BUILT ENVIRONMENT AND CRIME IN A SOUTH KOREA CONTEXT

Hyunjoong Kim[1], Sooa Lee[2] and Jinyong Lee[2]

[1]Department of Geography & Anthropology, Louisiana State University, USA
[2]Singapore Korean International School, Singapore

ABSTRACT

The primary purpose of this paper is to test the applicability of environmental criminology in the case of South Korea. Also, it explores more effective strategies from a spatial planning perspective by taking control of diverse spatial planning factors. The study area is South Korea, and the base year was 2016. The relationship between the built environment and three crimes (theft, violence, sexual assault) was analyzed using the spatial econometric model. As a result, the best spatial regression models for violent crime rate and sexual assault rate are SEM and SAC, respectively. The most prominent finding is that the regression results in the three crimes are slightly different. The broken windows effect was negligible for significant crimes in South Korea. The influence of regional disorders on the incidence of crimes was marginal. In the three crime types, mixed land use affected raising crime rates, which is a line with some previous studies that mixed land use increases the likelihood of crime incidences. Unlike a series of relevant works, brighter nighttime light has not effectively decreased crimes in South Korea. In South Korea, CCTV did not play a role in deterring crimes. Lastly, socio-economic characteristics were closely connected with crime rates in South Korea. Findings of theft rate, violent crime rate, and sexual assault rate confirm the reliability of environmental criminology. Although this study has examined the likelihood of applying environmental criminology, further researches and discussions are followed for concrete plans.

KEYWORDS

Crime, Environmental Criminology, Spatial Regression Models, Spatial Planning, South Korea.

1. INTRODUCTION

Why does crime highly concentrate in small areas? Academic efforts to this question date back to the 19th century when interests in the spatial distribution of crime were triggered in France. The spatial distribution of criminals and crime studied by the French government in 1825 is considered the first study on crime distribution (Bruinsma et al., 2018). Due to the lack of proper statistical models, the study could not provide substantial results, but the variability of crime across regions was identified. Only after the 20th century, researches on the spatial distribution of crime started to evolve in earnest. Through pioneering studies, such as the concentric zone model (Park & Burgess, 1925) and social disorganization theory (Shaw & McKay, 1942), the spatial characteristics that crime manifests in specific places were identified. In the late 1980s, with advances in computer technology, it was enabled to detect the concentration of crime in micro places (i.e., crime hot spots) with accuracy (Pierce, Spaar, & Briggs, 1988). The resulting spatial patterns of crime stirred interests among researchers in the tie between crime and place and eventually leading them to give birth to the environmental criminology.

Environmental criminology is a broad concept that crime is closely associated with the environmental conditions of places (Brantingham & Brantingham, 1981). This theory focuses on offenders' decision-making process, noting that spatial circumstances can provide offenders with

cues or opportunities (Weisburd et al., 1992). This perspective enables proactive criminal prevention through effective control of space because poor performance (inadequate knowledge on attractors, generators, and patterns of crime) of spatial conditions might lead to increasing the possibility of crime occurrence (Kamalipour, Memarian & Faizi, 2014). More importantly, proper design and effective use of the built environment can result in a reduction of fear of crime along with incidence, which will eventually lead to improved quality of life (Crowe, 2000). Various preceding researches have proved the potential and effectiveness of environmental criminology, and the achievement and development of the theory are ongoing (Bruinsma & Weisburd, 2014; Weisburd, Bruinsma, & Bernasco, 2009; Brantingham & Brantingham, 1981). Bruinsma et al. (2018) divides evolution stages of environmental criminology into four periods: (1) its beginning in Europe in the 19th century; (2) the heyday of the Chicago school of neighborhood research in the first half of the 20th century; (3) spatial research in Canada, Europe, and the United States from the 1980s; and (4) a more international focus on the study of crime in smaller spaces in the 21st century. These developmental stages directly inspired this research. The usefulness of environmental criminology should be documented in a broader range of countries to take a step forward, focusing on areas where relevant studies and applications are scarce.

The main contributions of this paper are threefold. First, this study tests the applicability of environmental criminology in the case of South Korea. Second, it explores more effective strategies from a spatial planning perspective by taking control of diverse spatial planning factors. Third, the study identifies common spatial planning practices that can apply to multiple crime types rather than a specific crime.

Further explanation is needed as to why South Korea was chosen as a study area and why it is necessary to consider multiple crime types. In 2005, the Korean National Police Agency (KNPA) announced its plan to enforce environmental criminology, focusing on crime prevention through environmental design (CPTED), which has been vigorously fostered in the field of public policy (Shim, 2017). The scope of CPTED is expanding, particularly in the fields of redevelopment, criminal vulnerability, and school zones. In 2014, CPTED-oriented revision were enforced in the national building code and the redevelopment plan. In sum, South Korea has endeavored to embrace environmental criminology. However, only a few studies have attempted to investigate the effects of environmental criminology in South Korea. What is worse, no comprehensive diagnosis has been made on the utility of the theory in practice on a national scale. Hence, it is very timely to verify the effectiveness of environmental criminology in South Korea, which has been active in location-based crime prevention policies. Given the present situations, South Korea is an excellent study area to test environmental criminology. The empirical results of those researches can inspire the crime policies of South Korea.

In analyzing the applicability of environmental criminology, it is required to consider various crime types to achieve generalization (Weisburd et al., 1992). On the policy front, generalized connections between crime and place suggest that generic environmental interventions may be both widely applicable and scalable (Jeffery, 1977). W first consider the five major crimes: homicide, robbery, theft, violent crime, and sexual assault. Due to their massive negative impact on society, these crimes are of the highest interest in almost all countries. Given the unique feature of crime occurrences in South Korea and insights from preceding studies, We finally selected three significant crimes: theft, violent crime, and sexual assault. The details for this choice are as follows.

Among the five major crimes in South Korea, the proportion of homicide and robbery is marginal. As of 2016, the target year of the study, there were 914 homicides and 1,149 robberies, accounting for 0.17% and 0.21% of the five major crime (536,694), respectively. In 2016, there was no homicide in 32 districts of the total 216 police districts, and 54 districts where the robbery

rate per 100 population was close to zero. When it comes to low crime occurrences of homicide and robbery, it is reasonable to exclude the two types of crimes from the analysis. Besides, a link between homicide and robbery and place has not been established in South Korea so far.

A series of works also provides empirical evidence suggestive of a direct link between space and the three crime types of the study. Cohen & Felson (1979) mentions the importance of guardianship in any type of property crime. Fleming (1999) finds that hunting ground such as malls can provide places for teenagers' illegal activities. Activity nodes, such as schools offer awareness space for thieves (Brantingham & Brantingham, 1993). Space vulnerable to crimes is reported to cause theft crime (Copes & Tewksbury, 2011; O'Connor & Kelly, 2006). Additionally, interventions at places that are most attractive to motivated offenders have a positive impact on reducing violent crimes (Baughman & Caplan, 2010). Disadvantaged areas (Madensen & Eck 2008; Harding, 2009; Wilson, 1996), and place around alcohol outlets, pubs, or clubs (Groff, 2011; Graham & Homel, 2008) are identified as key places with higher likelihood of violent crimes. Lastly, researchers find that place largely affect sex offenders' site selection (Hewitt et al., 2012; Beauregard & Leclerc, 2007; Cohen & Felson, 1979). From the environmental criminology point of view, the mechanism of sexual assaults is the same as that of theft and violent crimes in that the dynamic relationship between offender behavior and the environment is ubiquitous. In this regard, in response to offenders' decision-making processes, removing the situational variables to motivate crimes is a vital strategy from the environmental criminology perspectives. It would be interesting to confirm whether such a strategy is effective in a South Korea context in terms of not only expanding environmental criminology but providing realistic policy implications to South Korea.

The rest of this paper is structured as follows. Section 2 reviews central theories of environmental criminology and demonstrates its development processes and key implications. Section 3 gives the outlines of the study area, including crime rates and opines why South Korea is appropriate as a case study. Section 4 explains about methodology and variable selection. We explain why we should choose spatial regression models to reflect spatial autocorrelation. In addition, we provide information on variable selection and data construction process. In section 5, the most important part of the study, we demonstrate the regression results of the three types of crimes and highlight the main findings and implications. Finally, as a conclusion, section 5 addresses the significance and limitations of the findings. In particular, we shed light on the possibility of the expansion of environmental criminology to the new countries. Also, we illustrate the primary points to be considered in subsequent studies.

2. THEORETICAL BACKGROUND

Environmental criminology, which is recognized as a key strategy for preventing crime, has evolved systematically until recently. Various theories have been established and introduced so far, and the relevant studies have examined the core theories including, but not restricted to, the concentric zone model, social disorganization theory, routine activity theory, crime pattern theory, broken windows theory, environmental criminology, and CPTED. By looking into the development of environmental criminology, we can find reference points on Environmental criminology, while establishing a theoretical framework. In particular, the spatial and environmental factors covered in the related works are directly referenced for the selection of variables of regression analysis.

A pioneering work that figured out the relationship between crime and space is the concentric zone model (Park & Burgess, 1925). Although the main purpose of this creative study was to build a new conceptual framework to explain the complex urban land use with the concentric ring theory, this study illustrated where crime is high and which regional feature can lead to a high

crime rate. Of the five classified land use zones suggested by the study, the second zone (the transition zone) showed a loss in a sense of community, resulting in large social disorganization, which in turn acted as a mechanism to increase deviant behavior and criminality. The argument that poor neighborhood conditions could impact much more on crime than other factors such as race and ethnicity has been supported by a bevy of studies until recently (Holzman-Escareno, 2015).

Social disorganization theory (Shaw & McKay, 1942), which is mentioned as one of the important theories in criminology, is basically spatial criminology because it succeeds Park & Burgess (1925). They analyzed the causes of higher rates of juvenile delinquency in the transition zone by Park & Burgess (1925) from social disorganization perspectives. The authors thought that social organization or cohesion at the neighborhood level is vital for combating crime, and therefore neighborhood in the lack of voluntary control through social cohesion and integration is more likely to be crime victims. In social disorganization theory, various characteristics of neighborhoods, such as demographic, economic, and spatial contexts, are considered essential factors for understanding crime. The macro approach to social disorganization theory is sometimes criticized (Eck & Weisburd, 2015), but its usefulness and generalizability is proved by many studies (Barnet & Mencken, 2002).

Routine activity theory (Cohen & Felson, 1979), one of the main sources of environmental criminology, pays heavily attention to the circumstances that can stimulate crime at any given space and time. It is presumed that crime occurs when the presence of a motivated offender, an accessible target exist, and the absence of capable guardians that could intervene is all met (Paulsen & Robinson, 2004). They argue that it is possible to curb the chance of crime in advance through appropriate guardians' activities. In addition, under the understanding of the crime situation that all three conditions are known, the opportunities, trends, and periods of crime occurrence are predictable in advance, which could allow people to carry out crime prevention. However, the lack of explanation of the connection between criminals and victims, and the lack of the individual's moral beliefs or the strength of social bonds, factors that can suppress crime, are perceived as limitations of routine activity theory (Haider & Lamtrakul, 2018).

Felson & Clarke's (1998) crime pattern theory focuses on the mechanism of crime, that is, crime occurs when a victim and a target intersect in a particular space. The theory describes crime move in space and time by taking three spatial features into accounts: nodes (place), paths (actual paths), and edges (boundaries of districts). It is noteworthy that this theory explained the relation between space and crime based on the patterns of activity in human life. Also, the theory can be effectively used to clearly explain the spatial concentration of certain crime patterns. While crime pattern theory has a limitation in that it focuses only on crime at the individual level (Eck & Weisburd, 2015), the various theoretical advantages mentioned above show why the theory still holds an important position in environmental criminology.

Broken windows theory (Wilson & Kelling, 1982), the most familiar theory among various criminal theories, also has an important position in environmental crime. As Wilson & Kelling (1982) illustrated, disorder and crime are usually inextricably linked, in a kind of developmental sequence. In theory, the broken window is a symbolic expression of disordered space where it is likely to attract crime over time. This concept also includes the effect of spatial spillover effect in terms of crime, in which disorder space causes crime, which gradually extends to neighboring areas. Therefore, efforts to suppress the dangers of disordered space in advance are important for the prevention of crime. Besides, the theory shows why policing should be concentrated in neighborhoods, in which are vulnerable to criminal invasion.

Even if several theories had had a profound effect on environmental criminology, before appearing Brantingham & Brantingham (1981, 1984), environmental criminology existed as fragmented theories. Many agree that they have provided valuable implications for improving concepts and applications of environmental criminology for a long time since the 1980s. According to Brantingham & Brantingham (1991), a crime occurs only when space, time, law, offender, and target or victim come together. Conversely, if one of the factors that constitute a crime is missing, no crime occurs. In describing the five factors as reasons for crime, this theory deals with strategies for the physical environment and nature of neighborhood structures. In particular, by systematically explaining the connection between land use, traffic patterns, urban design and daily activities, and movements of victims and offenders, environmental criminology contributed to crime prevention. From a spatial planning point of view, these articles can be highly valued in that it provides a theoretical framework for understanding spatial planning's roles to curb crime through land use, transportation, and facility planning, which are the central part of spatial planning. Like other relevant theories, this study also has limitations. Too much emphasis on place-based factors and the lack of consideration of the spatial patterns of crime have been pointed out as representative limitations of the theory (Cozens, Saville & Hillier, 2005).

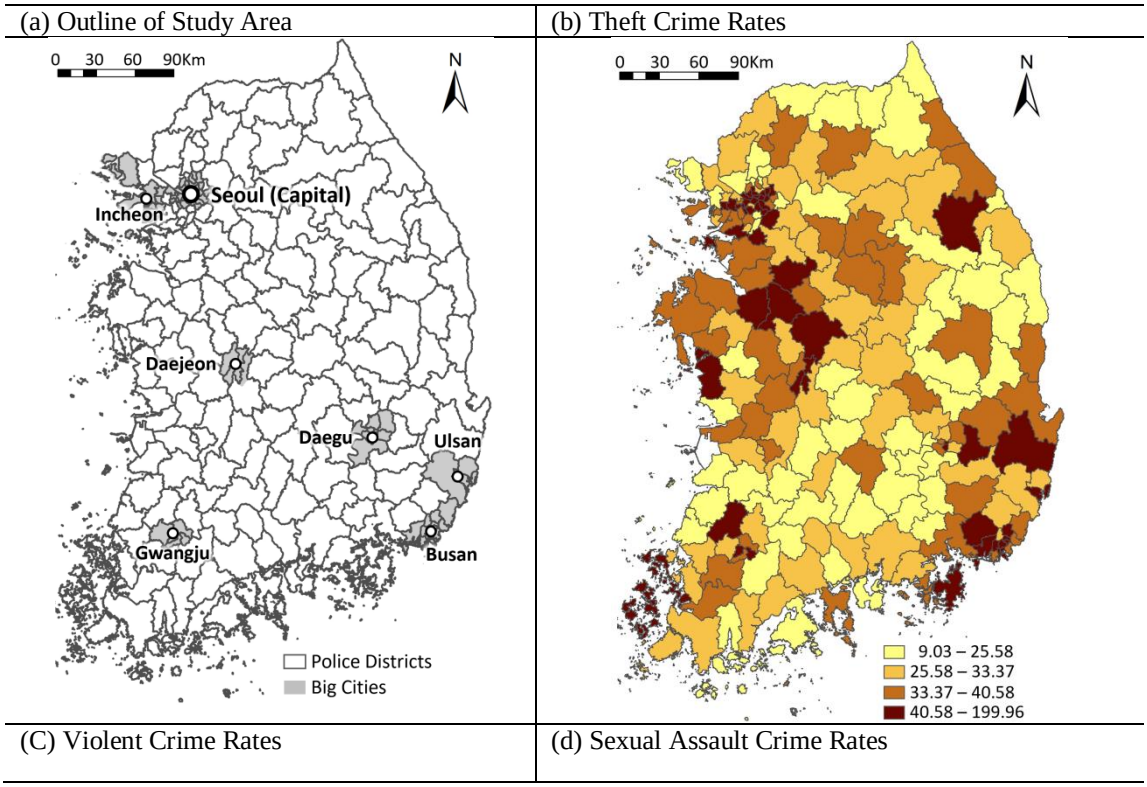
The last theory needed to review is CPTED. The pioneering concept of this theory is Newman's (1973) defensible space. Newman 's ideas centered on public housing design helped to shape environmental criminology as a new area of focus in urban housing and accessibility (Gibson, 2016). While Newman's theory focuses on crime prevention activities primarily from an architectural point of view, CPTED aims a comprehensive approach. In other words, it would design a safe building and place from crime by using a wide range of environmental design elements that can minimize the chance of crime. There is a criticism that CPTED is a defense-oriented strategy and ignores crime motives or offenders (Cozens, Saville & Hillier, 2005). However, CPTED has been receiving the most attention in environmental criminology since 2000, and its application has been expanded to developed countries such as the United Kingdom, Australia, the United States, and Singapore due to its successful crime-reduction capability. In South Korea, the study area of the current paper, CPTED has been actively implemented in recent years, and its utilization is expected to continue to increase at a fast speed.

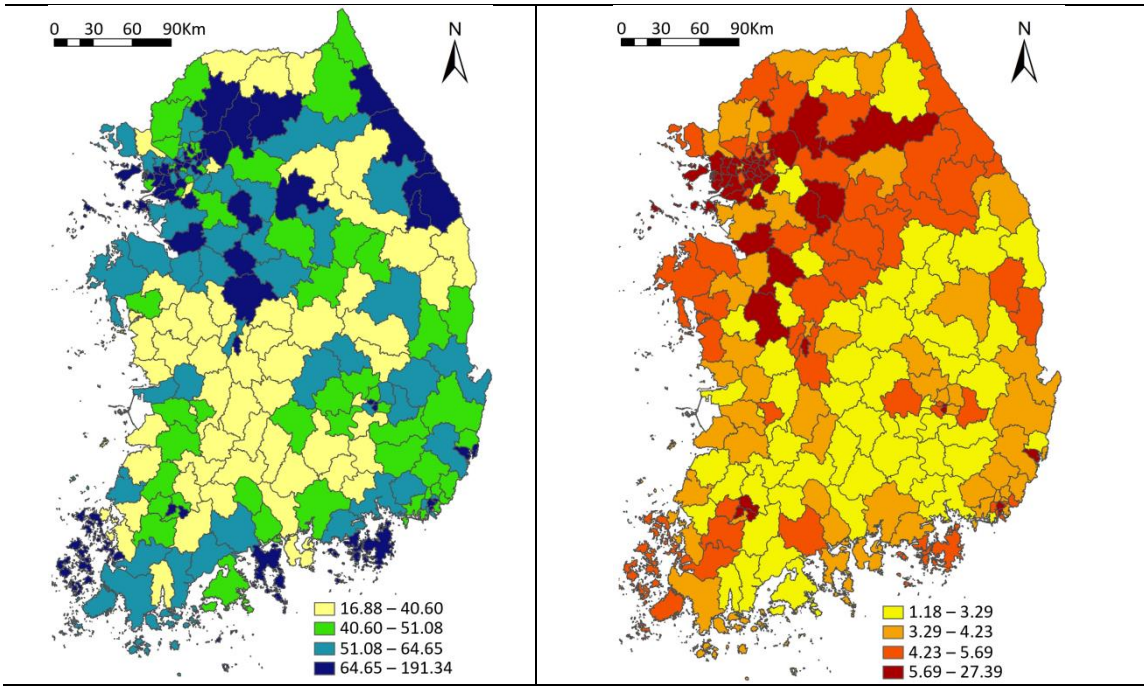
The two key takeaways can be drawn from the theory review on environmental crime. First, the research areas in space and crime have been greatly expanded and achieved remarkable theoretical development. Given the enormous impact of place on crime, the rapid growth of environmental criminology is foreseeable. Second, previous researches illustrate the usefulness and crucial position of environmental crime. In modern criminology in which proactive crime prevention activities are recognized much more importantly, the great influence of environmental criminology is more likely to be strengthened in the future. The present study aims to complement the existing researches in two aspects. For systematically understanding determinants of crime from the lens of environmental crime, it is necessary to more comprehensively identify the effects of spatial planning factors on crime. The study investigates the possibility of spatial factors for proactive crime prevention strategies. As noted, until now, environmental crime has been active in some developed Western countries. To expand the validity and practicality of environmental crime across the globe, new researches should be conducted in countries where relevant research is scarce. The study ascertains the applicability of environmental criminology in South Korea, where the interest of environmental criminology has been low. This effort can contribute to the generalizability of environmental criminology.

3. STUDY AREA

The study area is South Korea, and the base year is in 2016. The study area covers almost all South Korea, except for some islands where there are no reliable materials or where spatial adjacency for spatial regression models is obscure to determine. Using the basic statistics provided by The Korean National Police Agency (2018), the crime trends in Korea are as follows. As of 2016, 1,849,450 total crimes (3,577 crimes per 100,000 population) occurred in South Korea (Korean National Police Agency, 2018). Over the last ten years (2009-2018), about 1.8 million crimes per year have occurred in South Korea and have maintained the crime trends. From 2014 to 2018, sexual assault rates increased by 12%, while theft and violent crime rates decreased by 34% and 1%, respectively. Given the fact that homicide and robbery rates were also reduced by 13% and 39, respectively, in the same period, sexual assault was the only increase in the five major crimes. Thus, social concerns about sexual assault in South Korea have arisen.

Figure 1 displays the outlines of the study area and geographical distributions of theft, violent, and sexual assault rates (per 10,000 population) in 2016. The study area consists of 216 police districts. Due to the principle of boundary demarcation that actively considers people size, the police districts in and near big cities such as Seoul, the capital of South Korea, is very smaller than other regions. Figure 1 offers some baseline for our understanding of the distribution of the three crime rates and their variation across districts. As of 2016, there are 36.5 theft, 55.6 violent crime, and 5.0 sexual assault occurrences per 10,000 population in the study area (Korean National Police Agency, 2018). The spatial distribution pattern reveals the differences between the three types of crime rates. The theft crime rates tend to be relatively high in and surrounding big cities. The two types of crime rates are generally higher in the northern regions than in the southern regions when the study area is divided into two parts (south and north). Examining the link between the three types of crimes with different spatial distributions and environmental criminology can provide critical implications on how to contrive and develop effective crime prevention policies.





Note: Respective crime rates refers to the number of crimes per 10,000 population.

Figure 1. Study Areas and Spatial Distribution of Crime Rates in 2016

4. METHODOLOGY AND VARIABLE SELECTION

4.1. Spatial Regression Models

The classical linear multiple regression models presume that observations or regions are independent of one another. This assumption, however, is often unrealistic. Spatial data such as crime data tends to be dependent between adjacent regions, a phenomenon known as spatial autocorrelation (also referred to as spatial dependence). The presence of spatial autocorrelation will produce estimates that are biased and inconsistent in regression (Lesage &Fischer, 2008). Various spatial linear regression models have been developed to address the issue of spatial autocorrelation (Keitt et al. 2002) and are widely used in crime studies. The validity of applying spatial regression is highly associated with the existence of spatial autocorrelation. If spatial data has spatial autocorrelation, it is preferable to employ spatial regression. The Global Moran's I statistic that was introduced by Moran (1948) and elaborately formulated by Cliff & Ord (1981) is most often used for measuring spatial autocorrelation. The Global Moran's I value ranges from 1 (clustered) to -1 (dispersed). The value of 0 refers to no spatial autocorrelation indicating random distribution. The Global Moran's I offers z-score and p-value representing whether the outputs are statistically significant.

Table 1 shows the results of spatial autocorrelation tests for the three crime rates. We applied the logarithmic transformation to the three crime rates (see the next section 4-2 for the details) and a queen spatial matrix. The three crime rates had all a positive spatial autocorrelation (clustered) with high statistical significance ($p<0.001$). Hence, spatial linear regression models should be exploited to yield efficient and unbiased estimates by reflecting spatial autocorrelation.

Table 1. Results of Spatial Autocorrelation Tests for Crime Rates

Crime Type	Global Moran's I	z-score	p-value
Theft rate (log)	0.2595	7.2851	0.0000
Violent crime rate (log)	0.2521	6.8141	0.0000
Sexual assault rate (log)	0.4111	11.2089	0.0000

Spatial linear regression models have been developed in a wide range of forms. Given the cross-sectional crime data, the current paper employs four basic spatial linear regression models (Lesage & Pace, 2009): a spatial lag model (SLM), a spatial Durbin model (SDM), a spatial error model (SEM), and a spatial autoregressive model (SAC). SLM is an extension of the traditional regression model, ordinary least squares (OLS), and its specific form is as follows:

$$y = \rho \mathrm{W}y + \alpha\tau_n + \mathrm{X}\beta + \varepsilon, \varepsilon \sim N(0, \sigma^2 I_n) \quad \text{Eq. (1)}$$

where $y$and X refer to the dependent and independent variable in the form of a column vector; W indicates the weight matrix (here queen matrix), and τ_n is a one-column vector; ε is the error term and σ^2 is the variance of the error term; I_n means the $n \times n$ unit matrix. α, β, and ρ are coefficients to be estimated; Spatial lag effect can be captured by ρ, and thus its value and statistical significance are the most important to identify the impact of spatial autocorrelation.

SDM, also known as a special case of SLM, is developed to reflect spatial dependence both dependent and independent variables at the same time. SDM adds spatial lag effect to the independent variable as follows:

$$y = \rho \mathrm{W}y + \alpha\tau_n + \mathrm{X}\beta + \mathrm{WX}\gamma + \varepsilon, \varepsilon \sim N(0, \sigma^2 I_n) \quad \text{Eq. (2)}$$

where γ is the coefficient of spatial lag on independent variables.

SEM is presented in Eq. (3), where its error terms have spatial dependence:

$$y = \mathrm{X}\beta + \mu, \mu = \theta \mathrm{W}\mu + \varepsilon, \varepsilon \sim N(0, \sigma^2 I_n) \quad \text{Eq. (3)}$$

SAC assumes that spatial dependency exhibits in both the dependent variables y and the error term ε where spatial weight W_1 and W_2 may or may not be equal.

$$y = \alpha\tau_n + \rho W_1 y + \mathrm{X}\beta + \mu, \mu = \theta W_2 \mu + \varepsilon, \varepsilon \sim N(0, \sigma^2 I_n) \quad \text{Eq. (4)}$$

Among various tools for spatial linear regression models, We used in R with the "spdep" package (R Development Core Team, 2012).

4.2. Variables and Data

We summarize the variables and the data source used in the regression analysis in Table 3. The dependent variables are theft, violent crime, and sexual assault rates. The distribution of all three dependent variables is skewed to the left, which does not meet the assumptions of parametric statistical tests. We utilize the logarithmic transformation to approximately conform to a more normal distribution (Kurlychek & Johnson 2004). The independent variables consist of the spatial environmental variables mainly used in the environmental criminology discussed above, and the

police force variable and socio-economic variables that are known to be associated with crime at the neighborhood or region level. Each independent variable by three categories is as follows.

- Spatial environmental variables: vacant house, housing deterioration, intersection density, mixed land use, nighttime light
- Police force variables: police officer, closed-circuit television (CCTV)
- Socio-economic variables: youth population, single-person household, concentrated disadvantage index(CDI), company

As in other countries, most of the statistics in South Korea are based on administrative boundaries. However, the administrative boundaries and police districts in South Korea do not match, and thus constructing data for crime research involves many challenging issues. To address this, We extracted the boundaries of the police districts in ArcGIS 10.6.0, and then manually matched administrative datasets with the police districts. Except for independent variables that can be easily understood through Table 3, we further explain the process of constructing variables in detail.

The intersection density was established through precise spatial analysis techniques. We first searched for road intersections with the spatial join tool and then found intersections where three or more overlap, which is defined as the road intersection for this analysis. The road intersections extracted from the study area were 1,696,095, and the number of intersections per 10,000 population was used as the final variable. To capture mixed land use, we accepted the entropy index, the most commonly used index for representing the mixed land use (Bordoloia et al., 2013). Entropy index is formulated as:

$$Entropy = \sum_j P_J \times \frac{In(P_j)}{\ln(J)}$$

where, $P_j$denotes the proportion of the total land area of $j$land use category in a police district, and Jindicates total land uses in a police district. The higher value of entropy represents more mixed land use. For measuring mixed land use, we adopted the five specific land uses: residential, commercial, industrial, public, and amusement land use.

The U.S. National Oceanic and Atmospheric Administration (NOAA) provides nighttime lights calculated from weather satellite recordings as an annual time series. Of the three sources, we used "vcm-orm-ntl" (VIIRS Cloud Mask-Outlier Removed-Nighttime Lights). The sum of nighttime light intensity is extracted in police districts. CDI is an indicator of concentrated disadvantage at a local level. We adopted the two most dominant variables to reveal the local socio-economic level in South Korea: municipal financial independence rate and university graduate percent. CDI was gained by normalizing these two variables and taking their averages using Z-score. Many environmental and socio-economic variables affecting crime often involve a multicollinearity problem in regression. To mitigate a multicollinearity issue, the logarithmic transformation technique is applied for the three independent variables: nighttime light, youth population, and company.

Table 2. Variable Definitions and Sources

Variable	**Description**	**Source**
Dependent		
Theft rate (log)	Occurrence per 10,000 population	Korean National Police Agency
Violent crime rate (log)	Occurrence per 10,000 population	Korean National Police Agency
Sexual assault rate (log)	Occurrence per 10,000 population	Korean National Police Agency

Independent		
Vacant house	Proportion of vacant house to total house	Statistics Korea
Housing deterioration	House building year	Statistics Korea
Intersection density	Number of intersections per 10,000 population	Ministry of Land, Infrastructure and Transport of South Korea
Mixed land use	Entropy index (residential, commercial, industrial, public, and amusement land use)	Ministry of Land, Infrastructure and Transport of South Korea
Nighttime light (log)	Sum of nighttime light intensity	U.S. National Oceanic and Atmospheric Administration (NOAA)
Police officer	Population per a police officer	Korean National Police Agency
CCTV	Number of CCTVs per 10,000 population	Korean National Police Agency
Youth population (log)	Proportion of 15-29 year-old to total population	Statistics Korea
Single-person household	Proportion of one-person Household to total household	Statistics Korea
CDI	Combination both municipal financial independence rate and university graduate percent	Statistics Korea
Company (log)	Number of companies per 10,000 population	Statistics Korea

Note: CCTV and CDI indicate Closed-circuit television and Concentrated Disadvantage Index, respectively.

The independent variables in this study have been widely utilized in relevant studies. Thus, the claims and findings of related works can offer a baseline for comparing existing studies and results of South Korea. A tie between neighborhood environment and crime has long been explored and theorized in criminal-related researches. According to Broken Windows theory (Wilson & Kelling, 1982), the variance in crime is explained by the physical deterioration of a neighborhood. Many studies have found that this argument is highly persuasive. (Katz et al., 2011; Goodstein & Lee, 2010; Spelman, 1993; Skogan, 1990). We take the vacant house and housing deterioration into account to see whether this claim can be supported in South Korea.

Intersection density stands for the connectivity of street networks, and higher intersection density indicates higher street connectivity (Sallis et al., 2009). Higher street connectivity may provide criminals with diverse routes of escape and weaken access controls, leading to increasing crimes (Sohn, 2016; Loukaitou-Sideris, 1999; Brantingham & Brantingham, 1993). On the contrary to this, the construction of a pedestrian-friendly environment through higher street connectivity would be effective in preventing crime by increasing natural surveillance (Cozens, 2008; Hillier & Sahbaz, 2008).

For a similar reason to the intersection density, conflicting claims and evidence of mixed land use on crime exist simultaneously. On the one hand, mixed land use creates a situation that residents and nonresidents converge in time and space (Brantingham & Brantingham, 1995), exposing residents to more crime. Similarly, some studies posit that mixed land use, which degrades residents' social control, acts as a mechanism for increasing crime (Reynald, 2010; Sampson & Raudenbush, 1999). On the other hand, mixed land use exerts a salutary effect on crime (Browning et al., 2010; Talen, 1999; Jacobs, 1961). The underlying of this argument is that mixed land use enhances mutual cohesion and facilitate social control, decreasing crime rates. One interesting point is that this assertion is supported by many spatial planners who believe that mixed land use is a complement to the strict zoning system (e.g., a primary strategy of New

Urbanism). Along with two conflicting arguments, there is also the assertion that the relationship between land use diversity and crime may vary by offense type (Wo, 2019; Hayslett-McCall, 2002).

A sufficient amount of lighting for activities during the night is one of the primary strategies of CPTED because it helps maintain visual acuity and surveillance in nighttime environments (Chalfin et al., 2019). Articles have contended that higher nighttime night intensity allows people to enhance surveillance opportunities, resulting in inviting fewer criminals (Cozens & Love, 2015; Weisel, 2002). Contrastively, lower nighttime night intensity may be combined with exposure to offenders, resulting in a higher probability of crime occurrences.

The relationship between the police force and crime rates is one of the popular topics in criminology for a long time. The effect of police resources on decreasing crime rates has been controversial. Evans & Owens (2007) and Levitt (2002) maintains that police resources can reduce crime by deterring potential offenders. However, findings that a significant inverse and no relationship between the number of police officers and crime rates are found (Kim & Lee, 2011; Kleck & Barnes, 2010; Marvell & Moody, 1996). Although the crime-reduction effect of CCTV depends on the characteristics of the locations Lim et al. (2016), a great deal of research has agreed with the proof that CCTV has a positive impact on the reduction of crime.

It is now a truism that socio-economic feature is one of the most influential factors associated with criminal behavior. Hirschi & Gottfredson (1983) opine that the age-crime relationship is invariant, and crime rises rapidly in early adolescence, peaks in late adolescence, rapidly decrease throughout the 20s. There are varied opinions on the realistic span of the age-crime curve, but many studies support the invariant age-crime parameters (Ulmer & Steffensmeier, 2014; Kanazawa & Still, 2000). Single-person households are more vulnerable to crime because of less guardianship (Nicolaas et al., 2010; Dignan, 2005). Since the Chicago School, social or neighborhood disadvantages play a role in explaining criminal behavior (Becker, 2018). As noted earlier, an enormous body of work on environmental criminology has paid much attention to neighborhood disadvantages as a key factor in increasing crimes. We take advantage of CDI to examine whether this claim is appropriate in a South Korea context.

The association between the number of companies and crime can be explained from two different perspectives. First, as discussed above, according to the social control perspective, a large number of companies generate more floating populations, which can exert a salutary effect (advantage surveillance) or deleterious effect (disadvantage social control) on crime. The other is the regional economic point of view. The higher the number of companies, the lower the probability of crime, since regions with a poor economic condition is more likely to have more crime rates (Hoghe et al., 2011; Andresen, 2006).

5. RESULTS

5.1. Regression Model Selection

Prior to explaining the determinants of crime rates, we choose the most appropriate spatial regression model by crime type. Of all four spatial regression models, we select one model that has the best statistical power. The model selection is determined by two steps. As spatial regression models are applied, the first step should be statistically significant for ρ and γ, meaning spatial autocorrelation (at least $p < 0.05$). In the second step, we select the appropriate model based on the Akaike information criterion (AIC) value. The model with the smallest AIC is preferred. To take the theft rate as an example, except for SAC, all meet the first step because ρ

and γ are statistically significant. Since the AIC value of SEM is the smallest among the three models, the best model for the theft rate is SEM. Using this same approach, the best spatial regression models for violent crime rate and sexual assault rate are SEM and SAC, respectively. In the following section, we will explain the regression results for the three types of crimes based on the selected model.

Table 3. Comparison of Spatial Regression Models and Model Selection

Crime Type	Statistics	SLM	SDM	SEM	SAC
Theft rate	AIC	130.18	134.64	122.94	122.87
	ρ	0.1878(**)	0.3123(***)	-	-0.2119
	γ	-	-	0.3380(***)	0.5004
	Model Selection	-	-	○	-
Violent crime rate	AIC	22.06	14.98	8.37	11.27
	ρ	0.1716(*)	0.3601(***)	-	-0.2053
	γ	-	-	0.4253(***)	0.5542(***)
	Model Selection	-	-	○	-
Sexual assault rate	AIC	38.44	28.09	34.56	33.67
	ρ	0.0854	0.1047	-	-0.2363(*)
	γ	-	-	0.2701(*)	0.5140(***)
	Model Selection	-	-	-	○

**p < 0.05, **p < 0.01, ***p < 0.001*

5.2. Regression Results

Table 4 displays the descriptive statistics for each variable adopted in the analyses. Variance inflation factor (VIF) values for all models are below 6.6, indicating no problems of multicollinearity.

Table 4. Descriptive Statistics of Variables (N=216)

Variable	Mean	SD	Minimum	Maximum
Theft rate	12.70	0.43	11.41	14.51
Violent crime rate	13.16	0.37	12.04	14.46
Sexual assault rate	10.69	0.49	9.38	12.52
Vacant house	8.66	4.87	0.51	20.79
House deterioration	30.43	9.60	11.72	49.61
Intersection density	49.47	82.79	0.81	493.19
Mixed land use	0.48	0.40	0.05	1.39
Nighttime light	8.66	0.77	6.58	10.62
Police officer	489.25	183.13	125.37	1,021.10
CCTV	48.25	28.78	10.41	206.70
Youth population	2.84	0.18	2.38	3.19
Single-person household	30.31	5.32	17.70	45.10
CDI	0.00	0.85	-1.11	3.77
Company	6.69	0.29	6.14	8.57

Table 5 exhibits the regression's result of the theft crime rate derived from SEM. The vacant house had a negative impact on the theft crime rate, and house deterioration had no relationship with the theft crime rate. In light of these results, neighborhood deterioration was not a direct connection to theft crime in South Korea. Unlike the intersection density, more mixed land use increased the theft crime rate ($p < 0.01$). This finding is in line with previous arguments that more

mixed land use can cause reducing social control and exposing residents to more crime. The higher the nighttime light intensity, the higher the likelihood of theft crime ($p < 0.001$). In general, bright nighttime light can be an effective strategy in preventing crime by increasing surveillance, but this notion was not valid for the theft crime in South Korea. Instead, bright nighttime light can increase the amount of nighttime activity, augmenting the chance of being exposed to crime. Based on the lower theft crime rate, the larger the population in charge of police officers, the distribution of police force in South Korea is relatively efficient for repressing theft crime. Unlike police deployments, CCTV was not associated with curbing theft crime rate. With the exception of the youth population, socio-economic variables were closely related to the theft crime rate. The theft crime rate increased with more single-person households ($p < 0.001$), higher CDI ($p < 0.001$), and a larger number of companies ($p < 0.05$). Less guardianship, neighborhood disadvantages, and more floating populations can be said to be directly associated with the theft crime rate.

Table 6 represents the determinants of violent crime rate based on SEM. Even if house deterioration had a negative effect on the violent crime rate, a more reasonable interpretation is that neighborhood deterioration was not a close correspondence with the violent crime rate in South Korea. The impact of intersection density, mixed land use, and nighttime light on the violent crime rate was consistent with the results of the theft crime above. That is, the effect of intersection density was not confirmed, and more mixed land use ($p < 0.001$) and brighter nighttime light ($p < 0.001$) increased violent crime occurrence. The distribution of police officers was effective in combating violent crimes ($p < 0.05$), but there was no link between CCTV and violent crimes. Districts with more youth population were more vulnerable to violent crime ($p < 0.01$), indicating that there was a strong age effect on the violent crime in South Korea. In areas with high CDI, the violent crime rates were lower ($p < 0.001$). Conversely, it can be said that violent crimes tend to occur around richer places in South Korea. A number of companies also acted as inviting more violent crimes ($p < 0.001$).

Table 5. Regression Result of Theft Crime Rate (SEM)

Variable	Estimate	Std. Error	Z value
Intercept	8.6148	1.0121	8.5116 (***)
Vacant house	-0.0205	0.0083	-2.4560 (*)
House deterioration	-0.0689	0.0466	-1.4795
Intersection density	0.0648	0.0524	1.2375
Mixed land use	0.1736	0.0645	2.6924 (**)
Nighttime light	0.1954	0.0533	3.6657 (***)
Police officer	-0.0011	0.0027	-4.0671 (***)
CCTV	0.0045	0.0090	0.5034
Youth population	-0.1806	0.2407	-0.7504
Single-person household	0.0182	0.0067	2.7399 (***)
CDI	0.1286	0.0499	2.5782 (***)
Company	0.2098	0.1014	2.0694 (*)
γ	0.3380(***)	-	-

*AIC: 122.94; Log likelihood; -47.46; *p < 0.05, **p < 0.01, ***p < 0.001*

Table 6. Regression Result of Violent Crime Rate (SEM)

Variable	Estimate	Std. Error	Z value
Intercept	7.7885	0.7812	9.9701 (***)
Vacant house	-0.0134	0.0640	-0.2096
House deterioration	-0.0738	0.0364	-2.0247 (*)

Intersection density	0.0605	0.0405	1.4937	
Mixed land use	0.1768	0.0505	3.4977	(***)
Nighttime light	0.1402	0.0409	3.4278	(***)
Police officer	-0.0042	0.0021	-2.0407	(*)
CCTV	0.0050	0.0069	0.7333	
Youth population	0.4389	0.1850	2.3731	(**)
Single-person household	0.0052	0.0051	1.0241	
CDI	-0.1092	0.0397	-2.7490	(***)
Company	0.4982	0.0772	6.4552	(***)
γ	0.4253(***)	-	-	

*AIC: 8.37; Log likelihood; 9.81; *p < 0.05, **p < 0.01, ***p < 0.001*

Table 7 shows the regression result of sexual assault crime rate from SAC. The sexual assault crime rate was not a close correspondence with the physical conditions of the neighborhood. Of the three crime types, intersection density was the only correlated with sexual assault crime rate. The more the intersection density, the higher the odds of sexual assault crime ($p < 0.05$), demonstrating that higher street connectivity is favorable for the criminal behavior of sexual assault in South Korea. Mixed land use and nighttime light play a critical role in raising the probability of sexual assault crime ($p < 0.001$). The police force both geographical distribution of police officers and CCTV was not a connection to sexual assault crime rate. Among socio-economic variables, single-person households and a number of companies were associated with sexual assault crime. In districts where many single-person households live, sexual assault crime rate is more likely to be higher ($p < 0.001$). Given that women are the most victims of sexual assault crime in South Korea, areas with more women living alone were more susceptible to be disclosed to sexual assault crime. As with the other two types of crime, areas with a larger number of companies were more likely to be exposed to sexual assault crime ($p < 0.001$).

Table 7. Regression Result of Sexual Assault Crime Rate (SAC)

Variable	**Estimate**	**Std. Error**	**Z value**	
Intercept	10.8992	1.9288	5.6508	(***)
Vacant house	-0.0744	0.0674	-1.1044	
House deterioration	-0.0128	0.0389	-0.3282	
Intersection density	0.0109	0.0043	2.5294	(**)
Mixed land use	0.1936	0.0560	3.4590	(***)
Nighttime light	0.1447	0.0429	3.3737	(***)
Police officer	-0.0034	0.0022	-1.5628	
CCTV	-0.0070	0.0072	-0.9730	
Youth population	0.1541	0.1950	0.7901	
Single-person household	0.0142	0.0053	2.6905	(***)
CDI	0.0581	0.0443	1.3121	
Company	0.4703	0.0858	5.4837	(***)
ρ	-0.2363(*)	-	-	
γ	0.5140(***)	-	-	

*AIC: 33.67; Log likelihood; -1.83; *p < 0.05, **p < 0.01, ***p < 0.001*

We summarize the regression results as follows. The most prominent finding is that the regression results in the three crimes are slightly different. A generalized strategy applicable to all crimes is required (Weisburd et al., 1992) for more effective anti-criminal operations, but the current analyses show that this approach is challenging in reality. Nevertheless, the same

influential variables in all three crime types can be adopted as a generalized strategy for preventing major crimes in South Korea.

The broken windows effect was negligible for significant crimes in South Korea. The result is consistent with Sampson & Raudenbush (1999) 's argument that increased disorder did not cause serious crime. Considering the environmental characteristics of physical activity in South Korea, such a result can be convincing. Since 1995, a year when the local autonomy system was regularized, local governments have made great efforts to improve their physical properties. As a result, the influence of regional disorders on the incidence of crimes was marginal. Another interpretation is possible. In South Korea, neighborhood deterioration in rural areas is more severe than in urban areas, and due to the low crime rate in rural areas, the effects of the broken window did not work.

In the three crime types, mixed land use affected raising crime rates, which is a line with some previous studies that mixed land use increases the likelihood of crime incidences (Reynald, 2010; Brantingham & Brantingham, 1995). South Korea has run the zoning system to control land use, which is equivalent to the U.S, but the level of mixed land use is very high, compared to the countries of the world. Although new planning ideas such as New Urbanism encourage human activities through mixed land use, mixed land use in South Korea has been found to cause crimes. Thus, proper intervention is needed from a crime-prevention standpoint.

Unlike a series of relevant works, brighter nighttime light has not been effective in decreasing crimes in South Korea. The result can be understood through South Korea's unique nightlife. South Korea is one of the countries with the most developed nightlife. Even after midnight, it is common for many people to enjoy the nightlife in various regions. Most restaurants and convenience facilities are open until late dawn, welcoming people who want to entertain nightlife. In areas with brighter nighttime light, the nightlife is more intense, and thus those engaged in nightlife are more subject to crimes. In this regard, policies that effectively control and manage nightlife may be more practical than offering brighter nighttime light.

In South Korea, CCTV did not play a role in deterring crimes. As Lim et al. (2016) noted, the crime prevention effect of CCTV is directly related to its location, so efforts to increase the efficiency of CCTV location will emerge as one of the essential crime prevention strategies in South Korea. This study proved why location-oriented approaches in terms of CCTV should be accompanied by, not just the number of CCTVs in districts.

Lastly, socio-economic characteristics were closely connected with crime rates in South Korea. In all three crimes of the study, a number of companies allured offenders to commit crimes. In violent crime, the impact of youth populations was identified. A district with more single-person households tends to have higher theft and sexual assault crime rates. CDI increased theft crime and decreased sexual assault crime vice versa. The Chicago School's argument that the neighborhood disadvantages cause more offenses is still valid in South Korea. Thus, efforts to improve neighborhood environments will be regarded as an important policy for crime-free areas.

6. CONCLUSION

Can environmental criminology be an effective strategy to curb crimes in South Korea? Yes, it can. Findings of theft rate, violent crime rate, and sexual assault rate confirm the reliability of environmental criminology. Although this study has examined the likelihood of applying environmental criminology, further researches and discussions are followed for concrete plans. From effective spatial planning to policy applications, many research fields have not yet been validated from the lens of environmental criminology. With the interest of the public, follow-up

studies should dive deeper into finding practical spatial planning and policy strategies to suppress crimes.

Since the spatial autocorrelation of crime rates is confirmed in South Korea, it will be necessary to consider spatial autocorrelation in subsequent studies actively. Under the premise of spatial autocorrelation in crime data, follow-up works should produce more general outputs by actively applying spatial panel regression models rather than cross-sectional analysis. Additionally, microscopic studies will be preferred for mitigating structural limitations of aggregated data (e.g., ecological fallacy and modifiable areal unit problem). Further, environmental criminology should be active use for crime prediction. As with this study, studies analyzing the effects, impacts, and possibilities of environmental criminology in various countries or regions should continue to extend its valid generalization and utilization.

REFERENCES

[1] 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.

[2] Barnett, C., & Mencken, F. C. (2002). Social disorganization theory and the contextual nature of crime in nonmetropolitan counties. Rural sociology, 67(3), 372-393.

[3] Baughman, J., & Caplan, J. (2010). Applying risk terrain modeling to a violent crimes initiative in Kansas City, Missouri. RTM Insights 1. In.

[4] Beauregard, E., & Leclerc, B. (2007). An application of the rational choice approach to the offending process of sex offenders: A closer look at the decision-making. Sexual Abuse, 19(2), 115-133.

[5] Becker, J. H. (2018). Within-Neighborhood Dynamics: Disadvantage, Collective Efficacy, and Homicide Rates in Chicago. Social Problems. 66(3), 428-447.

[6] Bordoloi, R., Mote, A., Sarkar, P. P., & Mallikarjuna, C. (2013). Quantification of land use diversity in the context of mixed land use. Procedia-Social and Behavioral Sciences, 104, 563-572.

[7] Brantingham, P. J., & Brantingham, P. L. (1981). Introduction: the dimensions of crime, in P.J. Brantingham and P.L. Brantingham (eds.) Environmental Criminology. Prospect Heights IL, Waveland Press, 7 – 26.

[8] Brantingham, P. J., & Brantingham, P. L. (1984). Patterns in crime: Macmillan New York.

[9] Brantingham, P. J., & Brantingham, P. L. (1991). Introduction to the 1991 Reissue: Notes on Environmental Criminology. In Environmental Criminology (P.J. Brantingham and P.L. Brantingham, eds) pp. 1-6. Waveland Press; Prospect Heights, ILL.

[10] Brantingham, P. L., & Brantingham, P. J. (1993). Nodes, paths and edges: Considerations on the complexity of crime and the physical environment. Journal of environmental psychology, 13(1), 3-28.

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

[12] Browning, C. R., Byron, R. A., Calder, C. A., Krivo, L. J., Kwan, M.-P., Lee, J.-Y., & Peterson, R. D. (2010). Commercial density, residential concentration, and crime: Land use patterns and violence in neighborhood context. Journal of Research in Crime and Delinquency, 47(3), 329-357.

[13] Bruinsma, G. J. (2018). Classical theory: The emergence of deterrence theory in the age of enlightenment. In Deterrence, Choice, and Crime, Volume 23 (pp. 3-28): Routledge.

[14] Burgess, E. W. (1925). The Growth of the City: An Introduction to a Research Project In Park et al The City. In: Chicago: The University of Chicago Press.

[15] Chalfin, A., Hansen, B., Lerner, J., & Parker, L. (2019). Reducing Crime Through Environmental Design: Evidence from a Randomized Experiment of Street Lighting in New York City. Crime Lab New York & Science in Service of Cities.

[16] Cliff, A. & Ord, J. K. (1981). Spatial processes: models and applications. London: Pion.

[17] Cohen, L. E., & Felson, M. (1979). Social change and crime rate trends: A routine activity approach. American sociological review, 44, 588-608.

[18] Copes, H., & Tewksbury, R. (2011). Criminal experience and perceptions of risk: what auto thieves fear when stealing cars. Journal of Crime and Justice, 34(1), 62-79.

[19] Cozens, P. M. (2008). New urbanism, crime and the suburbs: A review of the evidence. Urban Policy and Research, 26(4), 429-444.

[20] Cozens, P. M., Saville, G., & Hillier, D. (2005). Crime prevention through environmental design (CPTED): a review and modern bibliography. Property management, 23(5), 328-356.
[21] Cozens, P., & Love, T. (2015). A review and current status of crime prevention through environmental design (CPTED). Journal of Planning Literature, 30(4), 393-412.
[22] Dignan, J. (2005). Understanding victims and restorative justice: McGraw-Hill Education (UK).
[23] Evans, W. N., & Owens, E. G. (2007). COPS and Crime. Journal of Public Economics, 91(1-2), 181-201.
[24] Felson, M., & Clarke, R. V. (1998). Opportunity Makes the Thief: Practical Theory for Crime Prevention. Police Research Series, Paper 98. Home Office, London.
[25] Fleming, Z. (1999). The thrill of it all: Youthful offenders and auto theft. In their own words: Criminals on crime, an anthology, 2, 71-79.
[26] Gibson, V. (2016). Third generation CPTED? Rethinking the basis for crime prevention strategies. Doctoral thesis, Northumbria University,
[27] Goodstein, R., & Lee, Y. Y. (2010). Do Foreclosures Increase Crime?(No. 2010-05) (pp. 1–53). Washington, DC: Federal Deposit Insurance Corporation.
[28] Graham, K., & Homel, R. (2008). Raising the bar: Preventing aggression in and around bars, clubs and pubs. UK: Willan Publishing, London.
[29] Groff, E. (2011). Exploring 'near': Characterizing the spatial extent of drinking place influence on crime. Australian & New Zealand Journal of Criminology, 44(2), 156-179.
[30] Haider, M. A., & Iamtrakul, P. (2018). Theoretical Concepts of Crime and Practices in Urban Planning and Design Process for Safe Urban Life. International Journal of Building, Urban, Interior and Landscape Technology; BUILT, 12, 7-24.
[31] Harding, D. J. (2009). Collateral consequences of violence in disadvantaged neighborhoods. Social forces, 88(2), 757-784.
[32] Hayslett-McCall, K. L. (2002). Neighborhoods, land-use, and robbery rates: a test of routine activity theory. Doctoral thesis, Pennsylvania State University.
[33] Hillier, B., & Sahbaz, O. (2008). An evidence based approach to crime and urban design. Or, can we have vitality, sustainability and security all at once. Bartlett School of Graduates Studies University College London.
[34] Hirschi, T., & Gottfredson, M. (1983). Age and the explanation of crime. American journal of sociology, 89(3), 552-584.
[35] Hodge, A., Shankar, S., Rao, D. P., & Duhs, A. (2011). Exploring the links between corruption and growth. Review of Development Economics, 15(3), 474-490.
[36] Holzman-Escareno, A. (2015). English 215 final project: The cause of crime. Retrieved from https://hilo.hawaii. edu/academics/hohonu/documents/Vol07x03TheCause ofCrime.pdf
[37] Jacobs, J. (1961). The death and life of great american cities. New York, NY: Random House.
[38] Jeffery, C. R. (1977). Crime prevention through environmental design: Sage Publications Beverly Hills, CA.
[39] Kamalipour, H., Faizi, M., & Memarian, G. (2014). Safe Place by Design: Urban Crime in Relation to Spatiality and Sociality. Current Urban Studies, 2(2), 720-726.
[40] Kanazawa, S., & Still, M. C. (2000). Why men commit crimes (and why they desist). Sociological Theory, 18(3), 434-447.
[41] Kaplan, J. (2019). The Effect of Moonlight on Outdoor Nighttime Crime. Available at SSRN 3369228.
[42] Katz, C. M., & Schnebly, S. M. (2011). Neighborhood variation in gang member concentrations. Crime & Delinquency, 57(3), 377-407.
[43] Keitt, T. H., Bjørnstad, O. N., Dixon, P. M., & Citron-Pousty, S. (2002). Accounting for spatial pattern when modeling organism-environment interactions. Ecography, 25(5), 616-625.
[44] Kim, H. J., & Lee, S. W. (2011). Determinants of 5 major crimes in Seoul Metropolitan Area: application of Mixed GWR model, Seoul Studies, 12(4), 135–155.
[45] Kleck, G., & Barnes, J. C. (2014). Do more police lead to more crime deterrence? Crime & Delinquency, 60(5), 716-738.
[46] Kurlychek, M. C., & Johnson, B. D. (2004). The juvenile penalty: A comparison of juvenile and young adult sentencing outcomes in criminal court. Criminology, 42(2), 485-515.
[47] LeSage, J. P., & Fischer, M. M. (2008). Spatial growth regressions: model specification, estimation and interpretation. Spatial Economic Analysis, 3(3), 275-304.
[48] LeSage, J., & Pace, R. K. (2009). Introduction to spatial econometrics: Chapman and Hall/CRC.

[49] Levitt, S. D. (2002). Using electoral cycles in police hiring to estimate the effects of police on crime: Reply. American Economic Review, 92(4), 1244-1250.
[50] Lim, H., Kim, C., Eck, J. E., & Kim, J. (2016). The crime-reduction effects of open-street CCTV in South Korea. Security Journal, 29(2), 241-255.
[51] Loukaitou-Sideris, A. (1999). Hot spots of bus stop crime: The importance of environmental attributes. Journal of the American Planning Association, 65(4), 395-411.
[52] Madensen, T. D., & Eck, J. E. (2008). Violence in bars: Exploring the impact of place manager decision-making. Crime Prevention and Community Safety, 10(2), 111-125.
[53] Marvell, T. B., & Moody, C. E. (1996). Specification problems, police levels, and crime rates. Criminology, 34(4), 609-646.
[54] Moran, P. A. (1948). The interpretation of statistical maps. Journal of the Royal Statistical Society. Series B (Methodological), 10(2), 243-251.
[55] Newman, O. (1973). Defensible Place: New York: Mac Millan.
[56] O'Connor, C., & Kelly, K. (2006). Auto theft and youth culture: A nexus of masculinities, femininities and car culture. Journal of Youth Studies, 9(3), 247-267.
[57] Paulsen, D. J., & Robinson, M. B. (2004). Spatial aspects of crime: Theory and practice: Allyn & Bacon.
[58] Pierce, G. L., Spaar, S., & Briggs, L. R. (1988). The character of police work: Strategic and tactical implications: Center for Applied Social Research, Northeastern University.
[59] R Development Core Team (2012). R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
[60] Reynald, D. M. (2010). Guardians on guardianship: Factors affecting the willingness to supervise, the ability to detect potential offenders, and the willingness to intervene. Journal of Research in Crime and Delinquency, 47(3), 358-390.
[61] Sallis, J. F., Saelens, B. E., Frank, L. D., Conway, T. L., Slymen, D. J., Cain, K. L., . . . Kerr, J. (2009). Neighborhood built environment and income: examining multiple health outcomes. Social science & medicine, 68(7), 1285-1293.
[62] Sampson, R. J., & Raudenbush, S. W. (1999). Systematic social observation of public spaces: A new look at disorder in urban neighborhoods. American journal of sociology, 105(3), 603-651.
[63] Shaw, C. R., & McKay, H. D. (1942). Juvenile delinquency and urban areas. University of Chicago Press.
[64] Shim, M. S. (2017). A Study on the Development Direction of CPTED Policy in Communities: Based on Cooperation Between the Police and the Local Governments, Korean Association of Police Science, 66, 37–63.
[65] Skogan, W. G. (1990). Disorder and decline: Crime and the spiral of decay in American cities. New York: The Free Press.
[66] Sohn, D. W. (2016). Residential crimes and neighbourhood built environment: Assessing the effectiveness of crime prevention through environmental design (CPTED). Cities, 52, 86-93.
[67] Spelman, W. (1993). Abandoned buildings: magnets for crime? Journal of Criminal Justice, 21(5), 481-495.
[68] Talen, E. (1999). Sense of community and neighbourhood form: An assessment of the social doctrine of new urbanism. Urban Studies, 36(8), 1361-1379.
[69] The Korean National Police Agency (2018), Korean Police Crime Statistics in 2018.
[70] Ulmer, J. T., & Steffensmeier, D. J. (2014). The age and crime relationship: Social variation, social explanations. In The nurture versus biosocial debate in criminology: On the origins of criminal behavior and criminality (pp. 377-396): SAGE Publications Inc.
[71] Weisburd, D., Bruinsma, G. J., & Bernasco, W. (2009). Units of analysis in geographic criminology: Historical development, critical issues, and open questions. In Putting crime in its place (pp. 3-31): Springer.
[72] Weisburd, D., Maher, L., Sherman, L., Buerger, M., Cohn, E., & Petrisino, A. (1992). Contrasting crime general and crime specific theory: The case of hot spots of crime. Advances in criminological theory, 4(1), 45-69.
[73] White, S., Hewitt, J., Turbitt, E., Van Der Zwan, Y., Hersmus, R., Drop, S., . . . Looijenga, L. (2012). A multi-exon deletion within WWOX is associated with a 46, XY disorder of sex development. European Journal of Human Genetics, 20(3), 348.
[74] Wilson, D. (1996). Metaphors, growth coalition discourses and black poverty neighborhoods in a US city. Antipode, 28(1), 72-96.

[75] Wilson, J. Q., & Kelling, G. L. (1982). Broken windows. Atlantic monthly, 249(3), 29-38.
[76] Wo, J. C. (2019). Mixed land use and neighborhood crime. Social science research, 78, 170-186.