

Innovative Spatial Analysis of Violent Crime Hot Spots in Korea: Implications for Urban Policy

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Abstract Empirical applications to explain criminogenic events are abundant. While much of the research in criminal studies concentrates on understanding the motivations of offenders and preventing victimization from a micro perspective, there have been recent theoretical advancements that give priority to the role of spatial factors in directly impacting crime rates. The primary purpose of this study is to investigate the empirical inference between violent crime incidence and spatial characteristics of local areas focusing particularly on spatial accessibility conditions in the areas. Applying discrete spatial econometrics models, this study reveals a significant relationship between spatial accessibility and the formation of violent crime hot spots in South Korea. Along with other variables, it is revealed that road accessibility has a clear association with violent crime hot spots. Based on the findings, this study suggests some policy implications such as effective surveillance systems, land use restrictions, and advanced street lighting.

Keywords Crime, Accessibility, Discrete Spatial Econometrics Model, South Korea

I. Introduction

The high volume of crime can inhibit innovation by diverting resources away from education, public investment, and other crucial public functions. This is because expenditures on crime control must be traded off against expenditures in these areas (Chalfin, 2015). Additionally, it can create a sense of fear and insecurity among citizens, which limits their participation in social activities (Foster et al., 2010).

Many studies have been conducted to understand the causes of crime in Western societies by using empirical methods to analyze criminogenic events and environments. Research in this field has often examined the relationship between crime rates and socio-economic factors such as race, gender, age,

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education, income inequality, poverty, and social exclusion. Traditional criminological research has focused on understanding the motivations of offenders and the risk of victimization from an individual or micro perspective. However, there have been recent developments in the field that acknowledge the importance of space as a crucial factor in the crime incidence. This approach might be more pragmatic for planners and policy makers who are primarily interested in understanding crime patterns and developing effective prevention strategies rather than just controlling criminal behavior.

The current study employs spatial econometrics models since this approach enables the examination of how covariates influencing crime incidence may vary across different spatial locations (Browning et al., 2010; Cahill and Mulligan, 2007; Cheong, 2014; Hipp, 2007; Hooghe et al., 2011; Kim and Lee, 2013; Lee and Cho, 2006; Park et al., 2018). Previous research have demonstrated that disregarding the likelihood of spatial differences between covariates and crime occurrence can violate the assumption of independent observations in many conventional statistical models since spatial autocorrelation and interdependence are prevalent in macro data (Anselin, 1988). Cahill and Mulligan (2007) emphasized the importance of incorporating spatial data into ecological studies of crime, even in the absence of explicit identification of local processes. Based on these insights, this study aims to understand the potential effect of spatial heterogeneity on criminal activities in Korea.

This study is innovative in the following three aspects: First, this study has established accessibility indicators representing traffic infrastructure of areas that affect crime, which has limitedly been tried before. The use of accessibility indicators allows for a more comprehensive analysis of crime patterns and can provide new insights into the relationship between crime and spatial accessibility. Second, the study classifies spatial characteristics based on the occurrence of violent crime into hot spots and areas that do not experience such crime. This distinction is crucial since crime tends to cluster in specific geographical units rather than evenly distributed across urban areas (Braga et al., 2010; Papachristos and Bastomski, 2018; Taylor, 1997; Weisburd, 2015). By identifying and analyzing these hot spots, the study could lead to more targeted crime prevention efforts and a better understanding of the factors that contribute to the formation of crime hot spots. Third, the present study applies spatial discrete models to investigate the relationship between violent crime hot spots and spatial factors. These methods, which have rarely been employed, provide a more accurate representation of the properties of violent crime hot spots and their statistical traits. Overall, the findings from this analysis offer valuable insight into factors that contribute to the formation of violent crime hot spots and suggest the development of targeted policy recommendations for spatial planning to address and prevent crime.

II. Background

As crime continues to be a significant concern impeding social development, researchers have been focusing on understanding the various factors that contribute to its occurrence. This includes studying crime from multiple perspectives such as criminology, sociology, and economics. While previous efforts have mainly focused on identifying and apprehending the actors committing crimes, recent research has been shifting towards understanding the larger macroscopic factors that influence crime.

Various macroscopic explanations of crime explain factors affecting crime. Social disorganization theory is one of the most representative sociological theories. Proposed by Shaw and McKay (1942), this suggests that crime is closely related to the lack of social solidarity and integrity in a community, referred to as social disorganization. Factors such as poverty, residential mobility, diversity of races and ethnic groups, population density, family disorganization, and single-parent families are frequently used to assess the level of collective control in a community. A number of studies have found a strong correlation between social disorganization and crime (Barnet and Mencken, 2002; Bruinsma et al., 2013; Lee and Choi, 2019; Petee and Kowalski, 1993; Petee et al., 1994; Sampson and Groves, 1989; Warner and Pierce, 1993; Witt et al., 1999).

Another prominent sociological theory that explains crime is the routine activity theory, proposed by Cohen and Felson (1979). This theory states that crime occurs when criminal offenders and targets exist in the presence of a lack of control that deters crime (Hollis-Peel et al., 2011; Kim et al., 2014; Louderback and Roy, 2018; Miller, 2013; Paulsen and Robinson, 2004; Roncek and Maier, 1991; Smith et al. 2000). This theory has a strong connection to spatial planning as the design and land use of urban spaces can either exacerbate or improve the circumstantial conditions that contribute to crime.

Economic approaches propose the correlation between criminal activity and opportunities for economic gain (Corman and Mocan, 2005; Mocan and Rees, 2005). These theories, based on the rational choice hypothesis, suggest that individuals will engage in criminal behavior when the potential benefits outweigh the potential costs (Becker, 1968). These approaches can be broadly classified into two categories: microscopic approaches that focus on individual behavior and macroscopic approaches that consider the economic conditions of a community or region, such as unemployment and income disparities. According to these macroscopic approaches, areas with lower economic activity tend to have higher crime rates. This theory has been supported by a wide range

of empirical studies conducted in different contexts (Andresen, 2006; Byeon et al., 2020; Ceccato et al., 2002; Chun and Park, 2008; Han et al., 2013; Hooghe et al., 2011; Ko, 2016; Lauridsen et al., 2013; Lee and Cho, 2006; Sampson and John, 1987).

The defensible space theory, proposed by Newman (1973), posits that effective design and control of the built environment can prevent crime occurrence. This theory emphasizes the importance of territorial control, natural surveillance, image, and milieu in deterring crime. Additionally, crime prevention through environmental design (CPTED) has become a significant method for preventing crime, which aims to reduce crime and fear of crime through the strategic use of the built environment. This theory has gained significant attention in recent years, particularly in Korea and other Western countries, as research has shown that spatial factors play a crucial role in determining crime rates. Studies have focused on various spatial factors, such as spatial connectivity (Cozens and Love, 2009; Hiller and Shu, 2000; Johnston and Bowers, 2010), mixed land use (Lockwood, 2007; Wo, 2019), zoning (Anderson et al., 2013; Paulsen, 2012), and public spaces such as parks and pedestrian paths (Groff and McCord, 2012; Marselle et al., 2012).

Despite the recognition of the importance of spatial planning in crime prevention, little research has been conducted in Korea on the association between spatial characteristics and crime. Limited studies in Korea, including those by Chang (2009) and Yoon and Joo (2005), have solely focused on the sociological determinants of crime and have overlooked the impact of spatial planning. In addition, these studies have assumed that the covariates of crime do not vary in space, which may be an overly simplistic assumption as previous studies in diverse contexts have shown evidence of spatial dependencies and heterogeneities (Baller et al., 2001; Browning et al., 2010; Cahill and Mulligan, 2007; Hipp, 2007; Kim and Lee, 2011; Kim and Lee, 2013; Morenoff et al., 2001). Furthermore, most studies in Korea have disregarded spatial heterogeneity in their analytical models, except for Lee et al. (2021), who examined the relationship between regional factors and violent crime in Korea. However, they only focused on the overall number of crimes rather than cluster patterns of violent crime occurrences. The aim of the current study is to reveal the relationship between spatial factors and the development of violent crime hot spots. By utilizing the formation of violent crime hot spots as the dependent variable, the present study will focus on identifying cluster patterns of violent crime incidence and providing insights for the development of effective crime prevention policies.

III. Methodology and Data

1. Methodology

The purpose of this study is to investigate the spatial factors that give rise to violent crime hot spots¹. Hot spots are typically defined as small areas or locations where crime is concentrated (Anselin et al., 2000) or places where crimes occur repeatedly and progressively (Alex and Kate, 2001). To identify the violent crime hot spots, the LISA (Local Indicator of Spatial Association) technique was applied to detect hot spots suggested by Anselin (1995). The LISA is a methodology that identifies hot spot clusters based on the numerical similarity of attribute values among neighboring regions. The LISA identifies four types of areas: high values surrounded by other high values (high-high), low values surrounded by other low values (low-low), low values surrounded by high values (low-high spatial), and high values surrounded by low values (high-low). The use of the LISA technique reflects spatial autocorrelation in the data, which is important for the accurate analysis of spatial patterns. This consideration enables the reliable identification of spatially auto-correlated violent crime hot spots (Anselin, 1995).

Among the four types of areas, high-high and high-low areas are generally designated as hot spots. Baumont et al. (2004) and Boots and Nelson (2008) extended hot spots from high-high areas to include high-low areas, while some studies strictly defined high-high areas only as hot spots (Moons et al., 2009). In this study, high-high areas are solely treated as the hot spots to clearly differentiate the violent crime hot spots from other areas. The identification of hot spots was based on the volume of violent crime incidents rather than the crime rate since the deployment of law enforcement resources is commonly guided by the volume of crime rather than the crime rate (Shin, 2019).

To detect spatial autocorrelation, it is necessary to define a spatial weight matrix that reflects the spatial interaction between areas. The spatial weight matrix is based on the assumption that geographically proximate areas exhibit a significant degree of spatial interdependence. There are various types of spatial weight matrices that can be used, and it is often recommended to compare the results of multiple matrices to ensure that spatial effects are being appropriately captured. A number of studies utilizing spatial econometrics models have employed several spatial weight matrices for this reason (Can, 1992; Dubin, 1988). In this study, an inverse distance matrix was adopted for the spatial

¹ In this study, violent crime encompasses a broad range of illegal acts of violence including murder, burglary, arson, sexual violence, assault, kidnapping.

weight matrix since not all of the regions in the study were directly connected. In order to avoid scale effects, the weight matrices were row-standardized.

The present study aims to identify the relationship between violent crime hot spots and spatial factors. The dependent variable (violent crime hot spots) is discrete, where a crime hot spot is denoted as 1 and 0 otherwise. Generic spatial econometrics models that are compatible with discrete dependent variables include spatial logit, spatial probit, and spatial Tobit. To identify the determinants of crime hot spots, the present study adopts Spatial Autoregressive Probit Model (SAPM) and Spatial Error Probit Model (SEPM).²

The normal maximum likelihood spatial econometrics techniques are not suited to a binary dependent variable because the probit probabilities do not have a closed form and therefore require numerical approximation (Anselin, 2002). Bayesian methods represent a better approach to the traditional spatial probit, as they are flexible and accommodate both SAPM and SEPM. These methods use a Markov Chain Monte Carlo (MCMC) approach to estimate the parameters of the model (Lesage and Pace, 2009).

In expanding the binary choice decision to accommodate spatial dependence, the SAPM is expressed as in Equation (1).

$$\begin{aligned}
 Y &= \begin{cases} 1 & \text{if } Y^* > 0 \\ 0 & \text{if } Y^* \leq 0 \end{cases} \\
 Y^* &= \rho WY^* + X\beta + \varepsilon, \varepsilon \sim N(0, \sigma^2 V) \quad \text{Eq. (1)} \\
 V &= \text{diag}(v_1, v_2, \dots, v_n)
 \end{aligned}$$

ρ denotes the spatial autoregressive parameter that measures the spatial lag of the latent variable estimate, and V is the unit diagonal identity matrix. W denotes the spatial weight matrix. As heteroskedasticity (represented by Y, V) is often present in spatial models of probit estimation, this study applied a Bayesian spatial probit estimation with the Gibbs sampler suggested by LeSage (1999).

The SEPM can be written as in Equation (2). The difference between SAPM and SEPM is whether the spatial dependence is controlled by Y or u . Here, λ represents the coefficient for the error terms that are spatially correlated.

$$\begin{aligned}
 Y^* &= X\beta + u \\
 u &= \lambda Wu + \varepsilon, \varepsilon \sim N(0, \sigma^2 V) \quad \text{Eq. (2)} \\
 V &= \text{diag}(v_1, v_2, \dots, v_n)
 \end{aligned}$$

² Anselin (2002) noted that there are distinct ways to model spatial dependence in discrete choice models. He compared the probit and logit frameworks and found that the spatial probit has an advantage over the spatial logit since the error term in the latter is analytically intractable.

2. Data and Variables

The primary purpose of this study is to investigate the econometric inference between violent crime and spatial characteristics of local areas utilizing spatial discrete choice models and to propose alternative public policies for desirable urban environments in South Korea (hereafter Korea). According to the list of violent crime rates per 100,000 persons in OECD (Organization for Economic Co-operation and Development) member countries as of 2018, Korea was ranked 25th in the murder rate. Seok (2012) compared the total crime rates among major advanced countries and demonstrated that the total crime rate for Korea has been rising while those of other countries, including the U.K., the U.S., Germany, France, and Japan, are showing a decrease trend. Rapid industrialization and the consequent urbanization seem to have rendered such crimes to become more frequent and heinous, and as a result, the demand for powerful and effective crime prevention measures is increasing in Korea.

This study utilizes cross-sectional data from 2005, 2010, and 2015 in order to examine the spatial patterns of violent crime in urban cities of Korea. The data used in the analysis were obtained from the Supreme Prosecutors' Office (SPO) and the National Police Agency of Korea (KNPA) and are specific to the administrative units of cities (Si-Gun-Gu)³. It is worth noting that the study focuses on urban areas due to the absence of data on crime in rural regions, which limits the analysis to urban cities.

Figure 1 illustrates the subject regions of this study. The left-hand figure shows data from SPO, with 116 study areas in 2005 and 2010. The right-hand figure presents data from SPO, with the addition of KNPA data, resulting in 145 subject regions in 2015. The areas outlined in thick black lines represent the seven metropolitan cities, including Seoul.

³ 'Si-Gun-Gu' refers to the administrative divisions used in South Korea, which are similar to cities or districts in other countries.

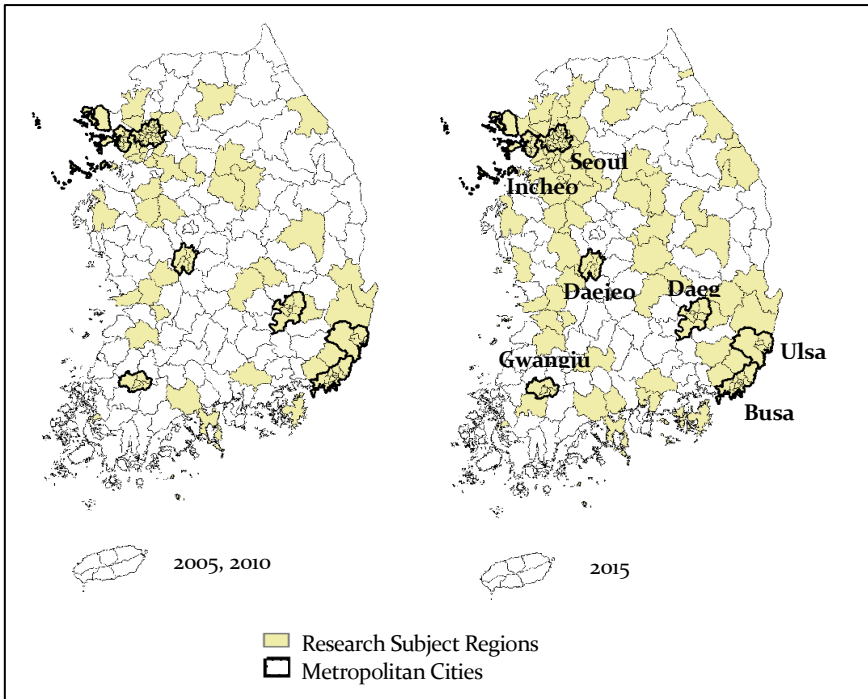


Figure 1 Research Subject Regions, 2005-2015

The present study was aimed at empirically analyzing the violent crime hot spots in Korea to understand the impact of spatial factors. Table 1 describes the variables utilized in this study. The variables used in this study are chosen based on their theoretical validity supported by previous research and the availability of relevant data. The dependent variable is whether the applicable area is a hot spot of violent crime.

The independent variables are categorized into three groups: demographic, socio-economic, and spatial variables. Demographic variables are population, the proportion of foreigners, and the proportion of female residents. Socio-economic variables are the proportion of the population who graduated from at least a college, the employment rate, and the proportion of residents living in their own houses. The spatial variables in this study are the ratio of bars and entertainment establishments to the total number of businesses and the road accessibility index, which provide insight into the structure of local industries and population influx in the study areas.

Most of the independent variables are aggregated statistics data obtained from Statistics Korea, an official government agency. Variables, including the proportion of residents with a college degree, the employment rate, and the

proportion of residents living in their own housing, are based on the 2% Population and Housing Micro Data collected by the same agency. The data on road accessibility was obtained from the Korea Transport Institute (KOTI).

Equation (6) shows the process of estimating the road accessibility index, the same index utilized in Lee et al. (2021). In this equation, n represents the number of regions in Korea, and road accessibility was calculated with 247 regions. T_{ij} represents the time it takes to travel between region i and region j using roads and T_{ik} denotes the time required to travel between region i and region k via roads. O_i indicates the number of people who depart in region i and D_i refers to the number of people who have region i as their destination.

$$Road\ Accessibility_i = \frac{1}{2(n-1)} \left(\sum_{j=1, j \neq i}^n \frac{O_i}{T_{ij}} + \sum_{k=1, k \neq i}^n \frac{D_i}{T_{ik}} \right) \quad Eq. (6)$$

A set of expectations with respect to the effects of the independent variables on determining violent crime hot spots was constructed prior to the analysis. The increased population size is expected to increase the number of crimes, and as such, it is likely to have a positive association with potential victims of crimes (Andresen, 2006). Therefore, it can be reasonably assumed that there is a high possibility of being a violent crime hot spot for regions with a larger population. According to Valier (2003), the concentration of the foreign population has a positive association with the crime occurrence level. In Korea, foreigner-related problems, such as illegal stay or illegal employment, have risen with the progress in economic development and the attainment of a higher status in the international society (Ha, 2017). Furthermore, the rate of increase in the crime rate by foreigners exceeds that of foreign residents in 2015 (Lee, 2020). However, some existing studies doubt any statistical association between the increase in the number of foreign residents and the rise in the crime rate (Kim et al., 2012; Leiva et al., 2020). Thus, it is not easy to predict the effect of the high ratio of foreigners on the likelihood of crime hot spots. Meanwhile, the proportion of female victims of violent crimes has been drastically rising (Kim et al., 2014). The possibility of the formation of crime hot spots in a region is expected to be higher where the proportion of women is greater.

Among the socio-economic variables, the proportion of residents with a college degree is expected to negatively affect the occurrence of crime incidents since the opportunity cost of committing a crime is higher for highly educated people (Lauridsen et al., 2013). Indicators of economic deprivation, such as unemployment, are often found to have a strong impact on crime rates (Blau and Blau, 1982; Hooghe et al., 2011; Messner, 1982; O'Brien, 1983; Sampson, 1985; Williams, 1984). Choi and Park (2018) revealed that there is an apparent relationship between poverty and the incidence of crimes. Crime incidence tends

to increase with deteriorating economic circumstances (Kwon and Jeon, 2016). Meanwhile, home ownership is a fundamental component of stability in life, and it is usually realized by means of income (Hwang and Lee, 2012). Thus, the ratio of residents living in their own housing was selected as a proxy variable of income. It is anticipated that the possibility of falling into a crime hot spot will be lower for regions where a high proportion of people reside in their own houses.

Considering the spatial variables, the ratio of bars and entertainment establishments usually has a strong impact on burglar and sexual violence (Eck and Weisburd, 2015; Roncek and Bell, 1981; Seo et al., 2019; Spicer et al., 2012; Sung et al., 2015). Lee and Cho (2006) also revealed a close relationship between crime incidence and the regional industrial structure. According to them, violent crimes are more likely to transpire in a region where the proportion of bars and entertainment establishments is high. Enhanced spatial accessibility is expected to either allow criminals to flee rapidly (Johnston and Bowers, 2010) or support crime prevention efforts, such as police patrol (Cozens and Love, 2009). In a rare attempt to testify to the impact of accessibility conditions in areas on crime in Korea, Lee et al. (2021) found transportation infrastructure is positively associated with crime incidence.

Table 1 Description of Variables

| Variables | | | Definition |
|-----------------------|--------------------------|------------------------|---|
| Dependent Variable | | Violent Crime Hot Spot | Violent crime hot spot |
| Independent Variables | Demographic Variables | POP | Population (Unit: 10,000 persons) |
| | | FOREIGN | Number of foreign residents (Unit: 1,000 persons) |
| | | FEMALE | Proportion of the female population |
| | Socio-economic Variables | COLLEGE | Proportion of residents with a college degree |
| | | EMP | Employment rate |
| | | OWN | Proportion of residents living in their own houses |
| | Spatial Variables | BAR | Proportion of bars and entertainment establishments in the region |
| | | ROAD | Road accessibility in the region |

IV. Results

1. Violent Crime Hot Spots in Korea

Figure 2 demonstrates the violent crime hot spots identified by the LISA analysis. According to the LISA analysis, there were 38 areas identified as violent crime hot spots among 116 areas in 2005, and the number increased to 39 in 2010. Contrary to 2005, one city in Gangwon Province, the northeast province of Korea, was included. In 2015, the number of hot spots of violent crimes slightly increased to 42 among 145 cities. However, if the total number of areas is considered, the ratio of hot spots seems to have diminished over time. One of the findings, which warrants attention, is that most of the violent crime hot spots are located in the Seoul Metropolitan Area (SMA).

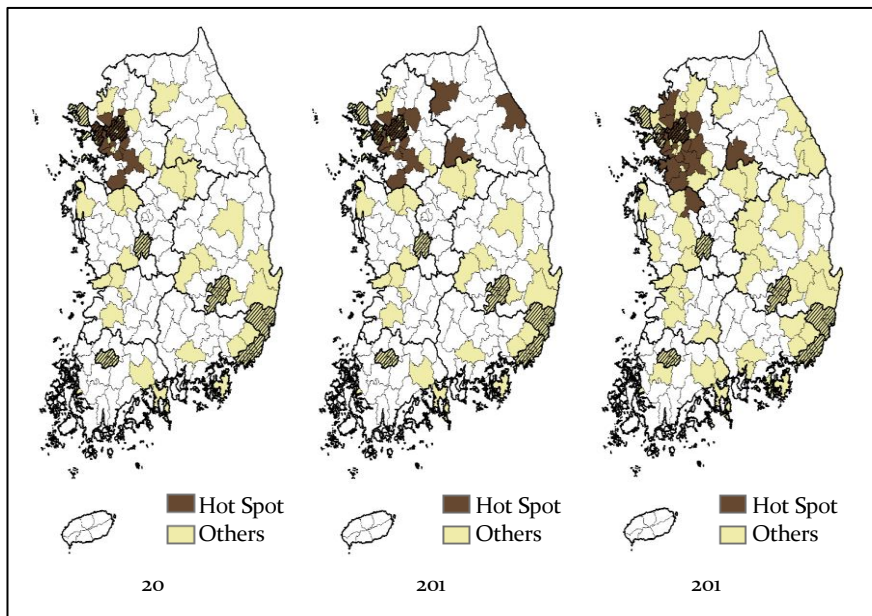


Figure 2 hot Spots of Violent Crime

The descriptive statistics of the variables are presented in Table 2. The mean population had reduced by 25,000 between 2005 and 2015. This is due to the data of small cities that were added in 2015. The average proportion of foreign residents showed a continuous increase and reached almost 7% by 2015. The mean proportion of female residents has been generally constant with a slight fluctuation.

Among the socio-economic variables, the mean employment rate shows an increasing trend. Between 2005 and 2015, the rate rose by more than 5%. The average proportion of residents with a college degree is also increasing. In 2015, about 28% of people were college graduates. Furthermore, the mean ratio of residents living in their own houses rose during the same period by around 3%.

The proportion of bars and entertainment establishments among local businesses decreased from 4.23% in 2005 to 3.33% in 2015. The average road accessibility also reduced during the same period. It might be associated with the limited data from KNPA, which only covers relatively small cities.

Table 2 Descriptive Statistics

| Variables | 2005 | | | | 2010 | | | | 2015 | | | |
|-----------|-------|-------|-------|--------|-------|-------|-------|--------|-------|-------|-------|--------|
| | Mean | S.D | Min | Max | Mean | S.D | Min | Max | Mean | S.D | Min | Max |
| Pop | 33.34 | 19.00 | 1.56 | 104.56 | 34.49 | 20.03 | 1.87 | 107.75 | 30.87 | 20.88 | 2.1 | 118.46 |
| Foreign | 3.24 | 3.04 | 0.11 | 18.23 | 6.19 | 6.81 | 0.11 | 38.97 | 6.92 | 8.31 | 0.18 | 55.72 |
| Female | 51.08 | 1.11 | 47.37 | 53.8 | 51.28 | 1.13 | 48.08 | 53.42 | 51.31 | 1.29 | 45.17 | 54.01 |
| College | 22.27 | 6.92 | 8.29 | 47.65 | 25.78 | 7.23 | 11.81 | 52.54 | 28.78 | 8.27 | 13.53 | 56.04 |
| Emp | 50.67 | 4.56 | 41.15 | 64.49 | 55.78 | 3.75 | 46.5 | 66 | 55.86 | 3.95 | 43.97 | 68.91 |
| Own | 60.79 | 7.68 | 43.17 | 82.65 | 60.01 | 9.43 | 38.32 | 82.04 | 63.84 | 10.33 | 39.11 | 87.58 |
| Bar | 4.23 | 1.23 | 0.54 | 7.49 | 4.01 | 1.24 | 0.73 | 7.17 | 3.33 | 1.18 | 0.53 | 6.42 |
| Road | 0.72 | 0.72 | 0.02 | 3.73 | 0.72 | 0.72 | 0.02 | 3.74 | 0.61 | 0.69 | 0.02 | 3.74 |
| N | 116 | | | | 116 | | | | 145 | | | |

2. Determinants of Violent Crime Hot Spots

Table 3 presents the regression outcomes for the SAPM and SEPM models. Two spatial econometric models that reflect spatial dependence and spatial autocorrelation present similar results. This study focuses on the regression results of SAPM model. The results of the study on the impact of the factors on determining violent crime hot spots in Korea generally align with expectations, but nonetheless, there were some notable disparities.

All the demographic variables were proved to be statistically significant in determining violent crime hot spots in 2010 and 2015. The size of the population increases the probability of becoming a hot spot for violent crimes. The proportion of foreign residents also increases the chance of forming a violent crime hot spot. The proportion of female residents had a negative effect on such a likelihood in the case of 2005, but the effects were positive in 2010 and 2015 with statistical significance.

Among the socio-economic variables, the employment rate had a negative impact on the likelihood of an area becoming a hot spot for violent crimes in 2005 and 2010. However, in 2015, the impact of the employment rate was positive but not statistically significant. On the other hand, the proportion of residents with a college degree and the proportion of residents living in their own houses were negatively correlated with the likelihood of an area becoming a violent crime hot spot, and these correlations were statistically significant at a $p < .10$. In other words, areas with higher levels of education and home ownership tend to have a lower likelihood of experiencing high rates of violent crime.

The proportion of bars and entertainment establishments, as well as road accessibility, is an important factor that contributes to the formation of violent crime hot spots. Specifically, the analysis found that these factors are statistically significant in predicting hot spots of violent crime in all years. The study suggests that the concentration of bars and entertainment establishments and the enhanced road accessibility can increase the likelihood of forming violent crime hot spots. This may be due to the fact that these factors contribute to an increase in the floating population in an area, which can, in turn, lead to a higher prevalence of crime incidents (Lee and Cho, 2006). The results suggest that effective spatial planning needs to be formulated with an aim of lowering the chance of falling into hot spots of violent crimes.

Table 3 Spatial Probit Estimations for Violent Crime Hot Spot, 2005-2015

| | 2005 | | 2010 | | 2015 | |
|-----------|------------------------|------------------------|------------------------|-------------------------|------------------------|------------------------|
| | SAPM | SEPM | SAPM | SEPM | SAPM | SEPM |
| Intercept | 40.791 ^{***} | 19.3265 | -58.1553 ^{**} | -41.7433 ^{***} | -28.2255 ^{**} | -31.1858 ^{**} |
| Pop | 0.0581 ^{***} | 0.0417 ^{***} | 0.0519 ^{***} | 0.0484 ^{***} | 0.0528 ^{***} | 0.0631 ^{***} |
| Foreign | 0.0411 | 0.1862 ^{**} | 0.1588 [*] | 0.1608 ^{***} | 0.0378 | 0.0804 ^{**} |
| Female | -0.7132 ^{***} | -0.6720 | 1.1754 ^{**} | 0.8973 ^{***} | 0.4208 ^{**} | 0.5117 ^{**} |
| College | -0.1098 [*] | -0.1572 | -0.0064 | -0.0029 | -0.0452 | -0.0659 [*] |
| Emp | -0.1708 ^{***} | -0.1931 ^{***} | -0.1743 ^{***} | -0.1646 ^{***} | 0.1233 ^{**} | 0.1364 ^{**} |
| Own | -0.0345 | -0.0220 | -0.0627 ^{***} | -0.0976 ^{***} | -0.0552 [*] | -0.1075 ^{***} |
| Bar | 0.2866 ^{**} | 0.4878 ^{**} | 0.5502 ^{***} | 0.3605 ^{**} | 0.3840 [*] | 0.4839 ^{**} |
| Road | 3.9450 ^{***} | 5.1606 ^{***} | 1.1571 ^{***} | 1.2552 ^{**} | 1.0126 ^{**} | 1.0833 ^{**} |
| ρ | 0.5555 ^{***} | | 0.7305 ^{***} | | 0.6363 ^{***} | |
| λ | | 0.8514 ^{***} | | 0.7884 ^{***} | | 0.5386 ^{***} |
| N | 116 | | 116 | | 145 | |

*** $p < .01$, ** $p < 0.05$, * $p < .1$

V. Conclusion

Crime occurs disproportionately, and regional disparities in crime opportunities are quite rampant over space across the world. Investigating idiosyncratic spatial characteristics of crime is important for criminological inquiries since crime is not randomly distributed over space, and different neighborhood circumstances can give rise to different crime motivations. Certain regional characteristics may be crime conducive that provide crime opportunities with low levels of vigilance. On the other hand, areas with high levels of social and physical guardianship can enjoy a safe neighborhood environment that is free from crime occurrence.

Crime is a regional phenomenon that reflects the spatial characteristics of a particular area. However, detecting the effects of regional variables on crime is not easy. This paper tried to find out the empirical inference between violent crime and spatial features using diverse spatial econometric models and proposes alternative policies for desirable urban planning. Following the argument that crime is heavily influenced by the built environment (Paulsen, 2012), this study found that spatial variables are highly correlated with violent crime hot spots. This study is innovative in that it analyzed the impact of regional transportation infrastructure on crime, which previous studies overlooked. In addition, this study made the impact of determinants affecting crime clearer through the introduction of hot spots.

The spatial variation in violent crime hot spots was analyzed by applying two spatial probit regression models (SAPM and SEPM). The key findings of the study are summarized below. First, the proportion of foreign and female residents proves to be a crucial factor that determines violent crime hot spots. It implies that where more foreigners and women reside, the level of violent crime incidence in those areas would not be lessened. The result highlights the necessity to reinforce the surveillance system and crime prevention environment in the regions where the ratio of foreign residents and female population is high. Second, the impact of spatial factors in determining violent crime hot spots proves to be significant. All spatial variables were found to be in the range of the designated significance level in all years. The proportion of bars and entertainment establishments shows positive effects on determining violent crime hot spots. Furthermore, the higher the road accessibility of an area, the higher the probability of becoming a violent crime hot spot.

Based on the findings, this study suggests some implications for urban planners and policymakers. First, it may be necessary to consider lifting restrictions on commercial area land use to prevent crime. These could be used by local governments to control the concentration of bars and entertainment businesses in a particular area. These regulations can specify where such

establishments are allowed to operate and may include requirements such as minimum distances between establishments. By establishing and enforcing proper zoning regulations, local governments can help prevent overcrowding and related problems in areas with a high concentration of entertainment establishments. Second, the study suggests that areas with high road accessibility should have a stronger surveillance system. Regions with high road accessibility can be at a higher risk of crime incidents as it allows for easier escape routes for criminals (Lee, 2011). Therefore, it is recommended to improve the efficiency of monitoring in regions with high road accessibility as an effective crime prevention strategy.

Additionally, tactical investments in enhanced street lighting can be an effective means of addressing crime in high-risk areas, especially because a significant number of violent crimes occur outdoors at night. In addition to reducing crime and improving public safety, street lighting can also improve perceptions of safety in disadvantaged urban areas. It is also a cost-effective crime prevention strategy since it does not have the unintended costs associated with reliance on incapacitation and has low variable costs (Chalfin et al., 2022). Policymakers can effectively control crime in a city without expanding the criminal justice system by implementing tactical investments in street lighting.

However, it is important to note that this study has several limitations. First, data on rural areas or neighborhood-level data on crime in Korea was not available, which might affect the generalizability of the findings. The data was not collected at a lower level of administrative units, such as Eup, Myeon, and Dong. Second, the large number of regions included in the study made it difficult to provide specific policy recommendations for each region. As a result, this study focused on providing general policy recommendations that could be applied to various regions. Third, some factors that could affect the formation of violent crime hot spots, such as the housing quality of the region, were not included. Previous research has suggested that the housing quality of the region can be associated with crime (Ellen et al., 2012; Lens, 2014; Schneider and Kitchen, 2002). Despite these limitations, this study provides valuable insights into the determinants of violent crime hot spots in Korea and can contribute to the development of more effective crime prevention policies. Future research could aim to address these limitations and further examine the relationship between regional characteristics and violent crime concentration, which can lead to a more in-depth understanding of crime patterns and ultimately promote innovation in the field of crime prevention.

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References

- Alex, H. and Kate, B. (2001). *Mapping and Analysing Crime Data*. London: Taylor and Francis.
- Anderson, J.M., MacDonald, J.M., Bluthenthal, R., and Ashwood, J.S. (2013). Reducing Crime by Shaping the Built Environment with Zoning: An Empirical Study of Los Angeles. *University of Pennsylvania Law Review*, 161(3), 699-756.
- Andresen, M.A. (2006). Crime Measures and the Spatial Analysis of Criminal Activity. *The British Journal of Criminology*, 46, 258-285.
- Anselin, L. (1988). *Spatial Econometrics: Method and Models*. Dordrecht: Kluwer Academic.
- _____. (1995). Local Indicators of Spatial Association LISA. *Geographical Analysis*, 27(2), 286-306.
- _____. (2002). Under the Hood: Issues in the Specification and Interpretation of Spatial Regression Models. *Agricultural Economics*, 27(3), 247-267.
- Anselin, L., Cohen, J., Cook, D., Gorr, W. and Tita, G. (2000). *Spatial Analysis of Crime, Measurement and Analysis of Crime and Justice*. U.S. Department of Justice, Washington, D.C.
- Baller, R., Anselin, L., Messner, S., Deane, G. and Hawkins, D. (2001). Structural Covariates of US County Homicide Rates: Incorporating Spatial Effects. *Criminology*, 39(3), 561-590.
- Barnet, C. and Mencken, F.C. (2002). Social Disorganization Theory and the Contextual Nature of Crime in Nonmetropolitan Counties. *Rural Sociology*, 67(3), 372-393.
- Baumont, C., Ertur, C. and Le Gallo, J. (2004). Spatial Analysis of Employment and Population Density: The Case of the Agglomeration of Dijon 1999. *Geographical Analysis*, 36(2), 146-177.
- Becker, G.S. (1968). Crime and Punishment: An Economic Approach. *The Journal of Political Economy*, 76(2), 169-217.
- Blau, J.R. and Blau, P.M. (1982). The Cost of Inequality: Metropolitan Structure and Violent Crime. *American Sociological Review*, 47 (1), 114-129.
- Boots, B. and Nelson, T.A. (2008). Detecting Spatial Hot Spot in Landscape Ecology. *Ecography*, 31(5), 556-566.
- Braga, A.A., Papachristos, A.V., and Hureau, D.M. (2010). The Concentration and Stability of Gun Violence at Micro Places in Boston, 1980-2000. *Journal of Quantitative Criminology*, 26(1), 33-53.
- Browning, C.R., Byron, R.A., Calder, C A., Krivo, L.J., Kwan, M.P., Lee, J.Y., and 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.
- Bruinsma, G.J.N., Pauwels, L.J.R., Weerman, F.M., and Bernasco, W. (2013). Social disorganization, social capital, collective efficacy and the spatial distribution of crime and offenders. *The British Journal of Criminology*, 53, 942-63.

- Byeon, J., Kim, I., Min, S., and Lee, D. (2020). Social Capital and Crime: Evidence from Felony Crimes in Seoul Municipalities. *Journal of Korean Economics Studies*, 38(1), 5-37.
- Cahill, M. and Mulligan, G. (2007). Using Geographically Weighted Regression to Explore Local Crime Patterns. *Social Science Computer Review*, 25(2), 174-193.
- Can, A. (1992). Specification and Estimation of Hedonic Housing Price Model. *Regional Science and Urban Economics*, 22 (3), 453-473.
- Ceccato, V., Haining, R. and Signoretta, P. (2002). Exploring Offence Statistics in Stockholm City Using Spatial Analysis Tools. *Annals of the Association of American Geographers*, 92(1), 29-51.
- Chalfin A. 2015. Economic costs of crime. In *The Encyclopedia of Crime & Punishment*, ed. WG Jennings, 1–12. New York: Wiley.
- Chalfin, A., Hansen, B., Lerner, J., and Parker, L. (2022). Reducing Crime Through Environmental Design: Evidence from a Randomized Experiment of Street Lighting in New York City. *Journal of Quantitative Criminology*, 38, 127-157.
- Chang, D.K. (2009). Social Crime or Spatial Crime? Exploring the Effects of Social, Economical, and Spatial Factors on Burglary Rates. *Environment and Behavior*, 43(1), 26-52.
- Cheong, J. (2014). Spatial Regression Analysis on the Relationship between Structural Characteristics and Homicide of Seoul. *Seoul Studies*, 15(1), 101-118.
- Choi, J. and Park, C. (2018). A Study on Environmental Factors Affecting Occurrence Depends on Types of Crime. *Journal of Korean Criminological Association* 12 (2), 159-186.
- Chun, Y.W. and Park, Y.H. (2008). Neighborhood Effects and Spatial Patterns in Urban Crime: A Case Study of the City of Dallas, Texas. *Journal of the Korean Urban Geographical Society*, 11(1), 85-99.
- Cohen, L. and Felson, M. (1979). Social Change and Crime Rates. *American Sociological Review*, 44(4), 588-608.
- Corman, H. and Mocan, H.N. (2005). Carrots, Sticks and Broken Windows. *Journal of Law and Economics*, 48(1), 235-266.
- Cozens, P. and Love, T. (2009). Manipulating Permeability as a Process for Controlling Crime: Balancing Security and Sustainability in Local Contexts. *Built Environment*, 35(1), 346-365.
- Dubin, R.A. (1988). Estimation of Regression Coefficients in the Presence of Spatially Autocorrelated Error Terms. *The Review of Economics and Statistics* 70 (3), 466-474.
- Eck, J. and Weisburd, D.L. (2015). Crime Places in Crime Theory. *Crime and Place: Crime Prevention Studies*, 4, 1-33.
- Ellen, I.G., Lens, M.C., and O'Regan, K.M. (2012). American Murder mystery revisited: do housing voucher households cause crime? *Housing Policy Debate*, 22(4), 551-572.
- Foster S., Giles-Corti B., and Knuiiman M. (2010) Neighbourhood design and fear of crime: a social-ecological examination of the correlates of residents' fear in new suburban housing developments. *Health Place*, 16(6), 1156–1165.
- Groff, E. and McCord, E.S. (2012). The role of neighborhood parks as crime generators. *Security Journal*, 25, 1-24.
- Ha, S. (2017). Review on the Status and Countermeasures of Foreigner's Crime. *Korean terrorism studies Review* 10(2), 150-163.

- Han, L., Bandyopadhyay, S., and Bhattacharya S. (2013). Determinants of violent and property crimes in England and Wales: a panel data analysis. *Applied Economics*, 45(34), 4820-4830.
- Hiller, B. and Shu, S. (2000). Crime and Urban Layout: The Need for Evidence, In: Ballintyne S, Pease K, McLaren V (eds) *Key Issues in Crime Prevention, Crime Reduction and Community Safety*. London: IPPR.
- Hipp, J. R. (2007). Block, Track, and Levels of Aggregation: Neighborhood Structure and Crime and Disorder as a Case in Point. *American Sociological Association*, 72(5), 659-680.
- Hollis-Peel, M., Reynald, D.M., van Bavel, M., Elffers, H., Welsh, B. (2011). Guardianship for Crime Prevention: A Critical Review of the Literature, *Crime, Law and Social Change*, 56, 53–70.
- Hooghe, M., Vanhoutte, B., Hardyns, W. and Bircan, T. (2011). Unemployment, Inequality, Poverty and Crime: Spatial Distribution Patterns of Criminal Acts in Belgium, 2001–06. *The British Journal of Criminology*, 51(1), 1-20.
- Hwang, J and Lee, S. (2012). The Impact of Divorce on Tenure Choice for Women in Korea. *Journal of the Korean Housing Association*, 23(1), 55-66.
- Johnston, S. and Bowers, K. (2010) Permeability and Burglary Risk: Are Cul-de-sacs Safer? *Quantitative Journal of Criminology*, 26(1), 89-111.
- Kim, H. and Lee., S. (2011). The Crime Hot Spot and Determinants of Rural Crime. *The Journal of Rural Society*, 21(2), 141-172.
- _____. (2013). Changes in Spatial Dependence of Crime and Distribution of Crime Hot Spots in Korea, 2001-2010. *RESIDENTIAL ENVIRONMENT: JOURNAL OF THE RESIDENTIAL ENVIRONMENT INSTITUTE OF KOREA*, 11(2), 27-41.
- Kim, I., Byeon., J., and Ahn., H. (2014). Violent Crime in Korea: With Focuses on Deterrence, Income Inequality, and Female Victimization. *Korean Journal of Law and Economics*, 11(3), 389-417.
- Kim, S.M., Lagrange, R.L. and Willis, C.L. (2012). Place and Crime: Integrating Sociology of Place and Environmental Criminology. *Urban Affairs Review*, 49(1), 141-155.
- Ko, K. (2016). Determinants of sexual assault in Korea: an empirical analysis (Masters dissertation). Sungkyunkwan University, Seoul, Korea.
- Kwon, T. and Jeon, S. (2016). A study on the violent crime and control factors in Korea. *Journal of the Korean Data and Information Science Society*, 27(6), 1511-1523.
- Lauridsen, J.T., Zeren., F., and Ari., A. (2013). A spatial panel data analysis of crime rates in EU. *Discussion Papers on Business and Economics*, 2.
- Lee, G. (2020). A Study on the Characteristic of Foreign Crimes. *Korea Criminal Intelligence Review* 6(1), 121-135.
- Lee, H. and Choi., J. (2019). An Empirical Study on the Determinants of Property Crime and Violent Crime: Focusing on Social Disorganization Theory and Life Course Theory. *Journal of the Korean Urban Management Association*, 32(2), 67-86.
- Lee, K., Choi, E., and Lee, S. (2021). The effects of spatial factors on the incidence of violent crime in Korea, 2005-2015. *Asian Journal of Innovation and Policy*, 10(2), 249-273.
- Lee, S. (2011). Evaluation of Crime Prevention Performance of Urban Spatial Structure through Network Analysis. *JOURNAL OF THE ARCHITECTURAL INSTITUTE*

- OF KOREA Planning & Design, 27(8), 243-250.
- Lee, S. and Cho, J. (2006). The Effects of Spatial and Environmental Factors on Crime Victimization. *Seoul Studies*, 7(2), 57-76.
- Leiva, M., Vasquez-Lavin, F., and Oliva, R.D.P. (2020). Do immigrants increase crime? Spatial analysis in a middle-income country. *World Development*, 126.
- Lens, M.C. (2014). The Impact of Housing Vouchers on Crime in US cities and Suburbs. *Urban Studies*, 51(6), 1274-1289.
- Lesage, J.P. (1999). *The Theory and Practice of Spatial Econometrics*. Available: <http://www.spatial-econometrics.com/html/sbook>.
- LeSage, J.P. and Pace, R.K. (2009). *Introduction to Spatial Econometrics*. Boca Raton: CRC Press/Taylor & Francis.
- Lockwood, D. (2007). Mapping Crime in Savannah: Social Disadvantage, Land Use, and Violent Crimes Reported to the Police. *Social Science Computer Review*, 25(2), 194-209.
- Louderback, E.R., and Roy, S.S. (2018). Integrating Social Disorganization and Routine Activity Theories and Testing the Effectiveness of Neighbourhood Crime Watch Programs: Case Study of Miami-Dade County, 2007-15. *The British Journal of Criminology*, 58, 968-992.
- Marselle, M., Wootton, A.B., and Hamilton, M.G. (2012). A design against crime intervention to reduce violence in the night-time economy. *Security Journal*, 25, 116-133.
- Messner, S.F. (1982). Poverty, Inequality, and Urban Homicide Rate: Some Unexpected Findings. *Criminology*, 20(1), 103-114.
- Miller, J. (2013). Individual Offending, Routine Activities, and Activity Settings: Revisiting the Routine Activity Theory of General Deviance. *Journal of Research in Crime and Delinquency*, 50, 390-416.
- Mocan, H.N. and Rees, D.I. (2005). Economic Conditions, Deterrence and Juvenile Crime: Evidence from Micro Data. *American Law and Economics Review*, 7(2), 319-349.
- Moons, E., Brijs, T. and Wets, G. (2009). Improving Moran's Index to Identify Hot Spots in Traffic Safety. *Geocomputation Urban Plan*, 176, 117-132.
- Morenoff, J.D., Sampson, R.J. and Raudenbush, S.W. (2001). Neighborhood Inequality, Collective Efficacy, and the Spatial Dynamics of Urban Violence. *Criminology*, 39(3), 517-559.
- Newman, O. (1973). *Defensible space: Crime prevention thorough urban design*. New York: McMillan.
- O'Brien, R.M. (1983). Metropolitan structure and violent crime: Which measure of crime?. *American Sociological Review*, 48(3), 434-437.
- Papachristos, A.V. and Bastomski, S. 2018. Connected in Crime: The Enduring Effect of Neighborhood Networks on the Spatial Patterning of Violence. *American Journal of Sociology*, 124(2), 517-568.
- Park, J., Lee, K., and Lee, S. (2018). A Study on Fear of crime of people in Seoul. *Seoul Studies*, 19(4), 111-129.
- Paulsen, D.J. (2012). *Crime and Planning: Building Socially Sustainable Communities*. Boca Raton, FL: CRC Press.
- Paulsen, D.J. and Robinson, M.B. (2004). *Spatial Aspects of Crime: Theory and Practice*. Boston: Pearson Education, Inc.

- Petee, T.A. and Kowalski, G.S. (1993). Modeling Rural Violent Crime Rates: A Test of Social Disorganization Theory. *Sociological Focus*, 26(1), 87-89.
- Petee, T.A., Kowalski, G.S. and Duffield, D.W. (1994). Crime, Social Disorganization, and Social Structure: A Research Note on the Use of Interurban Ecological Models. *American Journal of Criminal Justice*, 19(1), 117-132.
- Roncek, D.W. and Bell, R. (1981). Bars, Blocks, and Crimes. *Journal of Environmental Systems*, 11, 35-47.
- Roncek, D.W. and Maier, P.A. (1991). Bars, Blocks and Crimes Revisited: Linking the Theory of Routine Activities to the Empiricism of "Hot Spots", *Criminology*, 29, 725-53.
- Sampson, R.J. (1985). Neighborhood and Crime: Identifying the Effect of Unemployment on Crime. *Journal Research in Crime and Delinquency*, 22(1), 7-40.
- Sampson, R.J. and Groves, W.B. (1989). Community Structure and Crime: Testing Social-Disorganization Theory. *The American Journal of Sociology*, 94(4), 774-802.
- Sampson, R.J. and John, D.W. (1987). Linking the Micro-Level and Macro-Level Dimensions of Lifestyle-Routine Activity and Opportunity Models of Predatory Victimization. *American Journal of Sociology*, 3(4), 371-393.
- Schneider, R.H. and Kitchen, T. (2002). *Planning for Crime Prevention: A TransAtlantic Perspective*. New York: Routledge.
- Seo, M., Seo, Y., and Kang, S. (2019). A Study on the Spatial Characteristics of Land Use Areas and the Characteristics of Crime Occurrence. *Journal of Community Safety and Security by Environmental Design*, 10(3), 9-38.
- Seok, C.H. (2012). The Renovation Plan for Crime Prevention of Local Police in Korea. *Korea Association of Criminal psychology*, 8(2), 99-123.
- Shaw, C.R. and Mckay, H.D. (1942). *Juvenile Delinquency and Urban Areas*. Chicago: University of Chicago Press.
- Shin, S. (2019) Spatial Features Affecting the Occurrence of Hidden Camera Crime, the *Journal of Police Science*, 19(1), 59-83.
- Smith, W.R., Frazee, S.G. and Davison, E.L. (2000). Furthering the Integration of Routine Activity and Social Disorganization Theories: Small Units of Analysis and the Study of Street Robbery as a Diffusion Process. *Criminology*, 38(2), 489-523.
- Spicer, V., Reid, A.A., Ginther, J., and Seifi, H. (2012). Bars on blocks: A cellular automata model of crime and liquor licensed establishment density. *Computers, Environment and Urban Systems*, 36(5), 412-422.
- Sung, W., Chun, S., Yun, M., and Lee, H. (2015). The Effect of Alcohol On-premises Densities on Corresponding Local Criminal Rates in Seoul. *Korean Public Health Research*, 41(4), 75-86.
- Taylor, R.B. (1997). Social Order and Disorder of Street Blocks and Neighborhoods: Ecology, Microecology, and the Systemic Model of Social Disorganization. *Journal of Research in Crime and Delinquency*, 34(1), 113-155.
- Valier, C. (2003). Foreigners, Crime, and Changing Mobility. *The British Journal of Criminology*, 42, 109-128.
- Warner, B.D. and Pierce, G.L. (1993). Reexamining Social Disorganization Theory using Calls to the Police as a Measure of Crime. *Criminology*, 31(4), 493-517.
- Weisburd, D. (2015). The Law of Crime Concentration and the Criminology of Place. *Criminology*, 53(2), 133-157.

- Williams, F.P. (1984). The demise of the criminological imagination: A critique of recent criminology. *Justice Quarterly*, 1(1), 91-106.
- Witt, R., Clarke, A. and Fielding, N. (1999). Crime and Economic Activity: A Panel Data Approach. *The British Journal of Criminology*, 39(3), 391-400.
- Wo, J.C. (2019). Understanding the Differential Effects of Land Uses On Crime: An Examination Across Philadelphia Neighbourhoods. *The British Journal of Criminology*, 59(6), 1432-1454.
- Yoon, O. and Joo, H. (2005). A Contextual Analysis of Crime Rates: The Korean Case. *Crime, Law & Social Change*, 43(1), 31-55.