000). The Korean "examination hell": Long hours of studying, distress, and depression. *Journal of Youth and Adolescence*, *29*(2), 249-271.

Leitner, M. (Ed.). (2013). *Crime modeling and mapping using geospatial technologies*. New York, NY: Springer.

Levitt, S. D. (1995). Using electoral cycles in police hiring to estimate the effect of police on crime. *The American Economic Review*, *87*(3), 270-290.

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

Livingston, M. (2008). A longitudinal analysis of alcohol outlet density and assault. *Alcoholism: Clinical and Experimental Research*, *32*(6), 1074-1079.

Loehrer, R. K. (1992). *Child molester and rapist differences in anger and hostility as measured by the MMPI-2 and STAXI* (Doctoral dissertation), Texas A & M University, College Station.

Loukaitou-Sideris, A., Liggett, R., & Iseki, H. (2002). The geography of transit crime: Documentation and evaluation of crime incidence on and around the Green Line stations in Los Angeles. *Journal of Planning Education and Research*, *22*(2), 135-151.

Lynch, J. P. (1987). Routine activity and victimization at work. *Journal of Quantitative Criminology, 3*(4), 283-300.

Marvell, T. B., & Moody, C. E. (1996). Specification problems, police levels, and crime rates. *Criminology, 34*(4), 609-646.

McGarrell, E. F., Chermak, S., & Weiss, A. (2002). *Reducing gun violence: Evaluation of the Indianapolis Police Department's directed patrol project series: Special report*. Washington, DC: National Institute of Justice.

Miethe, T. D., Hughes, M., & McDowall, D. (1991). Social change and crime rates: An evaluation of alternative theoretical approaches. *Social Forces*, *70*(1), 165-185.

Miethe, T. D., Stafford, M. C., & Long, J. S. (1987). Social differentiation in criminal victimization: A test of routine activities/lifestyle theories. *American Sociological Review*, *52*(2), 184-194.

Moon, H., Choi, H., Lee, J., & Lee, K. (2017). Attitudes in Korea toward introducing smart policing technologies: differences between the general public and police officers. *Sustainability, 9*(10), 1921.

Nielsen, A. L., & Martinez, Jr., R. (2003). Reassessing the alcohol-violence linkage: Results from a multiethnic city. *Justice Quarterly, 20*(3), 445-469.

Newman, O. (1972). *Defensible Space: Crime prevention through urban design*. New York: McMillan.

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

Osgood, D. W., Wilson, J. K., O'Malley, P. M., Bachman, J. G., & Johnston, L. D. (1996). Routine activities and individual deviant behavior. *American Sociological Review, 61*(2), 635-655.

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

Payne, A. A., Gottfredson, D. C., & Gottfredson, G. D. (2003). Schools as communities: The relationships among communal school organizations, student bonding and school disorder. *Criminology*, 41, 749-777.

Payne, A. (2008). A multilevel model of the relationships among communal school disorder, student bonding, and delinquency. *Journal of Research in Crime and Delinquency*, 45, 429-455.

Pernanen, K. (1991). *Alcohol in human violence*. New York, NY: Guilford Press.

Peterson, B. E., Lee, D., Henninger, A. M., & Cubellis, M. A. (2016). Social bonds, juvenile delinquency, and Korean adolescents: Intra-and inter-individual implications of Hirschi's social bonds theory using panel data. *Crime & Delinquency*, *62*(10), 1337-1363.

Pihl, R. O., & Lemarquand, D. (1998). Serotonin and aggression and the alcohol-aggression relationship. *Alcohol and Alcoholism*, *33*(1), 55-65.

Polvi, N., Looman, T., Humphries, C., & Pease, K. (1991). The time course of repeat burglary victimization. *British Journal of Criminology*, *31*(4), 411-414.

Pridemore, W. A., & Eckhardt, K. (2008). A comparison of victim, offender, and event characteristics of alcohol-and non-alcohol-related homicides. *Journal of Research in Crime and Delinquency*, *45*(3), 227-255.

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

Reiss, Jr, A. J. (1986). Co-offender influences of criminal careers. In A. Blumstein, J. Cohen, J. A. Roth, & C. A. Visher (Eds.), *Criminal careers and career criminals,* vol. 2 (pp. 117-170). Washington DC: National Academy Press.

Rengert, G. F., Piquero, A. R., & Jones, P. R. (1999). Distance decay reexamined. *Criminology, 37*(2), 427-446.

Reynald, D. M. (2011). Factors associated with the guardianship of places: Assessing the relative importance of the spatio-physical and sociodemographic contexts in generating opportunities for capable guardianship. *Journal of Research in Crime and Delinquency*, *48*(1), 110-142.

Riley, D. (1987). Time and crime: The link between teenager lifestyle and delinquency. *Journal of Quantitative Criminology*, *3*(4), 339-354.

Roh, S. (2015). Testing the predictability of crime forecasting models using spatio-temporal analysis and risk terrain modeling. *Korean Criminological Review*, *26*(3), 239-266.

Roman, C. G., Reid, S. E., Bhati, A. S., & Tereshchenko, B. (2008). *Alcohol outlets as attractors of violence and disorder: A closer look at the neighborhood environment*. Washington, DC: Urban Institute.

Roncek, D. W., & LoBosco, A. (1983). The effect of high schools on crime in their neighborhoods. *Social Science Quarterly*, *64*(3), 598-613.

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

Rossmo, D. K. (2000). *Geographic profiling*. Boca Raton, FL: CRC press.

Sampson, R. J., & Wooldredge, J. D. (1987). Linking the micro-and macro-level dimensions of lifestyle-routine activity and opportunity models of predatory victimization. *Journal of Quantitative Criminology*, *3*(4), 371-393.

Sampson, R. J., Raudenbush, S. W., & Earls, F. (1997). Neighborhoods and violent crime: A multilevel study of collective efficacy. *Science*, *277*(5328), 918-924.

Schuerman, L., & Kobrin, S. (1986). Community careers in crime. *Crime and Justice*, *8*(1), 67-100.

Scott, M. (2004). *Burglary of Single-Family Houses in Savannah, Georgia: A Final Report to the US Department of Justice*. Retrieved May 4, 2019 from National Criminal Justice Reference Service.

Scribner, R. A., MacKinnon, D. P., & Dwyer, J. H. (1995). The risk of assaultive violence and alcohol availability in Los Angeles County. *American Journal of Public Health*, *85*(3), 335-340.

Shaw, C. R., & McKay, H. D. (1942). *Juvenile delinquency and urban areas*. Chicago IL: University of Chicago Press.

Sherman, L. W. (1995). Hot spots of crime and criminal careers of places. In J. E. Eck & D. Weisburd (Eds.), *Crime and place* (pp. 35-52). Monsey, NY: Willow Tree Press.

Sherman, L. W., Shaw, J. W., & Rogan, D. P. (1995). The Kansas City Gun Experiment. *Population*, *4*, 8-142.

Sherman, L. W., & Weisburd, D. (1988). *Policing the hotspots of crime: A redesign of the Kansas City preventive patrol experiment*. Unpublished manuscript. Washington, DC: Crime Control Institute.

Simon, L. (1997). Do criminal offenders specialize in crime types? *Applied and Preventive Psychology, 6*(1), 35-53.

Soothill, K., Francis, B., Sanderson, B., & Ackerley, E. (2000). Sex offenders: Specialists, generalists—or both? *British Journal of Criminology*, *40*(1), 56-67.

South Korean Ministry of the Interior and Safety. (2016). 2016 Annual report (Report No. 06-2016-12). Retrieved from http://www.index.go.kr

Speer, P. W., Gorman, D. M., Labouvie, E. W., & Ontkush, M. J. (1998). Violent crime and alcohol availability: relationships in an urban community. *Journal of Public Health Policy*, *19*(3), 303-318.

Stahura, J. M., & Huff, C. R. (1981). Persistence of suburban violent crime rates: An ecological analysis. *Sociological Focus*, *14*(2), 123-137.

Stahura, J. M., & Sloan III, J. J. (1988). Urban stratification of places, routine activities and suburban crime rates. *Social Forces*, *66*(4), 1102-1118.

Stevenson, R. J., Lind, B., & Weatherburn, D. (1999). The relationship between alcohol sales and assault in New South Wales, Australia. *Addiction*, *94*(3), 397-410.

Townsley, M., Homel, R., & Chaseling, J. (2000). Repeat burglary victimisation: Spatial and temporal patterns. *Australian & New Zealand Journal of Criminology*, *33*(1), 37-63.

United States Department of Justice, Federal Bureau of Investigation (September 2016). *Crime in the United States, 2016*. Retrieved October 5, 2017 from https://ucr.fbi.gov/.

Weisburd, D., & Braga, A. A. (Eds.). (2006). *Police innovation: Contrasting perspectives*. Cambridge, England: Cambridge University Press.

Weisburd, D., Groff, E. R., & Yang, S. M. (2014). Understanding and controlling hot spots of crime: The importance of formal and informal social controls. *Prevention Science*, *15*(1), 31-43.

Widom, C. S., & Maxfield, M. G. (1984). *Sex roles and the victimization of women: Evidence from the British Crime Survey*. Paper presented at the Annual Meeting of the American Society of Criminology, Cincinnati.

Wiles, P., & Costello, A. (2000). *The 'road to nowhere': The evidence for travelling criminals* (Vol. 207). London, UK: Home Office.

Zhu, L., Gorman, D. M., & Horel, S. (2004). Alcohol outlet density and violence: a geospatial analysis. *Alcohol and Alcoholism*, *39*(4), 369-375.

Zipf, G. K. (1949). *Human behavior and the principle of least effort*. Menlo Park, CA: Addison-Wesley