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The Effects of Spatial Factors on the Incidence of Violent Crime in Korea, 2005-2015

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Abstract While many criminal studies have focused on the motivation of offenders and avoidance of victimization in the micro perspective, there have been a number of theoretical developments emphasizing space as a direct factor that influences the incidence of crime. The main purpose of this study is to analyze the effects of regional characteristics and violent crime incidence in Korea. Applying diverse spatial econometrics models that have less been utilized in the crime literature, this study finds an important association between spatial accessibility and crime incidence. The results suggest that the type of predominant business and the level of road accessibility affect the vulnerability of areas with respect to the incidence of violent crime. This study concludes with some important implications for urban planners and policymakers with respect to crime control and prevention.

Keywords Crime Determinants, Road Accessibility, Spatial Econometrics Model, South Korea

I. Introduction

Increasing concerns regarding spatial characteristics for the causes of crime are widespread in Western societies (Eck and Weisburd, 1995). However, much less empirical criminal evidence is available from Asian countries, including South Korea (hereafter Korea). Do these explanations hold for other countries that have heterogeneous historical and cultural backgrounds? This question is particularly relevant regarding the empirical evidence from Clinard (1978). In a rare attempt at comparative analysis, Clinard (1978) showed pronounced differences in the crime rates between the US and Switzerland that cannot be

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explained by general crime theory. Hooghe et al. (2011) argued that a construct to explain the incidence of crime that is true for one country cannot be applied to another country.

The objective of this study is to investigate the effects of spatial factors on the incidence of violent crime in Korea over the periods of 2005 to 2015. Various spatial econometrics models are applied to identify factors between the incidence of violent crime and spatial planning factors. The spatial variables adopted in this study are: the proportion of hotel and restaurant establishments in an area, and road accessibility. These two variables are important factors that reflect the industrial structure and population influx. Based on the findings from these analyses, the present study suggests some implications for spatial planning to prevent crime.

Previous studies have paid particular attention to the recent development of spatial econometrics modeling in the field of criminology because covariates to determine the incidence of crime perform differently in different spaces (Brownning 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). These studies show that ignorance of the possibility of spatial differences between covariates and the incidence of crime can result in violation of the basic assumption (i.e., independence of observation) of many standard statistical models, as spatial dependence and spatial autocorrelation are widespread in most spatial data (Anselin, 1988). Cahill and Mulligan (2007) argued that applying spatial data in ecological studies of crime is useful even when local processes are not theoretically identified. Following these insights, the potential for the impact of spatial heterogeneity on the incidence of crime in Korea was considered in econometric models.

There have been numerous studies on crime in both Korea and abroad, and many of such studies were conducted with particular attention to the effects of regional characteristics on crime incidence. Previous studies utilized diverse spatial characteristics of regions as explanatory variables; however, the application of variables encompassing various regional characteristics as a whole has not been attempted. This study is innovative in that it developed and applied a transportation accessibility index that encompasses both economic and spatial characteristics of regions.

The remaining parts of this study are as follows. Chapter II explains the theoretical backgrounds of the present study, and Chapter III describes the structures of spatial econometrics models in addition to data and variables adopted in this study. Chapter IV presents the regression results focusing on the effects of independent variables on violent crime incidence. The final section concludes with summarizing major findings and policy implications to reduce the violent crime incidence.

II. Background

Theoretical arguments to explain criminogenic events and environments from Western experiences include social and economic factors, such as race, age, gender, income inequality, education, poverty, and social exclusion as major covariates to determine the incidence of crime (Buonanno, 2006). Some recent studies have proposed geographical and political factors, including (mixed) land use, residential concentration, political structure, and presence of deterrent public activities, such as the police distribution (Browning et al. 2010; Kim and Lee, 2013; Yoon and Joo, 2005).

While many criminal studies have focused on the motivation of offenders and avoidance of victimization in the micro perspective, there have been a number of theoretical developments emphasizing space as a direct factor that influences the incidence of crime. Empirical applications of this perspective can be found in Cahill and Mulligan (2007) and Stucky and Ottensmann (2009). This approach may be more insightful for policymakers if the major concern is to understand crime rather than criminality, as public policy is concerned with preventing crime rather than controlling the offender, which is in line with the core of environmental criminology.

Environmental criminology examines the link between crime and physical location, while explaining how human activities are spatially shaped (Brantingham and Brantingham, 1984). Deeply rooted in urbanism and human ecology (Palen, 2012), environmental criminology explains crime, criminality, and victimization related to place, space, and their interaction, especially in urban settings. The goal of this school is to identify ways to manipulate attributes of the physical environment to reduce the opportunities of crime at various points in time (Kim et al., 2012).

Environmental criminology has its roots in the social disorganization theory developed by Shaw and McKay (1942). Crime studies based on social disorganization theory mainly deal with characteristics of demographic, social, and economic environments but commonly neglect the fact that the physical environment of neighborhoods can affect crime in the corresponding areas. Research on the relationship between crime and physical environment was initiated by Jacobs (1961), who suggested urban planning approaches to prevent crimes, and then full-fledged research efforts were followed by defensible space theory by Newman (1973) and crime prevention through environmental design (CPTED) by Jeffery (1971). These two monumental theories of crime suggest various crime prevention strategies based on similar theoretical criteria, including surveillance, access control, and territorial reinforcement. However, both theories also neglect the characteristics of the entire physical environments, such as urban forms as density, concentration, accessibility, etc.

Research on the relationship between urban physical environment and crime has been mainly conducted by Cohen and Felson (1979), who introduced the routine activity theory that focuses on situations of crimes to identify drivers of crime. They insisted that crime opportunities are formed by the confrontation of routine living areas of criminals and potential victims. Although this theory focuses on the locations closely related to living areas to identify the relationship between crime and physical environments, it also has a limitation in that it cannot reflect physical factors, including land use and the location of residential areas.

The importance of diverse characteristics of the physical environment on criminology research is intensively supported by the perspective of environmental criminology propagated mainly by Brantingham and Brantingham (1975, 1981, 1993). They introduced new concepts that consist of diverse urban forms, including node, path, edge, and environmental backcloth, to explain the effect of the physical characteristics on crimes. These concepts are quite similar to the factors of urban form, as suggested by Lynch (1960), and accentuate the importance of factors in urban planning that mainly investigates the physical characteristics of urban spaces. There have been a number of empirical studies that investigate the relationship between urban planning factors and crime incidence based on the environmental criminology perspective. Spatial factors that have earned much of the research interests were spatial connectivity (Cozens and Love, 2009; Hiller and Shu, 2000; Johnston and Bowers, 2010), mixed land use (Taylor et al., 1995; Novak and Seiler, 2001; Lockwood, 2007), zoning (Paulsen, 2011), and public spaces, such as parks and pedestrian paths (Chapin, 1991; Hilbron, 2009).

In spatial sciences like environmental criminology, a prominent theoretical argument should be in parallel with a suitable method when it tries to secure its academic domain. There have been interdisciplinary efforts in the fields of geography, urban planning, and criminology to address the causal relationship between the physical environment and crime incidence. The relationship between crime and place is neither uniform nor static. As discussed before, crime incidence tends not to be randomly scattered over space but is clustered in certain areas. This concentrated pattern of crime incidence requires researchers to take two spatial phenomena into consideration, that is, spatial dependence and spatial heterogeneity (Anselin, 1988), if they want to investigate the causes of crime incidence using aggregated data.

Spatial dependence refers to the most common form of spatial effect, in which events in a location influence other events in other locations. Spatial heterogeneity, another form of spatial effect, implies that the stability of relationships may vary depending on geographical characteristics such as size, adjacency, etc. As one of the pioneering scholars in this field, Anselin (1988) proposed a way of identifying spatial effects in diverse empirical settings. More

recently, huge efforts have been made to explore the local effects of independent variables that affect crime incidence to correct the statistical caveats of spatial heterogeneity (Brownning et al., 2010; Cahill and Mulligan, 2007; Graif and Sampson, 2009; Hipp, 2007; Hooghe et al., 2011).

The following section explains the spatial econometrics models that are suitable for our data when spatial dependency and spatial heterogeneity are assumed to be present.

III. Methodology and Data

1. Methodology

Theories to explain the causes of crime are largely divided into microscopic and macroscopic methods. Microscopic methods focus on the individuals or actors, while macroscopic methods place more emphasis on social and structural factors. This categorization makes sense from the data structure viewpoint, as individual crime data are microscopic, while data on specific areas or nations are macroscopic. The spatial characteristics of the incidence of crime are critical when using macroscopic data on a regional scale. Crime is closely related to spatial characteristics and tends to concentrate in specific spaces due to spatial interaction or geographic dependence. Thus, the non-spatial model, such as the ordinary least square, may lead to biased and inconsistent estimates (Anselin, 1988).

Spatial autocorrelation is a method to validate the effectiveness of an empirical application of spatial econometrics models. Several indices are available for the autocorrelation test, but Moran's I, Geary's C, and Getis and Ord's G are the most widely used. The present study adopted Moran's I to test the spatial autocorrelation of the incidence of crime in our data. The results showed that the geographical dependence of violent crime incidence was significant at $p < .01$ (Table 1). This result shows that it is necessary to adopt spatial econometric models for the present study. Among the various spatial econometrics models that incorporate the characteristics of spatial dependency, the present study adopted three representative spatial econometrics models, such as the spatial autoregressive regression model (SAR), the spatial error model (SEM), and the spatial autoregressive confused model (SAC); the Durbin models, including the spatial Durbin model (SDM), the spatial Durbin error model (SDEM), and the spatial Durbin autoregressive confused model (SDAC), as well as the spatial lag of X (SLX) model are explained in the following section.

Table 1 Result of Spatial Autocorrelation Analysis

Year	Moran's I	p-value
2005	0.2266	0.0000
2010	0.1981	0.0000
2015	0.2467	0.0000

To identify spatial autocorrelation, it is important to define a spatial weight matrix, which represents the spatial effects. A spatial weight matrix defines spatial proximity based on the assumption that geographically adjacent areas have a high level of spatial interaction between them. The spatial weight matrix can vary in type. It is recommended to adopt a spatial weight matrix to verify whether the spatial effects are appropriately reflected by comparing the results from the application of diverse matrices. Thus, many studies that utilize spatial econometrics models have applied multiple spatial weight matrices in their empirical applications (Dubin, 1988; Can, 1992; Kim and Lee, 2013).

The present study adopted the inverse distance matrix. Due to the lack of data for rural regions, not all regions analyzed in this study were adjacent. Therefore, it is not appropriate to utilize the contiguity matrix. The inverse distance matrix was formed based on distance, where $W_{ij} = 1/d_{ij}$. The weight matrices were row-standardized to avoid probable scale effects.

The standard spatial econometric models are the SAR, the SEM, and the SAC, which have been explained in detail by LeSage (1999). They are the same in their fundamental concept but differ in the way they control spatial dependency and spatial autocorrelation.

The first model is the SAR, as shown by Eq. (1). This model assumes that observations adjacent to each other should reflect a greater degree of spatial dependence than those that are more distant, where Y is a $n \times 1$ vector of the dependent variable and X denotes a $n \times k$ matrix of the explanatory variables. W represents the spatial weight matrix containing distance. The scalar ρ is a coefficient on the spatially lagged dependent variable, and β denotes a parameter vector estimated from the explanatory variables.

$$\begin{aligned} Y &= \rho WY + X\beta + \epsilon \\ \epsilon &\sim N(0, \sigma^2 I_n) \end{aligned} \qquad (1)$$

The second model is the SEM represented by Eq. (2). This model is based on the assumption that the disturbances exhibit spatial dependence, where the scalar λ is a coefficient on the spatially correlated errors.

$$\begin{aligned} Y &= X\beta + u \\ u &= \lambda W u + \epsilon \\ \epsilon &\sim N(0, \sigma^2 I_n) \end{aligned} \quad (2)$$

The third model is the SAC represented by Eq. (3), which includes both spatial lag and spatially correlated error terms. This model accommodates spatial dependence in both the dependent variable and error terms. The SAC model can be described in vector form by using the following two-stage formulation: W_1 and W_2 are two spatial weight matrices.

$$\begin{aligned} Y &= \rho W_1 Y + X\beta + u \\ u &= \lambda W_2 u + \epsilon \\ \epsilon &\sim N(0, \sigma^2 I_n) \end{aligned} \quad (3)$$

In this study, the Durbin type SAR and SEM models were used, and the SAC and SLX models were also utilized. Durbin-type models account for the exogenous and endogenous interactive effects (Lesage and Pace, 2009).

The first Durbin type model is the SDM represented by Eq. (4). Θ indicates the spatial correlation coefficient of the independent variables.

$$\begin{aligned} Y &= \rho W Y + X\beta + WX\theta + \epsilon \\ \epsilon &\sim N(0, \sigma^2 I_n) \end{aligned} \quad (4)$$

The SDEM is represented by Eq. (5). It accounts for spatial dependence among the error terms and the exogenous interactive effect.

$$\begin{aligned} Y &= X\beta + WX\theta + u \\ u &= \lambda W u + \epsilon \\ \epsilon &\sim N(0, \sigma^2 I_n) \end{aligned} \quad (5)$$

The SDAC model can also be extended as the SAR and SEM models did. The SDAC is represented by Eq. (6).

$$\begin{aligned} Y &= \rho W_1 Y + X\beta + W_1 X\theta + u \\ u &= (I_n - \lambda W_2)^{-1}\epsilon \\ \epsilon &\sim N(0, \sigma^2 I_n) \end{aligned} \quad (6)$$

The SLX model assumes no endogenous interactive effects or spatial dependence in the error terms. It only incorporates the exogenous interactive effects into the linear regression model. The SLX model is described in vector form as Eq. (7).

$$Y = X\beta + WX\theta + \epsilon$$
$$\epsilon \sim N(0, \sigma^2 I_n) \quad (7)$$

2. Data and Variables

This study investigated the incidence of violent crime in Korea during 2005, 2010, and 2015. The dependent variable of the study was a violent crime as defined by the Supreme Prosecutors' Office of the Republic of Korea (SPO). Violent crime in this study refers to a broad range of acts of illegal violence encompassing murder, burglary, arson, sexual violence, assault, and kidnapping. Most previous studies used the crime rate as the primary indicator of the incidence of crime. However, this study adopted the number of incidents of violent crime in an area as the dependent variable. Such an approach reflects the fact that the police deploy a force based on the number of occurrences of crime rather than the crime rate (Shin, 2019).

Figure 1 depicts the subject regions of the present study. The two panels on the left side are data from the SPO, and there were 116 areas in 2005 and 2010. The data in the right panel came from the SPO and the National Police Agency of Korea (KNPA). The number of subject regions was 145 in 2015.

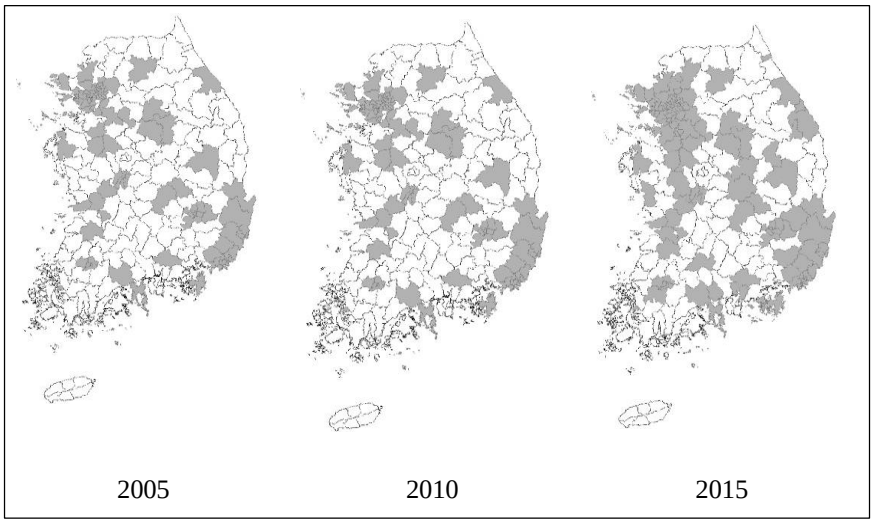

Figure 1 The Research Subject Regions, 2005-2015

All variables applied in this study were selected based on the theoretical and empirical validity of previous studies and the availability of relevant data. The independent variables were categorized into demographic, socioeconomic, and

spatial factors. The demographic variables included the population, the proportion of foreign residents, the proportion of seniors older than 65-years-of-age, the proportion of females, the divorce rate at the regional level, and the percentage of single-person households.

The socioeconomic variables included the proportion of the population with a college degree, the employment rate, the per capita local property tax, and the proportion of the population who had migrated from other regions. As data representing the economic status of the regions were not available, per capita property tax by region was adopted as an independent variable to denote the wealth of a region. The spatial variables included the ratio of hotel and restaurant establishments to the total number of businesses in the region and regional road accessibility.

Most of the independent variables were aggregated data derived from Statistics Korea, an official government agency. Using 2% randomly sampled microdata extracted from the Population and Housing Census by Statistics Korea, variables such as the immigration rate, the proportion of residents with a college degree, and the employment rate were adopted. The road accessibility data were derived from the Korea Transport Institute (KOTI).

The indicator of road accessibility was estimated based on Eq. (8), where n represents the number of Korean regions and the KOTI-derived road accessibility of 247 regions. T_{ij} denotes the time spent between region i and region j passing through roads, and T_{ik} indicates the time required between region i and region k when using the roads. O_i represents the number of passengers whose origin is region i, and D_i is the number of people whose destination is region i.

$$Road_i = \frac{1}{2(n-1)}\left(\sum_{j=1, j\neq i}^{n}\frac{O_i}{T_{ij}} + \sum_{k=1, k\neq i}^{n}\frac{D_i}{T_{ik}}\right) \qquad (8)$$

The ex-ante assumptions regarding the effects of the independent variables on the occurrence of violent crime provide useful insight. It is expected that the increase in the population will increase the number of crimes with a positive effect on the potential victims of crime (Andresen, 2006). Therefore, regions with larger populations would be faced with a higher incidence of crime.

As shown by Valier (2003), the size of the foreign population is likely to be positively associated with the level of crime. In Korea, problems associated with illegal stay or illegal employment tend to rise with economic development and status within the international community (Ha, 2017). Furthermore, the rate of increase in the crime rate of foreigners exceeded that of foreign residents in 2015 (Lee, 2020). However, some studies insist that the statistical association

between the number of foreign residents and the rise in the crime rate is rather weak (Leiva et al., 2020). As a result, the impact of a higher proportion of foreigners cannot be easily predicted.

Crimes that target older adults are rising in Korea (Ko, 2016; Lee, 2010). The rate of gender-based violent crimes that target women is also rising drastically (Kim et al., 2014). Crime is more frequent in socially disorganized areas, such as regions with a high divorce rate, due to the lack of a voluntary monitoring function (Cheong and Park, 2010; Lee and Lee, 2009; Sampson, 1985; Smith et al., 2000). Thus, there is a likelihood that crime would be higher in regions where the proportions of older adults and women, and the divorce rates, are high.

Table 2 Description of Variables

Variables			Definition
Dependent Variable		VIO CRIME	Number of violent crimes occurred by region (Unit: 100 cases)
Independent Variables	Demographic Variables	POP	Population (Unit: 10,000 people)
		FOREIGN	Number of foreign residents (Unit: 1,000 people)
		OLD	Proportion of residents over 65 years
		FEMALE	Proportion of female population
		DIVORCE	Divorce rate
		S_HOUSE	Proportion of single-person households
	Socio-economic Variables	COLLEGE	Proportion of residents with a college degree
		EMP	Employment rate
		TAX	per capita property tax by region (Unit: 10,000 won)
		IMMIG	Proportion of residents migrated from other provinces
	Spatial Variables	ENTER	Proportion of restaurant and hotel establishments
		ROAD	Road accessibility

In Korea, the proportion of single-person households is continuously increasing and accounted for nearly 30% of all Korean households in 2019 (KOSIS). Choi and Park (2018) revealed a positive relationship between the proportion of single-person households and the occurrence of sexual violence. Violent crimes are more likely to occur within regions where the proportion of single-person households is higher.

Among the socioeconomic variables, the proportion of residents who are college graduates is likely to decrease the incidence of violent crime, as the cost of committing a crime is higher for highly educated people (Lauridsen et al., 2013). Indicators of economic deprivation, such as the unemployment rate, often have strong and significant effects on the crime rate (Blau and Blau, 1982; Hooghe et al., 2011; Messner, 1982; O'Brien, 1983; Sampson, 1985; Williams, 1984). Therefore, the likelihood of crime occurring would be higher in regions with higher unemployment rates. Moreover, Choi and Park (2018) revealed an apparent relationship between poverty and the incidence of crime.

The incidence of crime increases with deteriorating economic circumstances (Kwon and Jeon, 2016). Therefore, it is anticipated that violent crimes are less likely to occur in affluent neighborhoods. Some studies have shown that regions with a continuous inflow of migrants tend to have more crime (Lee and Choi, 2019; Warner and Pierce, 1993). However, Park (2018) insisted that the recurrent movement of the population weakens social exchange and the sense of belonging to a region, which lowers the possibility of collective action occurring to prevent crime. Accordingly, the direction of the effect of the proportion of migrants on the incidence of crime is uncertain.

Considering the spatial variables, this study assumed that the type of local industry is closely associated with the likelihood of crime. The proportion of hotel and restaurant establishments is likely to positively affect the incidence of burglary and sexual violence (Cheong, 2013). Lee and Cho (2006) also revealed the relationship between the regional industrial structure and the incidence of crime. Such findings suggest that violent crimes are more likely to occur in regions where hotels and restaurants are highly concentrated. The direction of the effect of road accessibility on the occurrence of crime is uncertain; a higher level of spatial accessibility may allow criminals to escape from a crime scene (Johnston and Bowers, 2010), but it may also boost crime prevention by facilitating preventive activities, such as police patrols (Cozens and Love, 2009).

IV. Results

1. Incidence of Violent Crimes in Korea

According to a survey carried out by Statistics Korea (2018), 20.6% of Koreans consider crime the most serious threat to their social security. A series of SPO internal data indicated that there have been approximately 200,000 cases of violent crime per annum over the past 15 years (2005–2019) in Korea. The total number of violent crimes in 2005 was 299,615, and the number slightly decreased to 267,382 in 2019. On average, 279,333 incidents of crime occur

annually. However, heinous crimes (murder, burglary, arson, and sexual violence) increased by 75.8% from 19,941 to 35,066 during the period. In general, the total number of violent crimes has been maintained with slight fluctuations, but heinous crimes have increased significantly during the last 15 years. This indicates a social trend that heinous crimes are becoming more frequent in Korea over time.

The incidence of violent crime varies by region in Korea. Figure 2 presents the geographical distribution of violent crimes from 2005 to 2015. Due to the unavailability of data for rural regions, the focus of the analysis was narrowed to urban areas. In general, violent crimes are concentrated in the Seoul Metropolitan Area (SMA) and Southeastern Korea. Such a geographical tendency is likely to stem from the huge differences in population size by province.

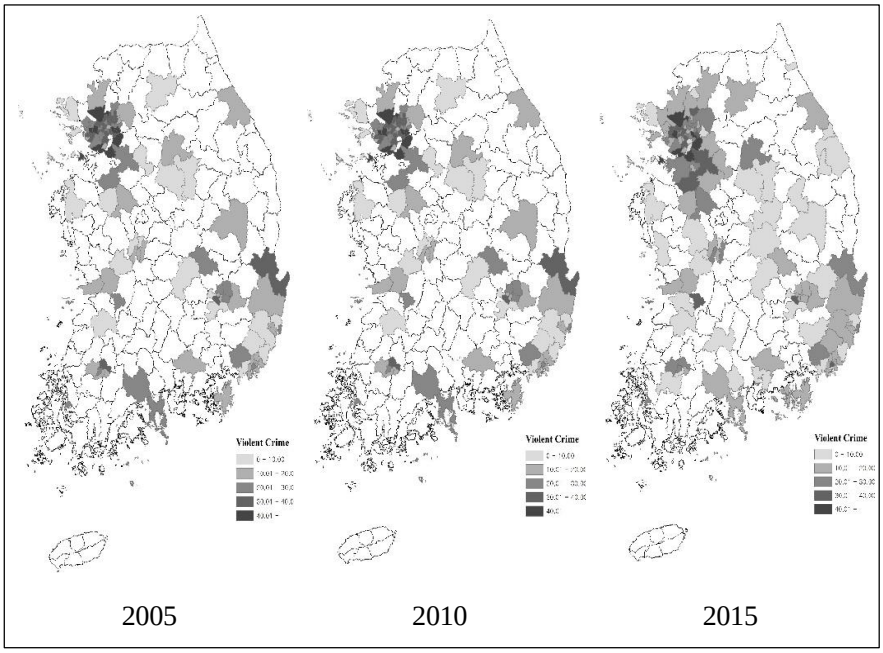

Figure 2 Violent Crime Incidence by Regions in Korea, 2005-2015

Since 2005, the region with the highest number of crimes has been Bucheon city located in SMA. A total of 6,781 cases of violent crime occurred in Bucheon in 2005. However, the most crime-prone area in 2010 and 2015 was Suwon city, also located in SMA. Gangnam-gu is one of the most affluent districts in Korea but ranked high in crime during 2010 and 2015.

Table 3 Top Five Regions With the Highest Incidence of Violent Crime, 2005-2015

	2005		2010		2015	
Rank	Region	Incidence	Region	Incidence	Region	Incidence
1	Bucheon	67.81	Suwon	63.76	Suwon	75.85
2	Suwon	67.75	Bucheon	58.94	Ansan	55.35
3	Seongnam	54.53	Seongnam	52.25	Seongnam	53.92
4	Goyang	49.24	Gangnam	46.98	Bucheon	52.93
5	Bupyeong	46.73	Goyang	43.21	Gangnam	46.70

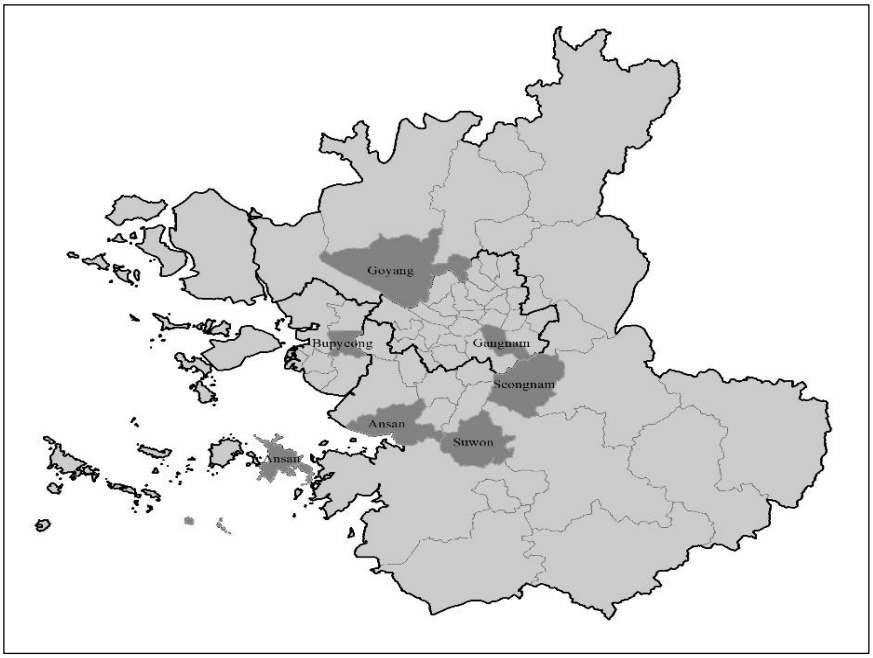

Figure 3 Top Regions With the Highest Incidence of Violent Crime

Table 4 shows the descriptive statistics for the variables. The average number of violent crimes among the study regions was 21.44 in 2005, and the number decreased continuously to 17.61 in 2015. In contrast, the proportion of foreign residents increased, comprising nearly 7% of the population. The proportion of older adults has also increased, as Korea has become an aging society. The ratio

of female residents was constant at 51%. The divorce rate continuously decreased from 2.65 to 2.12 during 2005–2015. Such a trend reflects the fact that, in contrast to the 2000s, the change in the divorce rate stabilized in the 2010s (Kim and Yim, 2020). That said, the mean proportion of single-person households increased. More than one-quarter of residents in the subject regions were living alone in 2015.

The average proportion of the population with at least a bachelor's degree or higher has been increasing in Korea. This can be regarded as an improvement in the regional average educational attainment level. The average employment rate has also increased by more than 5% between 2005 and 2015m while the standard deviation decreased. Moreover, the average property tax per capita gradually increased. In 2005, residents paid about KRW 57,000 in property taxes, but the amount increased to about KRW 155,500 in 2015. In particular, the standard deviation increased more than three times. One possible explanation is inflation, but it is more likely to reflect the aggravated property-value-related inequality among different regions. In contrast, the mean proportion of the population who have migrated from other provinces has decreased over time. This presents a social phenomenon of decreasing regional mobility.

The average ratio of hotel and restaurant establishments decreased throughout the analysis. In 2005, hotels and restaurants occupied about 20% of local businesses, but the proportion diminished by about 2.5% in 2015. Average road accessibility also decreased during the same period, but such an observation was related to the data obtained from the KNPA, which are limited to relatively small cities.

Developing countries would need Korea's help to achieve both economic growth and environmental protection; conversely, the developed countries would try to create more favorable conditions for them using Korea, a developing country, and its climate change public policy. Recently, more developed countries have shifted from hard diplomacy to soft policies to extol the importance of public diplomacy (Signizer & Wamser, 2006). This supports Ma (2011) argued that "the understanding and support on foreign policy from the people has increased, which means that the public is now included as a part of the public policy."

Table 4 Descriptive Statistics of Variables

	2005				2010				2015			
Variables	Mean	S.D	Min	Max	Mean	S.D	Min	Max	Mean	S.D	Min	Max
Vio Crime	21.44	13.13	0.56	67.81	18.03	11.81	0.69	63.76	17.61	11.88	0.59	75.85
Pop	33.34	19.00	1.56	104.56	34.49	20.03	1.87	107.75	30.87	20.88	2.10	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
Old	9.58	4.30	3.78	26.27	11.90	4.75	5.12	28.47	16.17	7.06	6.63	37.75
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
Divorce	2.65	0.44	1.80	4.10	2.30	0.34	1.60	3.50	2.12	0.39	1.30	3.50
S_house	19.84	4.28	12.1	32.6	24.00	4.93	14.2	39.6	27.65	5.21	17.3	46.3
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
Tax	5.70	5.26	2.20	38.35	10.01	9.92	3.06	65.48	18.52	15.55	6.68	123.03
Immig	17.94	7.35	5.36	49.70	15.84	5.57	5.62	31.74	14.34	5.37	5.27	34.84
Enter	20.72	4.57	9.16	41.37	19.91	4.34	8.61	36.63	18.29	4.45	6.82	37.74
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 the Incidence of Violent Crime

Table 5 shows the regression results of the SAR, SEM, and SAC models. The goodness-of-fit tests based on Akaike's Information Criterion and the Bayesian Information Criterion revealed that the SAC model possessed the highest explanatory power among the three models. However, the significance of rho, lambda, and the LM test result that assesses the presence of spatial dependence and autocorrelation support the validity of the SEM model during all three periods. For this reason, this study presents interpretations of the regression results solely focusing on the SEM model. The results show how the number of violent crime cases changed with the change in the independent variables. Although some results differed, the effects of the independent variables on crimes in Korea generally matched our expectations.

Table 5 SAR, SEM, SAC Results of Violent Crime, 2005-2015

	2005			2010			2015		
	SAR	SEM	SAC	SAR	SEM	SAC	SAR	SEM	SAC
Intercept	-2.8068	-3.0448	-3.6090	-12.2411	-8.0030	-8.5127	-41.8765	-38.7392	-27.4129
Pop	0.4110***	0.3804***	0.3935***	0.3669***	0.3597***	0.3702***	0.3360***	0.3763***	0.3869***
Foreign	0.3275	0.2948	0.2973	0.2480**	0.2296**	0.2320**	0.3085***	0.2486***	0.2582***
Old	-0.6892***	-0.6273***	-0.6472***	-0.4405**	-0.3404*	-0.3977**	-0.5213***	-0.2733**	-0.3116***
Female	0.6039	0.6272	0.5858	0.6782	0.4818	0.4925	1.1237**	0.6027	0.5595
Divorce	-0.5787	0.9411	0.5036	-0.2962	1.0456	0.2732	0.7194	3.6870***	1.7989
S_house	0.2371*	0.1960	0.2184	0.2562**	0.2215*	0.2724**	0.1702*	0.1611**	0.1907**
College	-0.5362***	-0.5307***	-0.5497***	-0.6030***	-0.5273***	-0.5583***	-0.3469**	0.0129	-0.0671
Emp	-0.3664**	-0.3240**	-0.3424**	-0.3054*	-0.2010	-0.2558	-0.1065	0.0696	-0.0665
Tax	0.0599	-0.0280	0.0116	0.1188	0.0699	0.1015	0.0568	0.0051	0.0350
Immig	-0.3208***	-0.2567***	-0.2759***	-0.3159***	-0.2258**	-0.2900**	-0.2144**	-0.3044***	-0.3409***
Enter	0.1465	0.1945*	0.1942*	0.2862***	0.2694**	0.2709**	0.3169***	0.1092	0.1527**
Road	7.8351***	9.9315***	9.2727***	7.4036***	8.2897***	7.4167***	4.7306***	3.6693***	2.3459**
ρ	0.4038***		0.2352	0.3339**		0.3195*	0.0429		0.2209**
λ		0.8470***	0.7616***		0.6567**	0.5071		-3.4268***	-3.8880***
LM(lag)	13.37***		1.42	5.23**		4.28**	0.09		6.56**
LM(error)		52.32***	13.29***		5.52**	2.45		4.04**	6.74***
AIC	717.3455	712.0702	712.8925	711.2050	712.3331	711.3988	843.8450	834.2185	830.8170
SBC	758.6493	753.3741	756.9499	752.5088	753.6370	755.4562	888.4960	878.8695	878.4447
N		116			116			145	

*** p<.01, ** p<.05, * p<.1.

The number of inhabitants was positively associated with the incidence of violent crime ($p < .01$). The proportion of foreign residents was positively related to violent crime in 2010 and 2015, but not in 2005. In contrast, unlike the prior expectation, the proportion of older adults was negatively associated with violent crime. The proportion of females tended to be positively correlated with the incidence of crime, but no statistical difference was observed. As proposed by the social disorganization theory, the breakup of families can lead to a higher level of crime. This theory supports the observation in Korea that the number of divorcees had a positive effect on the incidence of crime. Furthermore, more violent crimes occurred where the ratio of single-person households was high. This finding agrees with the ex-ante expectation that single-person households are more vulnerable to crime.

Among the socioeconomic variables, the educational level of the residents was a significant determinant of violent crime during all periods. Employment had a negative effect on the incidence of violent crime in 2005 and 2010, but the sign turned positive in 2015 with no statistical significance. The per capita property tax had a positive effect on the incidence of crime, but no statistical significance was detected. This finding indicates that the association between a region's level of wealth and the level of crime is uncertain. In contrast, the proportion of inhabitants migrating from other regions was negatively associated with the occurrence of violent crime ($p < .05$ dung all periods). Such a finding supports the statement that crimes are more frequent in regions with a stable inflow of a new population.

All of the spatial variables were positively correlated with the incidence of violent crime. The high concentration of hotel and restaurant establishments and better road accessibility had positive effects on crime. This observation suggests that the type of predominant business and the road accessibility level can make areas more vulnerable to violent crime.

Table 6 shows the results of the SDM, SDEM, SDAC and SLX models. The SDM and the SLX models accounted for the exogenous and endogenous interactive effects. The SDAC model exhibited the highest explanatory power among the models during 2005 and 2015, whereas the results of rho, lambda, and the LM test were significant in the SDEM model during all periods. Therefore, this study focused on interpreting the results based on the SDEM model.

Table 6 SDM, SDEM, SDAC, SLX Results of Violent Crime, 2005-2015

	2005				2010				2015			
	SDM	SDEM	SDAC	SLX	SDM	SDEM	SDAC	SLX	SDM	SDEM	SDAC	SLX
Intercept	-373.406	-430.760*	-247.868	-432.12	-524.794	-437.689	-394.927	-391.394	231.371	799.899**	705.213**	441.598
Pop	0.3700 ***	0.3547 ***	0.3699 ***	0.3650 ***	0.4109 ***	0.4237 ***	0.4221 ***	0.4035 ***	0.3231 ***	0.3187 ***	0.3304 ***	0.3008 ***
Foreign	0.2592	0.5741 **	0.4358	0.3228	0.3003 ***	0.2822 ***	0.2775 ***	0.2849 ***	0.3107 ***	0.3198 ***	0.3039 ***	0.3425 ***
Old	-0.6650 ***	-0.7985 ***	- ***	-0.6959 ***	-0.5058 ***	-0.4501 ***	-0.4427 **	-0.4767 ***	- ***	-0.5572 ***	-0.5071 ***	-0.550 ***
Female	0.9697 *	1.3494 **	1.0743 **	1.1070 *	0.8344	0.5517	0.5107	0.6805	0.7957 **	0.9953 **	0.8527 **	0.8694 *
Divorce	1.4802	-0.0813	0.4841	1.1162	-1.4520	-0.7330	-	-1.3348	0.6187	-0.0962	0.3095	-0.485
S_house	0.0664	-0.0236	0.0663	0.0327	0.2432 **	0.2589 **	0.2600 **	0.2458 **	0.1162	0.1203	0.1221	0.1119
College	-0.6154 ***	-0.8017 ***	-0.7213 ***	-0.6478 ***	-0.7351 ***	-0.6551 ***	- ***	-0.7160 ***	-0.3336 ***	-0.4398 ***	-0.3828 ***	-0.451 ***
Emp	-0.1951	-0.3189 **	- *	-0.2187	-0.2242	-0.2320	-0.2356	-0.2372	-0.1711 *	-0.1231	-0.1515	-0.192
Tax	-0.0672	0.0377	0.0166	-0.0513	0.1818 **	0.1657 **	0.1620 **	0.1691 **	0.0428	0.0519	0.0447	0.0615
Immig	-0.3229 ***	-0.3549 ***	-0.3375 ***	-0.3326 ***	-0.4132 ***	-0.4133 ***	- ***	-0.3956 ***	- ***	-0.2461 ***	-0.2774 ***	-0.254 ***
Enter	0.2091 *	0.3017 **	0.2773 **	0.2059	0.3026 ***	0.2336 **	0.2285 **	0.2932 ***	0.3372 ***	0.3373 ***	0.3289 ***	0.4088 ***
Road	10.9478 ***	10.8867 ***	10.7071 ***	10.8595 ***	6.0094 ***	5.1366 ***	5.1942 ***	6.2979 ***	5.8767 ***	6.3076 ***	6.1437 ***	6.3091 ***
W_pop	-0.3083	-0.3577	-0.5755	-0.1745	0.7991	0.6337	0.5666	0.5372	2.3032 ***	0.2821	1.9016 ***	0.4389
W_foreign	-4.4868	5.1490	1.5602	-2.7148	0.9796	1.4156	1.2877	0.4571	-0.0519	-0.8843 *	-0.1404	-1.167 *
W_old	-3.3602	-6.0422 **	-	-4.0684	-1.1946	0.2192	0.4013	-0.7375	2.0291 *	4.6331 ***	4.0051 ***	3.1150 **
W_female	8.9285	19.7639 ***	13.1343 **	11.484	13.2511 *	11.0578 *	10.1938	10.5582	-5.8390	-15.579 ***	-14.622 ***	-8.059
W_divorce	-25.739	- ***	-58.339 ***	-33.746 *	-39.038 **	-36.555 **	-36.637 **	-39.975 **	22.1577 *	21.2863 **	33.1991 ***	3.5654
W_s_house	-1.1914	-4.1547 **	-3.3601 **	-1.6637	-1.7273	- **	-2.5893 **	-1.7217	-1.0050	-2.6844 ***	-1.8334 **	-2.406 **
W_college	-0.4960	-5.2961 *	-3.6212	-1.1709	-2.0510	-	-0.8617	-1.7593	2.3302 **	3.1292 ***	3.4538 ***	1.8264
W_emp	3.7042 *	-0.0119	0.5162	3.3578	1.2635	1.3737	1.3965	1.4272	-0.2372	-2.1668 *	-1.9195 *	-0.659
W_tax	-4.4683 *	-1.6964	-3.0146	-3.8577 *	0.3671	1.1278	1.0662	0.0437	-	-0.7124 *	-0.6473 *	-0.708
W_immig	-2.3830 *	-3.4101 ***	- **	-2.6178 **	-3.8458 **	- ***	-4.3596 ***	-3.3962 **	-2.0317 **	-0.8735 *	-2.3022 ***	-0.530
W_enter	-4.8194 ***	-4.8870 ***	-4.3563 **	-5.0688 ***	-1.0470	-	-	-1.4438	-1.5121	-1.5697 *	-1.1809	-2.414 **
W_road	32.9479 **	32.2146 **	32.252 **	33.2838 **	17.794	6.0268	5.9393	17.6953	15.4419	14.7535	21.8056 **	11.151
ρ	0.4437		0.6882 ***		-		0.1198		- ***		-3.2614 ***	
λ		-2.3525 **	-2.7412 ***			-2.3629 ***	-2.4450 ***			-4.2098 ***	-3.4539 ***	
LM(lag)	1.94		8.48 ***		0.8		0.06		19.12 ***		10.92 ***	
LM(error)		1.8	5.08 **			4.91 **	4.28 **			16.23 ***	7.72 ***	
AIC	699.6751	697.6706	693.5048	699.3824	699.6018	692.7687	694.7064	698.4830	809.3654	812.7695	797.2012	839.2626
SBC	774.022	772.0175	770.6053	770.9758	773.9488	767.1156	771.8069	770.0764	889.7372	893.1413	880.5497	916.6576

Most of the endogenous effects presented similar results. However, the divorce rate was negatively associated with crime in contrast to that of the basic spatial linear regression models, but no statistical significance was detected. The proportion of single-person households had a negative effect on the incidence of crime in 2005, although it lacked statistical significance. As most of the independent variables presented analogous endogenous effects, this section mainly discusses the exogenous effects.

Among the demographic variables, the population had a negative effect on the incidence of crime in 2005, but a positive association was observed for cases in 2010 and 2015, indicating that an increase in population in one region could lead to a higher incidence of crime in adjacent areas. The proportion of foreign residents had a positive exogenous effect in 2005 and 2010, but the effect became negative in 2015 ($p < 0.1$). Unlike the endogenous effect, the ratio of the older population positively affected the incidence of crime in adjacent regions during 2010 and 2015. The rise in the number of female inhabitants had a positive effect in 2005 and 2010, but a negative effect was found in contiguous areas in 2015. The divorce rate negatively affected the incidence of crime in adjacent areas as an endogenous effect, but it positively affected other regions in 2015. The proportion of single-person households negatively affected the occurrence of violent crime in adjacent regions during all years.

The proportion of residents with at least a bachelor's degree had a negative effect on the incidence of violent crime in contiguous regions during 2005 and 2010, but such an effect was positive ($p < .01$) in 2015. The employment rate and the mean property tax per person had a negative effect on the occurrence of violent crime in 2010. However, these variables positively affected other regions in 2005 and 2015. The increase in the proportion of residents migrating from other provinces negatively affected the incidence of crime in contiguous areas regardless of the time.

The proportion of hotel and restaurant establishments negatively affected the occurrence of violent crime in adjacent regions during all years. However, improvements in road accessibility in one area caused more crime in neighboring cities.

V. Conclusion

The criminal policy should focus more on possible preventive measures rather than the post-hoc follow-up after an incident (Ha, 2017; Kim and Lee, 2011). This study investigated the determinants of violent crime in Korea, focusing particularly on spatial planning effects on crime. As the incidence of crime is closely related to the spatial characteristics of a city, spatial econometrics models

were applied to incorporate regional characteristics into the statistical models. The major spatial variables adopted in this study were the proportion of hotel and restaurant businesses and road accessibility.

The major findings of this study are summarized as follows. First, population size and the proportion of foreign residents were important factors identifying the incidence of violent crime, suggesting that more foreigners and women reside in areas where the level of violent crime was higher. The increase in single-person households led to more violent crimes. As regions with single-person households are vulnerable to crime, it is recommended to reinforce the surveillance and security systems in the areas where this type of housing is concentrated.

Second, the effect of spatial variables that identify violent crime proved to be highly effective. The increase in the number of hotel and restaurant businesses was positively associated with the incidence of crime. This is probably because the use of these industries leads to increased consumption of alcoholic beverages, which can provoke people to commit a crime. In addition, the enhancement of road accessibility has a positive effect on crime.

It is worth highlighting that the road accessibility variable developed in this study was not only statistically significant but also was found as a factor possessing the greatest explanatory power in crime incidence. Unlike previous studies that attempted to control spatial factors using diverse variables, this study is unique in that it developed and applied a single index that encompasses both socioeconomic and spatial characteristics. Such an innovative attempt allows concise interpretation of the results, which is especially useful in drawing policy implications for crime prevention in a clear manner.

The present study focused on the spatial effects of the incidence of violent crime and suggested some important implications for urban planners and policymakers. First, land use restrictions, if necessary, should be lifted to develop residential areas and prevent crime. If the government allows people to establish hotel and restaurant businesses without appropriate regulations, the incidence of aggregate crimes may soar. Therefore, commercial districts should be properly controlled by urban planning laws that regulate the maximum number of entertainment establishments and accommodations to reduce crime. Second, it is necessary to reinforce the surveillance system in regions with high road accessibility.

Monitoring is an important part of forestalling crime, while developed roads allow criminals to escape more easily (Lee, 2011). Therefore, enhancing the efficiency of monitoring in regions with high road accessibility could prevent crime. Furthermore, the Korean government should consider implementing Community Crime Watch (CCW) programs, which are designed to motivate neighborhood residents who witness suspicious behavior and crime to report such activities to law enforcement and are intended to increase informal and

formal crime control. Crime watch approaches have become the most prevalent means of citizen crime control and prevention at the neighborhood level in the United States (Louderback and Roy, 2018). CCW programs are expected to increase informal neighborhood social control and social cohesion, which will result in elevated collective efficacy among residents.

Some limitations of this study should be discussed. One is the unavailability of rural data. Owing to the lack of spatial data for rural regions, the subject areas were limited to urban areas. Moreover, it was not possible to accommodate factors related to violent crime in a spatial context. One of the independent variables not utilized was income inequality. Many studies have reported that income inequality leads to more crime (Coccia, 2018; Hauner et al., 2012; Hooghe et al., 2011; Jang and Cho, 2019; Kim et al., 2014; Quimet, 2012). Although our findings remain relevant, these limitations may restrict the interpretation and applicability of the results. More detailed data and information related to income inequality would yield a result that is more accurate and closer to reality.

Spatial characteristics are the major determinants of crime. Further studies on the relationship between crime and urban planning policies are necessary to prevent crime and provide safer urban communities. Interdisciplinary studies between criminology and urban planning are essential to prevent crime in urban areas.

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