

A Weighted Displacement Quotient model for understanding the impact of Crime Prevention through Environmental Design

Evidence from Seoul, South Korea

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Weighted
Displacement
Quotient model

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Received 5 July 2016
Revised 21 October 2016
10 December 2016
15 January 2017
Accepted 20 January 2017

Abstract

Purpose – The purpose of this paper is to investigate the impact of Crime Prevention Through Environmental Design (CPTED), a crime prevention tool, on reducing rates of sexual assault. In addition, the study attempts to understand if CPTED results in crime displacement in non-target areas.

Design/methodology/approach – This research utilizes a Weighted Displacement Quotient (WDQ) model to analyze the effects of CPTED, which is an appropriate tool in fields of regional-scale crime prevention and on sexual assault prevention. WDQ is capable of analyzing policy effectiveness while controlling for geographical crime displacement, a known side effect of CPTED in the literature.

Findings – The analysis results show that CPTED is an effective tool to prevent sexual assaults in South Korea. The sexual assault occurrence rate decreased in the CPTED implementation zone of Yeomri-dong Mapo-gu. WDQ showed that crime displacement occurred in adjacent areas in Daeheung-dong and Ahyun-dong. But, crime displacement was lower than the policy effectiveness in the target zone.

Originality/value – The policy implications of this research are immense. First, CPTED for the prevention of sexual assaults should be considered as a pre-control tool. Second, a strategic method for more effectively implementing CPTED is required. Third, because CPTED is a policy done on a regional scale, provisions need to be in place to manage crime displacement.

Keywords Crime Prevention through Environmental Design, South Korea, Situational crime prevention, Interrupted time series, Weighted Displacement Quotient

Paper type Case study

1. Introduction: statement of the problem

Despite South Korea's rapid economic growth over the last 50 years, problems associated with democracy's social dysfunctions, such as inequality, urban crime, environmental degradation, and poverty, have grown significantly. Crime is particularly noticeable as a problematic social issue that directly hinders the quality of life. In addition, crime is becoming more pronounced as social media instantly broadcasts its incidence, which creates a strong negative perception about public safety and increases fear among citizens. The incidence of violent crimes[1] has increased from 19,539 cases in 2004 to 31,642 cases in 2013, which is a 61.9 percent increase over the course of ten years. The crime rate per 100,000 people has increased from 40.2 cases in 2004 to 61.8 cases in 2013, which is a 53.7 percent increase. Such increases in crime have eroded social trust, which in turn has intensified public pressure on local leaders and policy makers to mobilize all possible resources and provide effective policies to reduce crime and, thus, appease the public.



Policing: An International Journal
of Police Strategies & Management
Vol. 41 No. 1, 2018
pp. 41-57
© Emerald Publishing Limited
1363-951X
DOI 10.1108/PJPSM-07-2016-0100

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2016S1A3A2924832).

In response to the social pressure of creating a safer environment, various policies have been proposed – the most recent being the Crime Prevention through Environmental Design (CPTED) policy. The objective of this policy is twofold: to improve the local environment and secure citizens' safety by physically eliminating vulnerable spaces (e.g. dimly lit streets) that may promote criminal activities. This new policy strategy suggests that traditional crime prevention activities, such as walking beats, making arrests, and reallocating resources to crime hotspots, have been insufficient for reducing crime. Advocates of the CPTED policy believe that building smarter urban environments can help reduce crime induction factors (National Police Department, 2005). However, this method requires an interdisciplinary approach that borrows from studies on policies, public administration, criminology, architecture, and urban design – to name a few.

There is some empirical evidence that the CPTED policy has been a successful and viable tool for reducing crime rates in numerous global cities as well as in South Korea (Baek *et al.*, 2010; Kim *et al.*, 2011; Kim, 2007; Park, 2010; Shin and Kim, 2012). However, the previous work has not considered whether the CPTED policy is simply creating crime displacement. In other words, does the CPTED policy actually reduce overall crime or are the crimes dispersed to other locations? In this regard, if the crime rate decreases in one area by applying the CPTED policy but increases in a nearby non-CPTED implemented region, then geographical displacement of crime would yield a net zero in terms of community-wide benefits. In addition, if crime displacement occurs, then the CPTED policy only functions in the implementation zone and is probably not a suitable policy for society in general. To assess a new dimension of CPTED policy effectiveness, the present study uses the Weighted Displacement Quotient (WDQ), which allows us to analyze crime displacement and measure the overall impact of the CPTED policy on the rate of sexual assaults.

This study begins by examining the relationship between the theory of crime prevention and crime displacement and then reviews the literature on the CPTED policy. Then, we introduce the WDQ models and explain the selection of the experiment area, buffer area, and control region to measure the impacts of the CPTED policy beyond the implementation zone. Also, it addresses the CPTED policy's impacts on sexual assault prevention and crime displacement by analyzing the data. Finally, it concludes by discussing the CPTED policy's implications.

2. Theoretical considerations

2.1 *Situational crime prevention*

From the perspective of criminals, a "situation" is critically important if it combines a low risk for apprehension and high risk for gain. For example, a thief might steal fruit from a grocery store when the owner is not around, but the criminal's actions will be restrained if the owner can visually track the would-be criminal. Moreover, a bank robber might conduct surveillance to find the most appropriate bank that can be robbed. If probable targets have an equal risk, the robber will then select the easiest target with the least number of security agents, cameras, and alarms (p. 5). In brief, crime is affected by the opportunity structure according to the situation, and this point can be considered as a strategy for crime prevention (Choi and Kim, 2007, p. 151).

According to Clarke (1995), all the programs attempted to manage a criminal's cost/benefit rationale, that is, the most beneficial situation based on certain calculations and risks (p. 292). Clarke (1997) also stated that situational crime prevention includes the following three distinct components: it targets specific types of crimes; it manages, designs, and/or adjusts the environment systematically and continuously; and it increases the risk of arrest and difficulty of committing the offense, thus decreasing the "reward" associated with committing a crime. The basic idea of situational crime prevention is that the environment can be altered in ways that increase the criminal's risk, which in turn makes criminal actions less attractive. Situational crime prevention does not rely on societal improvements;

rather, it is a preventive approach that reduces crime opportunities and increases the risk of detection (Clarke, 1992, p. 4). It also focuses on the immediate environment, situations, or peculiarities that can be manipulated through lighting, design, and planning to prevent crimes.

Studies on situational crime prevention have presented certain differences to positive criminology (Kim, 2009, p. 1047). Such an approach has provided the police and crime prevention officers with strategies that can help reduce crime (while increasing the risk of arrests for criminals) by controlling the environment (Choi, 1998, pp. 181-182). Such situational crime prevention strategies that focus on the reduction of criminal opportunities include: rational choice theory, lifestyle theory, and routine activity theory. All three theories are rooted in deterrence and connected to human free will, utilitarian human perspectives, and rational decision making; that is, they reflect important perspectives regarding a criminal's reaction to a certain opportunity and assume that he/she behaves rationally toward risk and reward incentives.

Rational choice theory states that the criminal decision-making process is influenced by factors such as the effort required to commit the criminal act, potential benefits, willingness of accomplices to support the crime, risk of arrest or punishment, and personal desires. Lifestyle theory focuses on the dangers of crime according to people's social backgrounds, while routine activity theory focuses on how changes in people's daily routines, caused by changes in society, impact crime rates. The combination of the latter two theories is referred to as opportunity theory or criminal opportunity theory (Lee, 1995, p. 18). In this regard, Hinderlang *et al.* stated that criminal damage occurs in a specific location, time, and situation, and individuals are more likely to suffer from criminal offenses when their routines are continuously exposed to high-crime opportunity situations. As part of the routine activity theory, Cohen and Felson suggested the following three factors associated with crime occurrence: motivated offenders; suitable targets; and the absence of guardianship.

2.2 Crime displacement effect

The most negative latent consequence that may occur while using a situational crime prevention program is the crime displacement effect. The interest in crime prevention strategies that control environmental factors has expanded to include the types of crimes including the time, place, and methods that occur outside the area of intervention (Bowers and Johnson, 2003; Lee *et al.*, 2008, p. 265). The geographic displacement of crime and the diffusion of benefits received have gained significant scholarly interest (Barr and Pease, 1990; Clarke, 1992). In brief, crime displacement is understood as the "place, time, and type of crime changing into another form, due to social crime prevention activities".

Regarding crime displacement, some scholars have claimed that overall crime levels are not diminished by decreasing crime opportunities in a targeted area. Instead, crime is displaced into other locations or into different types of crimes. More specifically, criminals generally react to higher risks in one area by looking for different targets, locations, or times to continue their criminal activities. Thus, an observed decrease in crime in an urban hotspot might be offset by an increase in crime in neighborhoods that lack intervention. For example, an area equipped with closed-circuit televisions (CCTVs) might experience lower crime rates, but if crime is displaced into areas without such surveillance, then the overall crime rate does not drop. Accordingly, in situational crime prevention activities, displaced crime deducted from the total reduced amount of crime and reduced crime in consideration of displaced crime is referred to as the net preventive effect.

Crime displacement rests on the following three assumptions (pp. 74-75; Choi and Kim, 2007, p. 154): first, the amount of crime and crime type is inelastic and thus, a fixed amount of crime occurs in a fixed amount of time, and crime cannot be completely eradicated through crime

prevention activities. Second, criminals have various levels of mobility, which differ according to each potential criminal. Third, potential criminals have free will and intellectual abilities, as explained in the rational choice theory. Accordingly, potential criminals make rational decisions and nefarious decisions according to physical and social environmental factors, and during this process, a crime displacement phenomenon may occur.

Crime displacement can also be classified according to the following six types: spatial displacement; temporal displacement; target displacement; tactical displacement; perpetrator displacement; and types of crime displacement (Barnes, 1995; Choi and Kim, 2007; Lee and Kim, 2009). The most representative of these types is spatial displacement in which the enforcement of police activity or implementation of a crime prevention strategy that predicts the crime in a targeted area may be displaced into a nearby area. In general, criminals react to interventions by moving from an area that is highly prone to arrest/detection to an area with lower risks. For example, a sex offender might react to a new program that includes better street lighting and safety phones by relocating to a nearby area without such features. Since Gabor's "hierarchy of displacement" emphasized spatial displacement as the most important type of displacement (Barnes, 1995, p. 107), the present study analyzes whether spatial displacement of sex offenses occurs in areas that implement environmental designs in accordance with situational crime prevention theories.

2.3 CPTED

The CPTED policy is a crime prevention strategy that attempts to protect local residents by changing the physical environment. This strategy has received added importance as a management method since western societies, such as the USA and the UK, have reached their limits in crime prevention through assailant punishments and police activities. In short, this study defines the CPTED policy as a method for increasing the quality of life by diminishing the fear of crime and the crime occurrence rate through the proper design and effective usage of constructed environments.

Interest in the relationship between the quality of the local environment and crime garnered widespread attention with the publication of *The Death and Life of Great American Cities* by Jane Jacobs in 1961. CPTED, as a term, was first used in the title of a 1971 book by American psychologist C. Ray Jeffery, who researched violent crimes and racism in American cities between 1964 and 1968. In 1972, Oscar Newman used the concept of "defensible space[2]." Since that time, the CPTED policy has received significant theoretical and practical attention (Kang, 2012, p. 17).

The CPTED policy merges both urban-architectural factors and social issue factors in a fixed location. This strategy can economically implement better environmental designs while only slightly modifying original plans and designs by revitalizing physical spaces. This field of study has become popular in the USA, the UK, Australia, the Netherlands, and Japan, with multidisciplinary fields such as urban design, public administration, sociology, and computer science. Such focus has also produced effective outcomes in both theory development and practical applications, due to policy support from respective governments[3]. Despite its appeal, the CPTED policy is not a panacea for crime prevention. For example, the simple act of installing CCTVs or increasing street lighting will not prevent crimes from occurring. To maximize the effectiveness of the CPTED policy, comprehensive crime prevention plans are necessary to control manageable environmental factors through the analyses of patterns and local dynamics. In addition, since the implementation of CPTED concepts/strategies can result in significant economic losses, the crime prevention concepts must be included in the planning stages and performed in conjunction with continuous/periodic environmental maintenance[4].

3. Research design and methods

3.1 WDQ

This study utilizes the WDQ to analyze the effects of the CPTED policy, which is an appropriate tool in the regional-scale crime prevention and sexual assault prevention fields. To understand the impact of the CPTED policy, the study area must be divided into implementation zones and non-implementation zones. If the crime rate of a region decreases due to the implementation of the CPTED policy, but the crime rate of other nearby non-implementation areas increase, then crime displacement occurs. Policy analysts can then examine the effects of the policy on society as a whole. The WDQ is a suitable analysis method that makes judging the policy's effects easier since it simultaneously includes implementation areas and non-implementation areas. Researchers have used the WDQ to analyze the effects of crime prevention policies and measure the expansion of geographical crime displacement (Bowers and Johnson, 2003; Lee *et al.*, 2008; Worrall and Gaines, 2006; Kim, 2008)[5].

The WDQ can be divided into three areas (i.e. the target area, comparison area, and buffer area) by using non-equivalent control group design (with pretest-posttest quasi-experimental design methods) and analyzing the effects by comparing the research results between the three areas (Lee and Kim, 2009, p. 262). The WDQ models in the present study require geographical classification into the aforementioned areas[6]. Figure 1 presents the two crime displacement effect models[7]. Within the formats of Models 1 and 2, the most important factor for ensuring the reliability of the analysis is the selection of the comparison areas that are most similar to the target area.

To measure the crime displacement effect, the fluctuation of the crime occurrence rate must be divided into preliminary (t_0) and concluding (t_1), based on the time of implementing the crime prevention strategy. As a result, positive identification of the crime displacement effect and diffusion of benefits can be achieved by comparing the crime rates between the target area and comparison area with those between the buffer area and the comparison area. Thus, the WDQ, a combined format of time and spatial concepts, includes the following formula (Bowers and Johnson, 2003, p. 285; p. 113):

$$WDQ = \frac{Bt_1/Ct_1 - Bt_0/Ct_0}{At_1/Ct_1 - At_0/Ct_0} = \frac{B'}{A'}$$

where A is the crime rate of the target area; B is the crime rate of the buffer area; C is the crime rate of the comparison area; (B/C) is the crime rate increase rate of the buffer area compared to

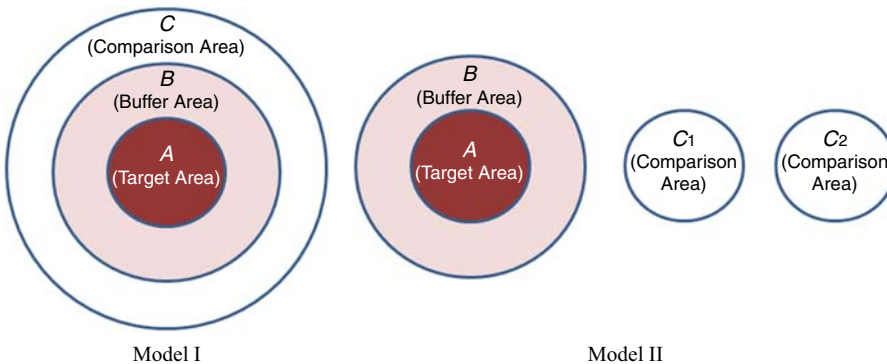


Figure 1.
Crime displacement
model

Source: Adopted from Bowers and Johnson (2003)

the comparison area; (A/C) is the crime rate increase rate of the target area compared to the comparison area, $((B/C)/(A/C))$ is the crime rate increase rate of the buffer area compared to the target area; t_0 is the time before the implementation of the crime prevention strategy; and t_1 is the time after the implementation of the crime prevention strategy.

To identify the success/failure of the crime prevention strategy on the target area, the value of the denominator (A') must be identified. If the denominator (A') is greater than 0, then the strategy is a failure. If it is less than 0, then the success of the strategy may be estimated. Moreover, to identify the diffusion of benefits or the crime displacement effect in the buffer area, the numerator (B') must be examined. Occurrence of the crime displacement effect may be forecast if the numerator (B') is greater than 0. If it is less than 0, then the diffusion of benefits may be anticipated. The measurement and interpretation of WDQ is organized in Tables I and II.

3.2 Analysis model

3.2.1 *Selecting the target of analysis.* The CPTED policy, as a criminal prevention tool, was implemented in Seoul, South Korea. The city has been installing CCTVs or adding security details in residential and public areas. In addition, the new developments in apartment complexes, schools, parks, and city blocks are well-lit, thus removing any “blind spots” that may provide opportunities for criminals. Overall, the CPTED policy is a recognized program that is being increasingly used in South Korea.

Considering the aspects of the CPTED policy, this study selected Yeomri-dong, Mapo-gu in Seoul as a case study. This particular area is not exclusively residential, and it is not a school where sexual assault crimes are rarely reported. It is simply an area in which

Table I.
Measurement of WDQ **Source:** Restructure of Park *et al.* (2011, p. 113)

Measurement	Measurement Index	Sign	Inequation	Analysis result
A'	Evaluation on success or failure of crime prevention strategy in the target area	+	$A' > 0$	Failure of crime prevention strategy
		–	$A' < 0$	Success of crime prevention strategy
B'	Evaluation on crime displacement effect and diffusion of benefit	+	$B' > 0$	Forecast of crime displacement effect
		–	$B' < 0$	Forecast of diffusion of crime control benefits

Table II.
Interpretation of WDQ **Sources:** Restructure according to Bowers and Johnson (2003, p. 286), Kim (2008, p. 228), Lee and Kim 2009, p. 267), Park *et al.* (2011, p. 114)

WDQ index	Effect comparison	Interpretation
WDQ > 1	Diffusion > Direct effect > Displacement effect	Positive effect of the policy
WDQ \cong 1	Diffusion \cong Direct effect > Displacement effect	
1 > WDQ > 0	Direct effect > Diffusion effect > Displacement effect	
WDQ = 0	Displacement effect \cong 0 and Diffusion \cong 0 or Displacement effect \cong Diffusion	
0 > WDQ > –1	Direct effect > Displacement effect > Diffusion	No positive effect of the policy Weakened by implementation of the policy
WDQ \cong –1	Displacement effect \cong Direct effect > Diffusion	
WDQ < –1	Displacement effect > Direct effect > Diffusion	

environmental design strategies were implemented (in October 2012)[8] to reduce crime in locations where sexual assaults tend to occur. Therefore, this case study was deemed suitable for analyzing the sexual assault prevention effects of the CPTED policy.

To select the buffer area, the nearby regions of Yeomri-dong Mapo-gu, Daeheung-dong, Ahyun-dong, Yonggang-dong, Gongdeok-dong, Dohwa-dong, and Sinsu-dong were selected as candidate areas. The WDQ formula binds the target area and buffer area in a concentric circular shape. Although the actual shape of the comparison area (after setting the target area, buffer area, and comparison area) might not be a concentric circle, it is important to assume that the target and buffer areas include similar characteristics, and they are adjacent to or near one another. It is also important to set the proper size since, if the buffer area is excessively large compared to the target area, then it is impossible to determine whether the crime rate has changed due to crime displacement or other variants (Lee and Kim, 2009, p. 279).

Table III presents the characteristics of the target and buffer area candidates used to select the buffer area. In comparison with the target area of Yeomri-dong, Gongdeok-dong was eliminated since its surface area and population were far greater than their counterparts. Dohwa-dong and Sinsu-dong were also eliminated since these regions yielded relatively greater surface areas and higher populations. For this study, Daeheung-dong, Ahyun-dong, and Yonggang-dong were ultimately chosen as buffer areas since they surround Yeomri-dong and have similar surface areas, number of households, and populations.

Finally, in choosing the comparison area, it is important to consider neighborhoods with characteristics similar to the target area. Yeomri-dong Mapo-gu was selected as the CPTED target area since it includes neighborhoods with similar crime vulnerabilities as those in the city of Seoul. This study selected three CPTED demo-implemented sites chosen by the city of Seoul in 2013 (i.e. Myeonmok 4-7-dong Jungrang-gu, Haengun-dong Gwanak-gu, and Yongsan2ga-dong Yongsan-gu) and ten sites selected as resident-participating regeneration projects. To select the areas that were relatively vulnerable to sexual assaults among the candidate areas, this study referred to the number of sexual offenders by region, which is included on the Sexual Offender e-Notification homepage. After reviewing the data, based on their relatively high number of identified sexual offenders, Bongcheon-dong Gwanak-gu[9] and Eungam-dong Eunpyeong-gu were selected.

Meanwhile, in selecting the comparison areas, it is appropriate to choose areas with similar crime occurrence patterns to that of the target area. It is particularly important to choose areas with similar crime occurrence patterns before the implementation of the CPTED policy to judge the program's effects after the policy's implementation. Thus, the sexual assault rates per 10,000 residents of both the comparison area and target area were compared in this study. The results are shown on Figure 2.

Devision	Region	Surface Area(km ²)	Households	Population	Selected
Target Area	Yeomri-dong, Mapo-gu	0.43	8,261	18,618	-
Buffer Area Candidate	Daeheung-dong, Mapo-gu	0.89	8,417	16,044	O
	Ahyun-dong, Mapo-gu	0.76	8,153	19,484	O
	Yonggang-dong	0.84	7,777	19,365	O
	Gongdeok-dong, Mapo-gu	1.02	16,126	37,399	X
	Dohwa-dong, Mapo-gu	0.62	9,408	23,943	X
	Sinsu-dong, Mapo-gu	0.78	9,801	23,720	X

Table III.
Comparison between
target area and
buffer area

The target area of Yeomri-dong exhibited a decreasing trend in sexual assault occurrences after the CPTED policy was implemented in October 2012. Meanwhile, the comparison areas of Bongcheon-dong and Eungam-dong exhibited a similar decrease in sexual assaults. Hence, it is considered valid to judge the effectiveness of the CPTED policy in the target area relative to the selected comparison areas of this study. Although the comparison areas of Bongcheon-dong and Eungam-dong have larger populations compared to Yeomri-dong, this issue was minimized by using sexual assault occurrences per 10,000 people.

3.2.2 Data, variables, and time series analysis. The data used in this study was obtained from two sources. First, the number of sexual assaults per region was retrieved through public records requests to Mapo Police station and Seoul Metropolitan Police Agency. Second, the population data used to standardize the number of crimes per resident were retrieved from the resident registration information data maintained by Seoul Statistics (stat.seoul.go.kr) and included on the city of Seoul's homepage.

In the analysis of the WDQ, policy intervention is considered as an independent variable, while the change due to such intervention is considered as the dependent variable. The independent variable representing the policy intervention in this study is the moment when the CPTED policy was implemented. In this case, the CPTED policy was implemented in the selected target area of Yeomri-dong Mapo-gu on October 1, 2012. As such, the analysis period was set from January 2010 to June 2014, which permitted an analysis before and after the implementation of the CPTED policy.

Furthermore, the CPTED policy expects general prevention effects related to sexual assaults. Thus, the dependent variable must be an index to measure such crimes. However, there were limitations regarding the data collection used to classify general sexual assaults, sexual assault under the age of 20, and second offenses of sexual assaults, since the data were from a regional unit (Beopjeong-dong). Consequently, this study measures the policy effectiveness based on the general sexual assault data.

One of the primary critiques in WDQ analysis is the lack of a statistic that confirms statistical significance of the calculation outcomes (Ratcliffe *et al.*, 2009; Ratcliffe and Breen, 2011; Cahill *et al.*, 2011; Johnsona and Ratcliffe, 2014). To fill this gap, the interrupted time series model in combination with the WDQ analysis is employed as a sensitivity analysis in this research (Worrall and Gaines, 2006; Ratcliffe *et al.*, 2009). The interrupted time series analysis with 54 time points from January, 2010 to June, 2014 tests the impact of the CPTED policy on the target area and the Mapo-gu. It also includes two intercepts, i.e., t_1 and t_2 used for eliminating potential autocorrelations among monthly data on sexual assaults. For a before/after comparison, this research also employs a quasi-experimental design to test the CPTED policy effect on the number of

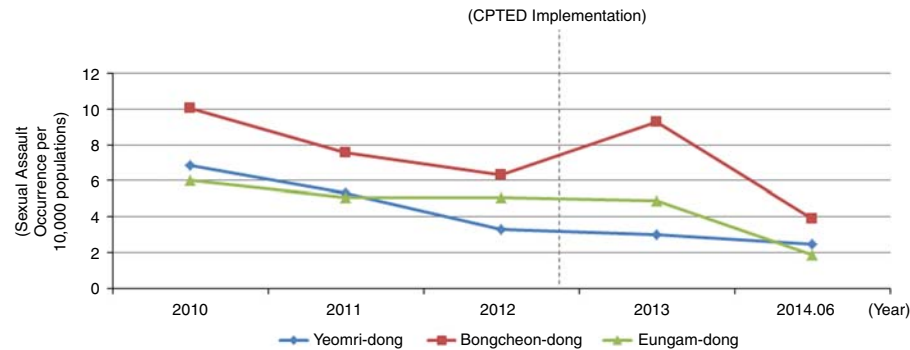


Figure 2.
Comparison of sexual
assault occurrence
between target area
and comparison area

sexual assault monthly reported in Yeomi-dong within Mapo-gu and Mapo-gu. It allows us to build a model using the WDQ analysis, which investigate the impact of the CPTED policy on sexual assault prevention at the target area.

As Lawton *et al.* (2005) highlighted, the auto-regressive integrated moving average (ARIMA) time series design aims to isolate and assess the impact of implemented policy tools on a targeted crime prevention. The ARIMA models, however, may not fully examine the direct effect of the CPTED policy on a target area as well as on buffer areas surrounding the targeted area (Mazerolle *et al.*, 2007; Wells *et al.*, 2012). Also, the CPTED policy for preventing sexual assaults was initiated as an experiment at the Census Block Group level, i.e., Yeomri-dong, Mapo-gu in Seoul, which is not implemented citywide. For this reason, a simple interrupted time series design, not ARIMA model, is used as a sensitivity analysis in this research (Worrall and Gaines, 2006; Ratcliffe *et al.*, 2009). The interrupted time series model plays a role in comparing a mean difference of sexual assaults before and after the CPTED policy implementation within a target area.

4. Analysis results

4.1 WDQ analysis results

4.1.1 Analysis results based on Comparison Area 1 (Bongcheon-dong Gwanak-gu).

4.1.1.1 Policy effectiveness of the target area. The analysis results of the WDQ, which are in contrast to the first comparison area of Bongcheon-dong Gwanak-gu, are presented in Table IV. To judge the policy's effectiveness in Yeomri-dong, the sexual assault occurrence fluctuation rate before and after the implementation of the policy (compared to the comparison area) must be measured. To judge the policy's effectiveness within the comparison area, the value of the denominator (A') must be understood by the formula for retrieving the WDQ value. The formula for A' is $At_1/Ct_1 - At_0/Ct_0$ and the result is -0.2072 . In addition, to interpret the result, the inequality must be considered. Since the value of A' is a negative ($-$) value of less than 0, this suggests that the CPTED policy is effective in reducing sexual assault occurrences. Furthermore, sexual assault occurrences in the target area of Yeomri-dong Mapo-gu decreased in comparison to Bongcheon-dong Gwanak-gu, signifying that the policy is also effective in this area.

4.1.1.2 Buffer area crime displacement effect. If an effect of a policy has appeared within the target area, the crime displacement effect within the buffer area must be measured. To judge this, the value of B' must be evaluated using the WDQ formula. This means that the fluctuation of sexual assault occurrences before and after the implementation of the policy within the buffer area (compared to the comparison area) must be computed. The formula for calculating this value is $Bt_1/Ct_1 - Bt_0/Ct_0$. Since there are three buffer areas selected in this study, all three areas must be separately examined. First, the B' values of Daehung-dong and Ahyun-dong are 0.0495 and 0.0775, respectively. Since these two values are greater than 0, it can be assumed that a crime displacement effect has occurred. Moreover, unlike those of Daehung-dong and Ahyun-dong, the B' value of Yonggang-dong is a negative value of -0.0553 . If the value of B' is less than 0, then the diffusion of benefits may be predicted. The diffusion of benefits mentioned here indicates the expansion of positive effects over

Comparison Area 1	Object area	B' or A'	Inequality	WDQ value	Inequality
Bongcheon-dong Gwanak-gu	Target area	Yeomri-dong	-0.2072	$A' < 0$	$-$
	Buffer area	Daehung-dong	0.0495	$B' > 0$	$0 > \text{WDQ} > -1$
		Ahyun-dong	0.0775	$B' > 0$	$0 > \text{WDQ} > -1$
		Yonggang-dong	-0.0553	$B' < 0$	$1 > \text{WDQ} > 0$

Table IV.
WDQ Analysis
Results based on
Comparison Area 1
(Bongcheon-dong
Gwanak-gu)

location, individual, crime, and time slot of the target area (Choi and Kim, 2007, p. 157; Kim, 2008, p. 220). It also means that the CPTED policy implemented in Yeomri-dong had a crime reduction effect in the nearby area of Yonggang-dong.

Although the CPTED policy implemented in Yeomri-dong appeared to be effective in reducing sexual assault occurrences, a crime displacement effect appeared in the nearby area of Daeheung-dong and Ahyun-dong, and the diffusion of benefits occurred in Yonggang-dong. Given these results, can the CPTED policy be deemed effective? The policy was effective in the target area, and it contributed to the diffusion of benefits in a nearby area. However, if the crime displacement effect is still greater, then can we determine if the policy had positive effects on society as a whole? This can only be judged by the WDQ values in the buffer areas.

The WDQ value is the value of fluctuation rate (B') of the buffer area compared to the comparison area divided by fluctuation rate (A') of the target area compared to the comparison area (B'/A'). First, the WDQ value of Daeheung-dong and Ahyun-dong are -0.2388 and -0.3741 , respectively. The WDQ values of both regions are less than 0 and greater than -1 . Further, the WDQ value of Yonggang-dong is 0.2668 , which is a value greater than 0, but less than 1. This means that the policy effectiveness within the target area is greater than the diffusion of benefits.

To summarize, compared to Bongcheon-dong Gwanak-gu, the implementation of the CPTED policy in Yeomri-dong appears to be effective in diminishing sexual assault occurrences. Moreover, although crime displacement occurred in Daeheung-dong and Ahyun-dong, the policy's effectiveness within the target area was greater than the crime displacement effect. Since the diffusion of benefits additionally occurred in Yonggang-dong, it can be stated that the CPTED policy contributed to an overall decrease in the number of sexual assaults.

4.1.2 Analysis results based on Comparison Area 2 (Eungam-dong Eunpyeong-gu).

4.1.2.1 Policy effectiveness of the target area. The analysis results of the WDQ in the second comparison area of Eungam-dong Eunpyeong-gu are provided in Table V. According to the analysis results, the A' value of -0.2478 shows an increase in sexual assault occurrences in Yeomri-dong, compared to Eungam-dong. This is a negative value of less than 0, which can be interpreted as the CPTED policy being effective in decreasing sexual assaults. When compared to the comparison area of Eungam-dong Eunpyeong-gu, a decrease in sexual assault occurrences within the target area of Yeomri-dong Mapo-gu is identified, implying that the CPTED policy was effective. In comparison to Bongcheon-dong Gwanak-gu (-0.2072) analyzed above, the small A' value suggests that the policy's effectiveness is greater.

4.1.2.2 Buffer area crime displacement effect. Since the policy's effectiveness appeared in the target area, compared to the second comparison area of Eungam-dong Eunpyeong-gu, the crime displacement effect on the buffer areas must be examined. For this procedure, the numerators of the WDQ formula, the B' values, were calculated. The B' values of Daeheung-dong and Ahyun-dong are 0.2253 and 0.2610 , respectively. Both results are positive values, thus suggesting a crime displacement effect in Daeheung-dong and Ahyun-dong. Conversely, the B' value of Yonggang-dong is a negative value of -0.0731 , thus suggesting

Table V.
WDQ analysis results
based on Comparison
Area 2 (Eungam-dong
Eunpyeong-gu)

Comparison Area 2		Object area	B' or A'	Inequality	WDQ Value	Inequality
Eungam-dong Eunpyeong-gu	Target area	Yeomri-dong	-0.2478	$A' < 0$	$-$	$-$
	Buffer area	Daeheung-dong	0.2253	$B' > 0$	-0.9093	$0 > \text{WDQ} > -1$
		Ahyun-dong	0.2610	$B' > 0$	-1.0532	$0 > \text{WDQ} > -1$
		Yonggang-dong	-0.0731	$B' < 0$	0.2951	$1 > \text{WDQ} > 0$

a probable diffusion of benefits. These results are similar to the contrast with the first comparison area of Bongcheon-dong Gwanak-gu. The CPTED policy implemented in Yeomri-dong appeared to be effective in sexual assault prevention. However, crime displacement occurred in the nearby areas of Daeheung-dong and Ahyun-dong, and the diffusion of benefits occurred in the nearby area of Yonggang-dong.

Next, the influence of the CPTED policy on society as a whole must be examined through a comparison of the policy's effectiveness and the size of crime displacement by calculating the WDQ value. The calculation of dividing fluctuation rate (B') of the buffer area (compared to the comparison area) by the fluctuation rate (A') of the target area (compared to the comparison area (B'/A')) is as follows. First, the WDQ value of Daeheung-dong is -0.9093 (the WDQ values of the region are less than 0 and greater than -1). This means that the policy's effectiveness of the target area is greater than the crime displacement effect in the buffer areas. Next, the WDQ value of Ahyun-dong is -1.0532 , which is a value near -1 , thus suggesting that there are no positive effects resulting from the policy in the target area, since the policy's effectiveness and crime displacement rates are similar. Finally, the WDQ value of Yonggang-dong is 0.2951 , which is a value greater than 0 but less than 1. Similar to the first comparison with Bongcheon-dong Gwanak-gu, the policy's effectiveness within the target area appears to be greater than the diffusion of benefits.

In sum, when compared to Eungam-dong Eunpyeong-gu, the CPTED policy in Yeomri-dong appears to be effective in diminishing sexual assault occurrences with a minimal diffusion of benefits occurring in Yonggang-dong. In addition, the data suggests that crime displacement occurred in Daeheung-dong and Ahyun-dong, but it was less than the policy's effectiveness. This means that crime displacement in Ahyun-dong is not as serious since it is actually similar to the policy's effectiveness. Therefore, the CPTED policy in Yeomri-dong has positively affected the society as a whole in Comparison Area 2 (Eungam-dong Eunpyeong-gu).

4.2 Time series analysis results and summary of the hypothesis verification

In this study, WDQ was used to measure the sexual assault prevention effect of the CPTED policy on a regional scale. The policy's overall effect is the prevention of sexual assaults. The analysis results are summarized in Table VI.

Comparison area	Object area	Interpretation	Effect comparison
Bongcheon-dong Gwanak-gu	Target area Yeomri-dong	Occurrence of policy effectiveness	–
	Buffer area Daeheung-dong	Occurrence of displacement effect	Policy effectiveness > Displacement effect
	Ahyun-dong	Occurrence of displacement effect	Policy effectiveness > Displacement effect
	Yonggang-dong	Occurrence of diffusion	Policy effectiveness > Diffusion
Eungam-dong Eunpyeong-gu	Target area Yeomri-dong	Occurrence of policy effectiveness	–
	Buffer area Daeheung-dong	Occurrence of displacement effect	Policy effectiveness > Displacement effect
	Ahyun-dong	Occurrence of displacement effect	Policy effectiveness \approx Displacement effect
	Yonggang-dong	Occurrence of diffusion	Policy effectiveness > Diffusion

Table VI.
WDQ analysis
result summary

The WDQ analysis results show that the CPTED policy implemented in the target area Yeomri-dong exhibited effectiveness, compared to the two comparison areas. Accordingly, it can be considered that the CPTED policy helped prevent sexual assault occurrences. However, if a sexual assault was displaced into another area, due to the policy's effectiveness in the target area, then it is difficult to consider it as an effective policy. Thus, an analysis on whether crime displacement occurred in areas adjacent to Yeomri-dong, Daeheung-dong, Ahyun-dong, and Yonggang-dong was performed.

The analysis of the crime displacement effect showed that the diffusion of benefits occurred instead of crime displacement in Yonggang-dong. Due to the CPTED policy's implementation in Yeomri-dong, sexual assaults decreased in the adjacent area of Yonggang-dong. However, in Daeheung-dong and Ahyun-dong, a crime displacement effect was found. Such results are assumed due to their proximity to the target area. The model also suggests that crimes that occurred in the target area were displaced to a nearby area with a more vulnerable physical environment. However, the level of crime displacement was minimal compared to the policy's effectiveness in the target area. Therefore, after combining all the results of the analysis, the net impact of the CPTED policy is positive in preventing sexual assaults for society as a whole.

As shown in Table VII, the results of the interrupted time series analysis provide evidence confirming the WDQ analysis results that the CPTED policy has a critical effect on decreasing the number of sexual assault within the target area while there is no statistical evidence for the effect on Mapo-gu at a city level. This implies that the selected buffer area surrounding the target area might not be affected by the CPTED policy, which the WDQ analysis indicated. As highlighted in the WDQ analysis results, for instance, a noteworthy trend that the number of sexual assaults had been consistently decreased after the CPTED was implemented in October, 2012 even though the sexual assaults in Mapo-gu, i.e., at the city level increased in the same time period. Again, the statistical evidence confirmed that the number of sexual assaults had dramatically increased during the time period from January 2010 to June 2014, but the assaults in the target area in which the CPTED policy initiated slightly decreased.

5. Conclusion and policy implications

This study investigated the impact of the CPTED policy, a crime prevention tool, on reducing the rate of sexual assaults. In addition, the objective was to understand if the CPTED policy results in crime displacement in non-target areas. In order to achieve this, the WDQ was used to analyze the policy's effectiveness while controlling for geographical crime displacement, a known side effect of the CPTED policy in the literature. The findings suggest that the CPTED policy is an effective and viable tool for preventing sexual assaults

Table VII.
CPTED's effect on
sexual assaults in
the target area and
Mapo-gu

	Target area		Mapo-gu	
	Coefficient	SE	Coefficient	SE
CPTED	-0.591**	0.204	5.915**	1.351
Constant	1.954**	0.143	12.786**	0.838
t_1	-0.385**	0.064	-0.254*	0.103
t_2	-0.321**	0.074	-0.291**	0.089
n	54		54	
F	33.16**		21.35**	
Adjusted R^2	0.7017		0.5353	

Notes: Intercept t_1 and t_2 are measured in statistical terms by the lag-1 and lag-2 autocorrelation. * $p < 0.01$; ** $p < 0.001$

in South Korea. For example, the sexual assault occurrence rate has decreased in the CPTED-implemented zone of Yeomri-dong Mapo-gu, even though the WDQ showed that crime displacement occurred in the adjacent areas of Daeheung-dong and Ahyun-dong. However, crime displacement was lower than the policy's effectiveness in the target zone, which supports the conclusion that the CPTED policy is effective in reducing the rate of sexual assaults in society as a whole.

The policy implications of this study are significant. First, using the CPTED policy for the prevention of sexual assaults should be considered as a pre-control tool. However, it requires more attention since many of the current sexual assault prevention policies are post-control methods that attempt to prevent repeated crimes. This study found that the CPTED policy increases the possibility of detection or arrest for sexual offenders, and it is considered an efficient strategy for reducing sexual assaults. Thus, continual attention and support from the central government must be reinforced so that the local governments can expand the CPTED implementation. Furthermore, future studies should focus on the types of environmental design features used to determine if certain tools are more effective than others in reducing sexual assaults or other related crimes.

Second, a strategic method for more effective implementation of the CPTED policy is required. If all the local governments in South Korea uniformly apply the CPTED policy according to a manual, then its effectiveness will most likely diminish. In other words, if the CPTED policy is applied mechanically through a "cookie-cutter approach," then it would be a serious mistake. Each city and neighborhood is unique, and the distinctiveness of each region must be considered when designing CPTED strategies. A comprehensive approach could involve local residents and galvanize public participation, which in turn could help citizens better understand the role of the CPTED policy in reducing sexual assaults and other types of crimes.

Third, since the CPTED policy is conducted on a regional scale, provisions need to be in place for managing crime displacement. The results of this study confirm that crime displacement does occur in areas surrounding CPTED-implemented areas. In addition, crimes are more likely to displace into a region where the risk of arrest is lower. Thus, it is important to maintain and increase the policy's effectiveness in society as a whole by enhancing traditional police patrols, supporting voluntary crime prevention groups, and raising community awareness in areas that lack CPTED implementation.

Sexual assault is a type of crime that negatively affects both the victim as well as the victim's family. Even though the CPTED policy might reduce the overall sexual assault rate in implementation zones, victims in communities where crime displacement occurs will not be satisfied by the effectiveness of this policy. Therefore, more research is necessary to understand the patterns of crime displacement and determine which features of the CPTED policy are the most effective for reducing crime. Finally, since this study only focused on Seoul, South Korea, future research on the application of the CPTED policy should examine other countries and cultural environments to expand the literature in this important field.

Notes

1. Violent crimes include murder, theft, sexual assault, and arson.
2. The components of defensible space, as suggested by Newman, include the following aspects: target hardening, access control, surveillance, and territoriality. Subsequently, Moffatt included image maintenance and activity support as additional components (p. 23; Park, p. 137; Kang *et al.*, 2010, pp. 41-43; p. 17).

3. Representative examples include the following aspects: the establishment of federal government-centered research and support institutions (such as the NIJ); the enactment of local regulations and development of design techniques from the USA; the Security by Design policy led by the British Central Government; and the Japanese Security Model Complex policy, which was tied to the community building projects, safety design policies, and crime influence assessments from Australia.
4. Refer to Seoul's Crime Prevention Through Environmental Design Guidelines (p. 6).
5. Such studies have used the WDQ to measure the control programs for specific types of crimes. These studies can be divided at the macroscopic level and microscopic level, according to the experiment area, displacement area, and comparison area. Details can be found in Lee and Kim (2009).
6. Bowers and Johnson (2003) classified these three areas into the action area, buffer area, and control area. However, in the present study, the term "comparative area" is used instead of the control area.
7. Model 1 is a concentric circular crime displacement model that sets virtual areas composed of circles. Here Area *A* is the target area, which was implemented with the policy and program; Area *B* surrounds Area *A* and it is the buffer area, which is foreseen due to the crime prevention activities of Area *A*; and Area *C* is the comparison area that is not affected by the changes in Areas *A* or *B*. Model 2 is a crime displacement model with the comparison area separated, and the subject areas set according to the comparison area (*C*) that does not surround the target area (*A*) or the buffer area (*B*). If various comparison areas similar to the target area are well secured, then a highly reliable analysis can be performed (Kim *et al.*, 2011, p. 12).
8. Initially, Yeomri-dong was the most urgent area that required countermeasures, out of the 161 areas designated by the National Police Agency as "resident security enforcement areas." In response, the city of Seoul, in collaboration with specialists from the fields of police, academia, and design, formed the Crime Prevention Design Committee and applied the CPTED policy in Yeomri-dong beginning in April 2012. First, the streets and alleys considered as "insecure" by the residents were connected and transformed into an exercise area named, "Salt Street," which was intended to encourage usage and make natural surveillance possible. The telephone poles in this area were numbered from 1 to 69 so that a victim/witness could easily inform the authorities of the exact location of a crime. To establish a safe location for any residents seeking help, six households (with no crime records and long resident histories) were chosen as "Salt Keeper's Houses." These houses were installed with bright lights, cameras, and alarms, along with gates that were painted yellow to easily identify them. Finally, the "Salt Port," which sells convenient goods, was established in the center of the town to act as a 24-hour guard post and guestroom for the residents.
9. There were difficulties in retrieving sexual assault data since Haengun-dong Gwanak-gu, which was selected as the CPTED demo-implementation area by the city of Seoul, is an administrative dong (division). Thus, Bongcheon-dong, a region that includes Haengun-dong, was selected as the comparison area since it includes many similarities to Yeomri-dong Mapo-gu.

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