World Academy of Science, Engineering and Technology
International Journal of Architectural and Environmental Engineering
Vol:9, No:3, 2015

An Analysis on the Appropriateness and Effectiveness of CCTV Location for Crime Prevention

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Open Science Index, Architectural and Environmental Engineering Vol:9, No:3, 2015 publications.waset.org/10000802/pdf

***Abstract*—**This study aims to investigate the possibility of crime prevention through CCTV by analyzing the appropriateness of the CCTV location, whether it is installed in the hotspot of crime-prone areas, and exploring the crime prevention effect and transition effect. The real crime and CCTV locations of case city were converted into the spatial data by using GIS. The data was analyzed by hotspot analysis and weighted displacement quotient (WDQ). As study methods, it analyzed existing relevant studies for identifying the trends of CCTV and crime studies based on big data from 1800 to 2014 and understanding the relation between CCTV and crime. Second, it investigated the current situation of nationwide CCTVs and analyzed the guidelines of CCTV installation and operation to draw attention to the problems and indicating points of CCTV use. Third, it investigated the crime occurrence in case areas and the current situation of CCTV installation in the spatial aspects, and analyzed the appropriateness and effectiveness of CCTV installation to suggest a rational installation of CCTV and the strategic direction of crime prevention. The results demonstrate that there was no significant effect in the installation of CCTV on crime prevention in the case area. This indicates that CCTV should be installed and managed in a more scientific way reflecting local crime situations. In terms of CCTV, the methods of spatial analysis such as GIS, which can evaluate the installation effect, and the methods of economic analysis like cost-benefit analysis should be developed. In addition, these methods should be distributed to local governments across the nation for the appropriate installation of CCTV and operation. This study intended to find a design guideline of the optimum CCTV installation. In this regard, this study is meaningful in that it will contribute to the creation of a safe city.

***Keywords*—**CCTV, Safe City, Crime Prevention, Spatial Analysis.

I. Introduction

DUE to a series of recent shocking incidents such as the Sewol Ferry Disaster, subway accidents, and fire in Korea, public demand for establishing a standard for basic safety measures is sharply on the rise.

Along the lines of this demand, prevention-centered policies such as Crime Prevention through Environment Design (CPTED), intensive allocation of police to crime vulnerable areas, and the installation of CCTV for crime prevention have become a priority. The use of CCTV has been noticed as the most effective means so that central government and each local government have expanded the installation of CCTV every year. For example, according to the Ministry of Security and Public Administration in Korea, the number of CCTV sets installed across the nation, including the public and private sector as of 2013, was 4.28million sets. This figure shows an increase of about 500,000 (13.2%) compared to 2012, indicating that the use of CCTV has been sharply.

Although the effectiveness has been demonstrated, it is obvious that the increase in CCTVs can infringe upon the privacy and cause redundant investment in the case that the CCTV is misused or overused due to the excessive reliability of its effectiveness. In addition, it cannot be ignored that there are considerable negative study results regarding the effects of CCTV [1], [2] Nevertheless, the cases of criminal arrest through CCTV have often been reported, so that the demand for installing CCTV has increased. Therefore, it is expected that the installation of CCTV in the places where citizens feel unsafe will increase. Meanwhile, the effects of CCTV are swayed by the location of the CCTV cameras. Therefore, the installation location should reflect the surrounding environment by making a scrupulous spatial analysis. In the case of Korea, the standards of CCTV installation are provided in the guidelines regarding the installation and operation of image information processing in public institutions and local ordinances, but there is a limit in the contents because they only include administrative procedures such as privacy and management organization.

Put simply, it is difficult to maximize the installation effect of CCTV because there is no post-evaluation method and the spatial access for the installation of CCTV is not easy. Accordingly, it is a reality that more precise and elaborate guidelines in regard to the installation of CCTV and operation are urgently required.

With such considerations, this study analyzed the relations between the spatial location of CCTV for crime prevention and crime occurrence to explore the ways of maximizing the installation effect of CCTV. As study methods, it analyzed existing relevant studies for identifying the trends of CCTV and crime studies based on big data from 1800 to 2014 and understanding the relation between CCTV and crime. Second, it investigated the current situation of nationwide CCTVs and analyzed the guidelines of CCTV installation and operation to draw attention to the problems and indicating points of domestic CCTV use. Third, it investigated the crime

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occurrence in case areas and the current situation of CCTV installation in the spatial aspects, and analyzed the appropriateness and effectiveness of CCTV installation to suggest a rational installation of CCTV and the strategic direction of crime prevention.

II. Existing Study Trends

Recently, the utilization of big data which opens the new possibility of the analysis on social phenomenon has been noticed. Accordingly, this study analyzed the study trends of CCTV and crime by putting 'culturomics (http://www.culturomics.org/)' to use.

The study results about crime, as shown in Fig. 1, show that the word 'crime' has constantly increased since the 1800s. In particular, crime has largely increased after the mid-1970s, but recently, it showed the tendency of a slight decrease. In terms of CCTV, the number of the word 'CCTV' began to increase in 1967, but it has sharply increased from 2004. Therefore, we can conclude that the use of CCTV has received increasing attention around the world.



Fig. 1 Research Trends of Crime and CCTV

To put it concretely, most reviews about the study cases of the relations between crime occurrence and CCTV are concentrated on the analysis on the effects of CCTV on crime prevention.

Reference [3] conducted an experiment study targeting 14 CCTVs installed in four police zones which are subject to the central part of Newcastle-upon-Tyne, including 7 police zones of surrounding areas for 15 months. The results show that the crime rates in the areas where CCTVs were installed were lower than the areas where CCTVs were not installed. In addition, the results of observation over 12 months targeting the central part of Birmingham reported that the crimes in the areas of CCTV installation had decreased, while the crimes in the areas without CCTVs had increased.

Reference [4] recorded the crime occurrence in the city center where 11 CCTVs were installed for 12 months. In this study, the study results were contrary to the expectation because crime rates decreased in the control areas where CCTVs were not installed at a greater rate than the experiment areas where CCTVs were installed.

Reference [5] evaluated 12 CCTV sets installed in the central part of Airdrie city as a program against molestation for 24 months and it revealed that the crime rate decreased more so in the experiment areas than in the control areas. This shows that the crime rates were liable to decrease in the areas of no CCTV installation, even though the areas were adjacent to the areas of CCTV installation.

Reference [6] analyzed 63 CCTV sets installed in the center of Norris city for 24 months. Crime decreased in the experiment areas of CCTV installation, while, crime increased in the control areas without CCTV installation. However, the reasons why crime in the experiment areas decreased and crime in the control areas decreased were not identified. Reference [2] conducted a comparative study on crime results, which was recorded by CCTV in the central part of Burnley city. In the experiment area, crime decreased and in the control area, crime increased and decreased in one place at the same time respectively, thus, the results were not consistent.

Reference [7] conducted a comparative experiment study for 11 months. Crime in the experiment area decreased at a greater rate than in the control area. In addition, this study made surveys on the insults, violence, and threats by selecting sample groups, where crime damages were inflicted before and after the CCTV installation. As a result, in the experiment area, crime increased slightly from 26.4% to 28.5%, while in the control area, crime decreased from 11.4% to 13.6%. This reveals that the installation of CCTV did not affect the decrease of crime.

Even though there have been only a few Korean domestic studies, [8] analyzed 27 CCTVs for crime prevention which were installed and operated in Gangnam-gu, Seoul. The results demonstrate that crime decreased by about 34% in the occurrence rate of crime incidents in comparison with crime rates over the last three years. In the response of the residents or workers in the district of Gangnam-gu, 78% of workers and 91% of police officers answered that they felt that crime had decreased or their districts became a safer place. This shows that CCTV was significantly effective in inhibiting the occurrence of crime.

Reference [9] verified the crime prevention effect and the effect of criminal arrest through the analysis of arrest rate after opening the CCTV control center in Gangnam-gu. CCTV was effective for four months before and after the installation, but in the analysis over one year, CCTV didn't gain the effect of the average. Accordingly, he came to the conclusion that the installation of CCTV for crime prevention was ineffective.

Reference [10] performed a study on the problems of introducing CCTV for crime prevention and rational remedy methods. They found that crimes decreased by 30% through the installation and operation of CCTV for crime prevention in the studio complex near Y University. He argued that on-site patrol, by increasing police manpower would be more desirable than installing CCTV.

In view of the facts, the effectiveness of CCTV has been studied in Korea, but specific analysis is difficult and the contents regarding the evaluation of CCTV installation, discovered in foreign cases are considerably lacking because it is quite difficult to obtain the crime occurrence data.

To put together the studies, conducted in Korea and abroad as mentioned above, most studies come to a conclusion that CCTV has a positive effect as shown in Table I. However, the range of domestic studies is limited to the areas of 'Dong' and

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'Gu', which is a basic administrative unit in Korea. Therefore, domestic studies can analyze only the tendency of entire crime occurrence, and the judgment of CCTV installation location is basically impossible.

Therefore, this study aims to find methods of CCTV installation and operation, which are helpful to a more realistic crime prevention method by analyzing the ripple effect through building a database up to special location where CCTVs are installed targeting the coverage area, composed of several blocks.

TABLE I
SUMMARIZATION OF STUDY RESULTS IN REGARD TO THE EFFECTS OF CCTV ON CRIME PREVENTION

Researcher	Effect of Crime Prevention
[3]	CCTV installation area- reduction by 21.6% / CCTV no installation area – reduction by 29.7% Installation < No installation
	CCTV Installation area - reduction in crime / CCTV non-installation area – increase in crime Installation > No installation
[4]	CCTV Installation area - reduction by 12.8% / CCTV non-installation area– reduction by 18% Installation < No installation
[5]	CCTV Installation area - reduction by 35% / CCTV no installation area – reduction by 12% Installation > No installation
[6]	CCTV Installation area- reduction by 21.3% / CCTV non- installation area – increase by 11.9% Installation > No installation
[2]	CCTV Installation area - reduction by 28% / CCTV no installation area - reduction by 1%, increase by 9% Installation > no installation
[7]	CCTV installation area- reduction by 13.9% / CCTV non-installation area – reduction by 26.9% Installation < No installation
[8]	After the installation of CCTV -reduction by 30% Before the installation < After the installation
[9]	After the installation of CCTV – reduction by 6.4% Before the installation < After the installation
[10]	After the installation of CCTV – reduction by 30.9% Before the installation < After the installation

III. AN ANALYSIS ON THE CCTV INSTALLATION AND OPERATIONAL CONDITIONS

A. The CCTV Installation in Korea

In Gangnam-gu, Seoul, the installation of CCTVs has been steadily increasing since the installation of five CCTVs in Nonhyeon 1-dong, Gangnam-gu, Seoul, in Dec. 30, 2002. The number of CCTVs has a tendency to rapidly increase across the nation. In addition, the installation of CCTVs was expanded due to the fact that CCTVs played a crucial role in criminal arrests, which is widely spread to people.

According to the data disclosed by each local government, the area where CCTVs were installed the most was Gyeonggi-do with 29,852 sets. That accounts for 31.3% of the entire country, which was followed by Seoul with 17,829 sets, which is at 17.8% (Fig. 2). However, CCTVs installed by the private sector were excluded.

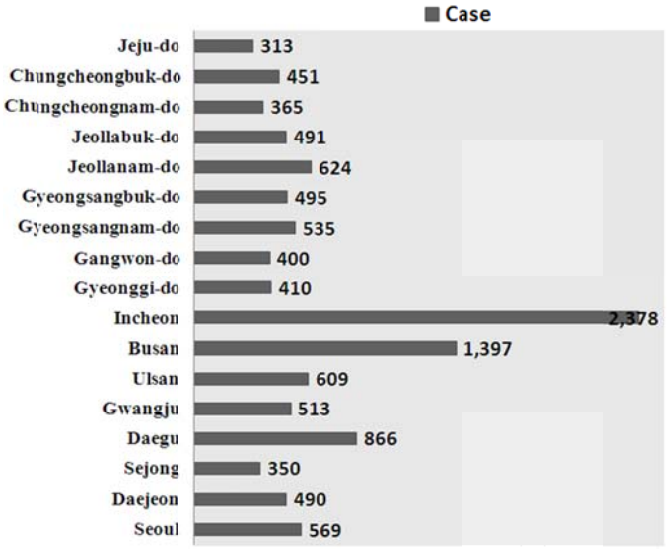


Fig. 2 CCTVs across the Country (As of Aug. 2014) [11]

There were differences in the installation numbers of CCTV according to areas. Nationwide, Incheon ranked the highest in the number of CCTVs installed per capita, which was followed by Busan (Fig. 3).

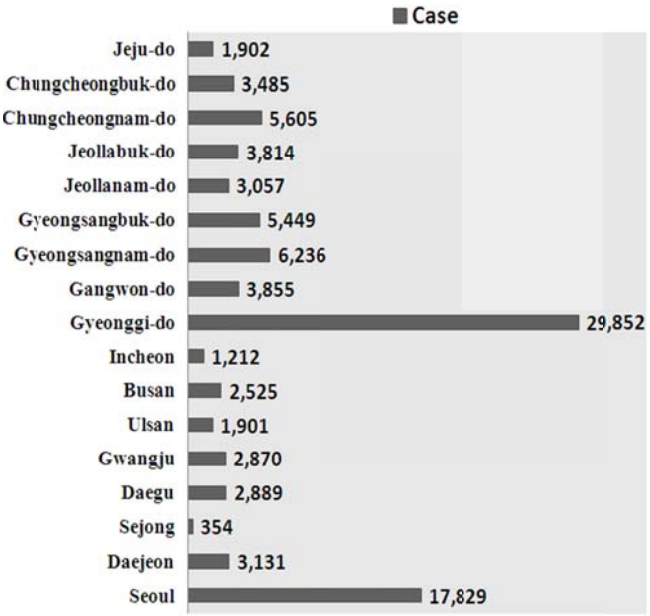


Fig. 3 Population Number per One CCTV Set Across the Entire Country (As of Aug. 2014) [12]

Meanwhile, the installation numbers of CCTV showed a high deviation according to areas. The reason for the deviation was attributed to the financial state of local government. However, the installation numbers of CCTV sets were not many in Busan and Ulsan which have higher in financial independency, while CCTV sets were comparatively more in Jeonnam, Gyeongbuk, and Chungnam, which are considered to have less financial independence. This reveals that the numbers of CCTVs installed were not significantly correlated to the financial independence of the region.

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B. The Standards of the CCTV Installation and Operation

In Korea, CCTV camera is installed and operated based on 'The Guidelines for the Installation and Operation of Image Information Processing in Public Institutions (GIOI)', 'Local Ordinances', 'Information and Communication Standards (ICS)', and the 'Design and Installation of the Closed Circuit Television by the Telecommunication Technology Association'. In particular, GIOI deals with all CCTV cameras and network cameras.

The contents are mainly intended to protect the privacy of the citizens and most contents are related to operating measures. However, the contents regarding the standards for determining the coverage area, the capacity of CCTV, and integrated control center are lacking. Therefore, it is necessary to strengthen spatial and institutional standards for the effective installation and operation of CCTVs. In addition local governments enacted ordinances about CCTVs, but such ordinances only consist of basic and conceptual contents dealing with the installation and operation of CCTVs. The ordinances lack clauses that deal with concepts of installation coverage area, integrated control centers, and intelligence facilities. ICS determined the contents related to technology, equipment, and function of CCTVs in terms of system design and installation. The contents of ICS are actually conducive to the installation and operation of CCTV.

However, the contents are confined to the institutional device or operating measures, and the contents regarding spatial installation methods, standards, and CCTV capacity are not addressed.

However, international cases are more specific. For example, in the UK, 'the Public Safety Closed Circuit Television Code of Practice' is in effect. The standards for the code of practice are provided based on the basic strategy for promoting the safety of the city with 'Practice of CCTV programs for Public Safety [13]'. Put simply, the CCTV installation standards for public safety in the UK plays the role of a guideline for supporting the police in discovery and prosecuting criminals in downtown by promoting the awareness of safety to residents, laborers, and visitors and preventing latent criminals. In the case of Australia [14], the standards set force are considered to be the representative model for the rest of the world. The Australian standards include detailed installation and operation regulations of CCTV by the local safety committee and CCTV committee, such as the occurrence areas and times of the crimes, a precise analysis of local crimes, the establishment of local community for crime prevention, the installation and evaluation, and the installation locations of CCTV in detail.

However the noticeable factor is the content dealing with the evaluation following the installation of CCTV in pursuit of maximizing the effect of CCTV by evaluating the significant reduction of crimes, the spatial transference effect of crimes, and cost-benefit analysis. In addition spatial analysis should be made and the surrounding environment should be reflected because the effect of CCTV is critically dependent on the location of the camera.

However, in Korea, the guidelines are not specific and the contents regarding spatial location are lacking. Accordingly, the location of CCTV installation should be determined in combination with urban spatial analysis and geographic profiling technique, and guidelines which can provide effective measurement is needed at the occurrence time of a particular incident. As evaluation methods of CCTV effects, the analysis of GIS using spatial density, and crime replacement analysis can be conducted.

Therefore, this study intends to analyze the effectiveness of CCTV installation by analyzing the current condition of actual crime occurrence before and after the installation of CCTV, targeting case areas as spatial approach for the maximization of the effects in the installation of CCTV.

IV. An Analysis on the Appropriateness of CCTV Location and Effectiveness

A. The Data Construction

Spatial analysis was conducted in a case city (J City in Korea) by using GIS to confirm whether CCTV is appropriately installed in crime hot spots. The data of crime occurrence used for the analysis, were collected by the crime management register spanning two years, 2008 and 2011. Those data were recorded by the district police stations of J city. Based on the address of crime occurrence, the location of crimes were identified with points on the map, and they were built up with GIS by appointing the crime attributes such as crime time and crime type to each point.

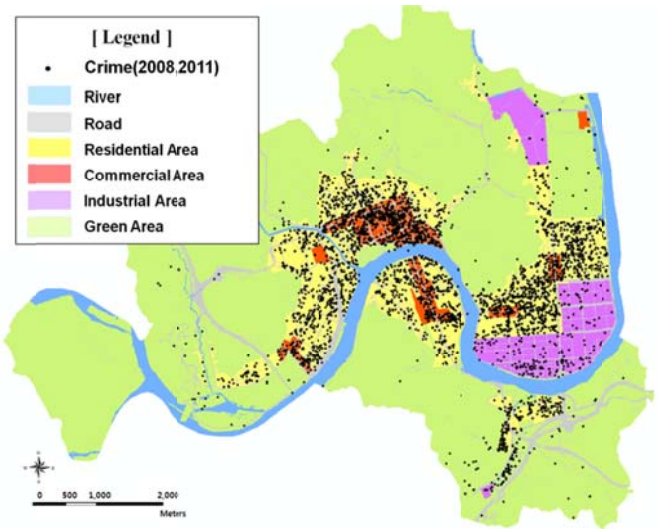


Fig. 4 Crime Distribution in Case City

According to the crime management register of J city, the total of crime cases reached to 3,930 in 2008. Of those cases, the cases with unclear and overlapped reports were omitted and 2,362 cases were left. In 2011, the total number of crime was 3,560 cases, in which data used for the analysis were 2,564 cases (Fig. 4).

In the case of CCTV, local governments manage the information about the location of CCTVs via an excel file, and geographical information is collected by going through on-spot identification based on the CCTV location data like the crime

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data as shown in Fig. 5.

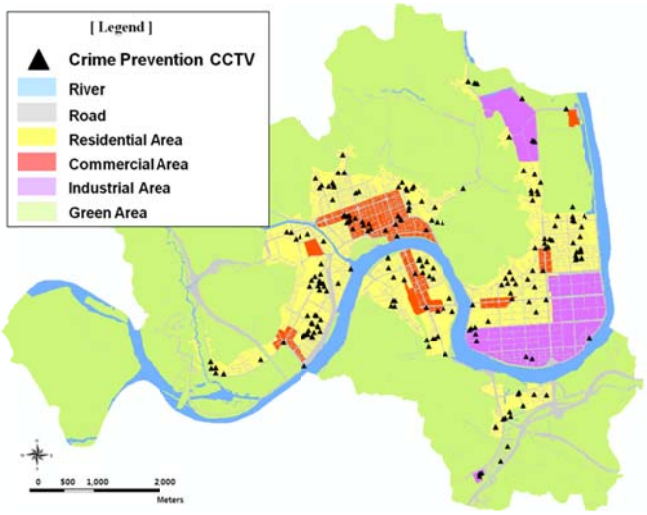


Fig. 5 CCTV Installation in Case City

In the case city, 876 CCTV sets were installed in 246 locations as shown in Table II. Of those sets, CCTVs particularly for crime protection were 115 sets in 24 locations. They were intensively installed in commercial areas and some parts of residential areas as shown in Fig. 5.

TABLE II
CCTVs IN J CITY

Installation purpose		No. of Installation	Installation Location
Disaster and fire*	River monitoring	6	6
	Facility management	1	1
Littering violation*	Crime-prevention	32	32
	Prevention of littering	8	1
Facility management*	Crime prevention	120	4
	Facility management	214	27
	School zone	257	113
	Decoding vehicle no.	26	4
Crime prevention*	Traffic control	32	11
	Littering & park management	2	1
	Park management	43	14
Crime prevention **		115	24
Parking violation **		20	8
Totals		876	246

* Multi-purpose CCTV ** Single purpose CCTV

B. An Analysis on the Appropriateness of CCTV Location

To analyze the appropriateness of CCTV location, a buffering analysis on crime hot spot areas and CCTV installation areas was conducted in both the aspect of global whole city and local specific area. First, it applied the analysis of Nearest Neighbor Hierarchical Clustering (NNHC) by interlocking GIS and CrimeStat to extract crime hot spots in J city. Since the statistical analysis on the secondary clustering as well as the primary clustering in NNHC is possible, NNHC is an easy way to identify the characteristics of crime distribution in the local aspect and find crime hot spots.

Two incidents or incidents more than two in NNHC were formed in the primary clustering and the first clustering is gathered again as secondary clustering like a tree structure. At this time, this study arranged the probability at 0.05% significance level, which has been adopted in general studies and confined the number of points included in the clustering to 20. The analysis results showed the crime hot spots in the commercial areas and residential areas around the commercial areas, as shown in Fig. 6.

Next, it attempted to analyze the possible areas of spatial surveillance by CCTV in J city. For the analysis, GIS buffering analysis was conducted under the standard of 50m radius in consideration of most CCTVs' capacity in J city. The results show that CCTVs did not make effective surveillance in comparison with the number of installed CCTV.

For example, since areas where the surveillance with CCTV is not possible, can occur, CCTVs should be installed securing a clear view at maximum through identifying local facilities or obstacles. However, currently, several CCTVs are intensively installed in certain places such as children protection zones or areas with frequent civil complaints. Thus CCTVs are not effectively used compared to the installed numbers.

Meanwhile, NNHC and buffering map were overlaid analyzing whether the CCTV location is appropriate. CCTV installation ratio was comparatively low in crime hot spot areas as shown in Fig. 6. This shows that the installation of CCTV was not effective. Therefore, additional installation and readjustment of location are required by prioritizing crime hot spot areas. Overall, the number of CCTVs was somewhat less than crime occurrence cases. However, CCTVs need to be installed in the target areas first and should be gradually expanded rather than being installed in the entire built up areas without considering the aspects of crime distribution.

C. An Analysis on the Effectiveness of CCTV

CCTVs for crime protection play a role in reducing the crime opportunities, which can be committed by latent criminals through official surveillance or employers [15] However, CCTV for crime prevention in particular areas can lead us to expect the crime transference phenomenon because criminals are likely to transfer crime areas to adjacent areas.

On the other hand, there are studies that argue the proliferation effect of the crime control benefit, reducing crime even in adjacent areas due to the CCTV, installed in a particular area [16], [17].

However, an analysis on the effect of crime transference and the proliferation effect of crime control has not been verified sufficiently yet. Therefore, this study attempts to measure the crime transference effect and the proliferation effect of crime controls targeting case areas.

To achieve this goal, this study employed the method of Weighted Displacement Quotient (WDQ), developed in studies of [18]. The WDQ is formulated as (1).

WDQ is an analysis technique that deals with the crime transference phenomenon and is a sort of integrated analysis of time-series analysis and geographical analysis.

$$WDQ = \frac{\{(Bt_1/Ct_1)-(Bt_0/Ct_0)\}}{\{(At_1/Ct_1)-(At_0/Ct_0)\}} = \frac{B'}{A'} \quad (1)$$

A: The crime rate in the experiment area (CCTV Installation area); B: The crime rate in the buffer area (the surrounding area of CCTV installation area); C: The crime rate of the control area (the area which is not affected by the change, occurred in A and B); t_0: Before the crime prevention strategy, t_1: After the crime prevention strategy.

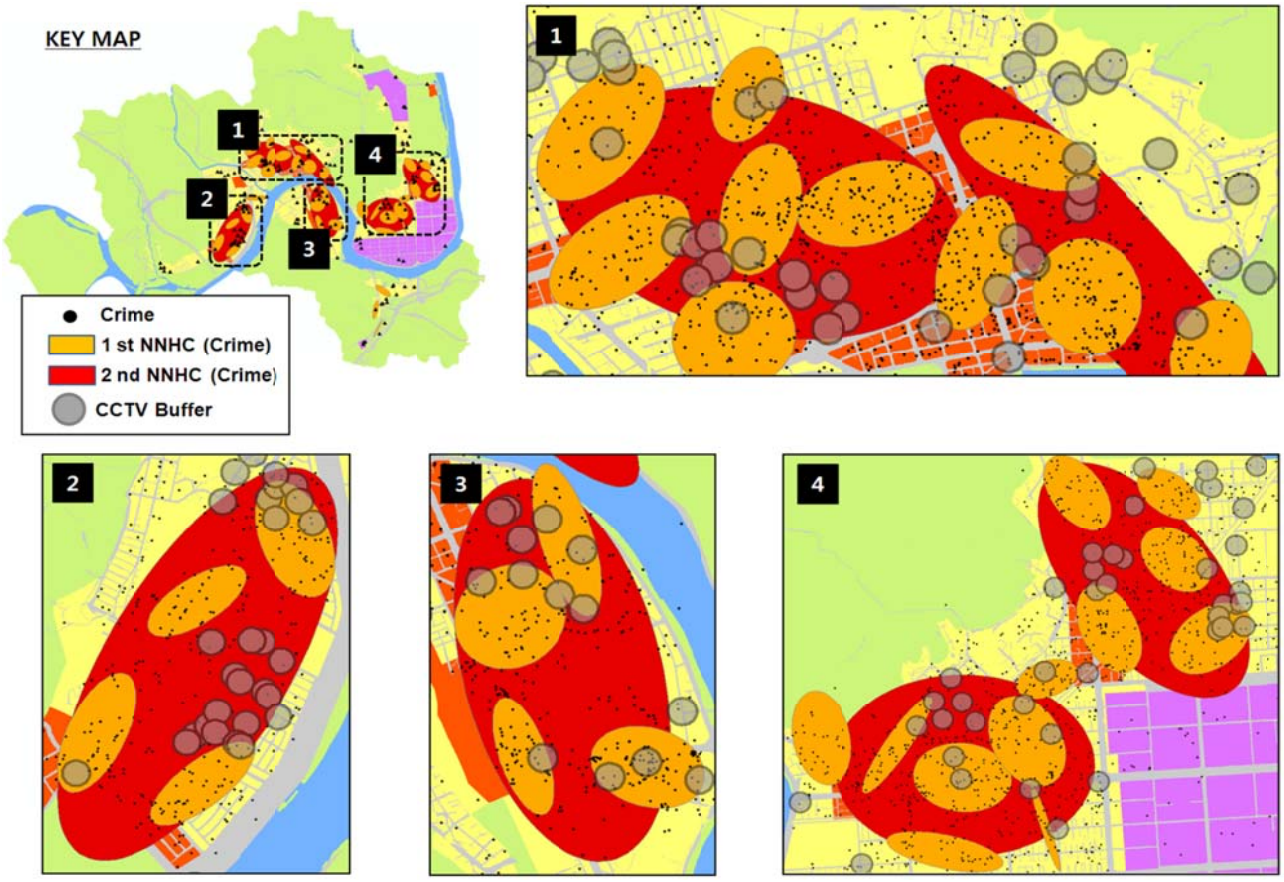


Fig. 6 Overlay of NNHC Analysis and CCTV Buffering (50m) of Crime Occurrence

WDQ indicator is explained by dividing the numerator and the denominator. The denominator compares the crime rates in the experimental area versus control area with the time of before and after crime prevention strategy. Meanwhile the numerator compares the crime rates with the time of before and after the installation of CCTV in the buffer area on the condition that the installation of CCTV is successful. Therefore, the interpretation presented in Table III is possible according to the value of WDQ.

TABLE III
INTERPRETATION OF WDQ

WDQ Value		Interpretation
A'	A'>0	Fail of crime prevention strategy
	A'<0	The success of crime prevention strategy
B'	B'>0	The expectation of crime transference effect
	B'<0	The expectation of the proliferation of crime control benefit

For the analysis of WDQ, case areas were selected and divided into the experiment area, control area, and buffer area. Areas, where the data of crime occurrence before and after the installation of CCTV were acquired and there was no environmentally significant change, were desirable for the analysis. Accordingly, case areas as shown in Fig. 7 were selected by investigating areas that satisfy such conditions in J city.

In this area houses are intensively concentrated, and there are no significant physical and social changes during the experimental period. The area where CCTVs were not installed surrounded by the experiment area and the crime transference phenomenon was expected according to the installation of CCTV, was selected as the buffer area. The area where a CCTV was not installed but residential conditions are similar to the experiment area around the buffer zone, was selected as the control area. It compared the experiment area and other areas to identify the effectiveness of crime prevention strategies through CCTV surveillance. Violence and burglary were subject to crime data input in the analysis of WDQ targeting these areas. Crime data of 2008 (17 cases) and 2011(37cases) were utilized for the analysis of crime data, and the installation and operation of CCTV began in 2010, so that these areas were

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suitable for measuring the effect before and after the installation of CCTVs. The distribution of crime occurrence is as shown in Fig. 8.



Fig. 7 Establishment of the Experiment Area, Buffer Area, and Control Area

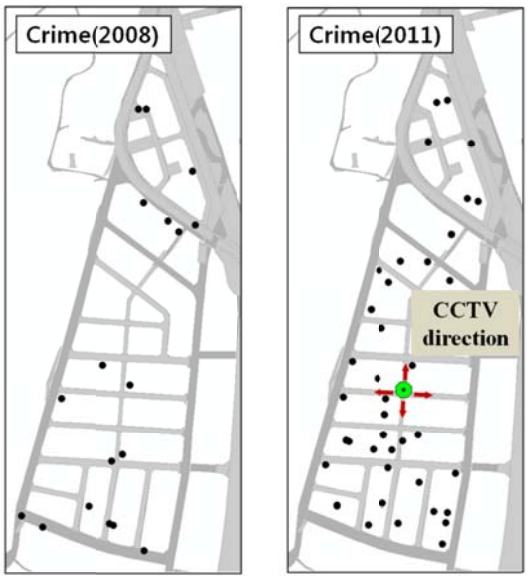


Fig. 8 Crime Occurrences Before and After CCTV Installation

The WDQ index in case areas is calculated as in Table IV. The results reveal that the crimes of burglary and violence increased in the control area versus the experiment area in spite of the installation of CCTV, and the installation of CCTV did not contribute to the reduction of crimes with A'>0, as shown in Table IV. In addition, B' was bigger than 0. A crime transference effect was expected, but crime occurrence was higher, which was insignificant. In other words, it was confirmed that the crime rate of surrounding areas would be likely to decrease with the installation of CCTV, even though there was no direct effect of a crime decline in crime occurrences.

However, the installation of CCTV in case areas did not bring about positive results and a remedy is needed. Put simply, the current conditions of crime occurrence and local spatial characteristics should be considered in the installation of CCTV in relevant areas. Furthermore, the spatial factors and standards for evaluation should be included in the CCTV guidelines when local governments install CCTV units across the nation.

TABLE IV
ANALYSIS RESULTS OF CRIME RATE AND WDQ

Division		Burglary		Violence	
		t0	t1	t0	t1
Experiment Area (A)		0.15	0.21	0.1	0.19
Control Area (B)		0.46	1.06	0.4	1.02
Buffer Area (C)		0.08	0.07	0.3	0.46
WDQ Results	A'	1.13		0.08	
	B'	9.39		0.88	

V. CONCLUSION

Like existing studies, there were some differences in crime prevention and control effects of CCTV according to crime types. However, it is obvious that most studies report that CCTV has a positive effect on crime prevention. It is also safe to mention that previous studies on the transference effect of CCTV have not come to a clear conclusion, and more scrupulous analysis according to areas is required. The fact that there was no appropriate analysis tool that can identify the crime transference phenomenon can be a cause.

In this regard, this study analyzed the appropriateness of CCTV location through the overlay analysis of crime hot spot areas and CCTV installation locations from a global (whole city area) level to the local specific area in the case city. The study results identified that most CCTVs were installed in residential areas and children protection zones so that many crime events actually occurred but were not observed.

Subsequently, this study analyzed how the installation of CCTVs, by using the concept of WDQ in the local aspect, is effective. As a result, it was demonstrated that the installation in case areas were not effective in the reduction of crimes. Furthermore, in the analysis of the possibility of crime transference, crime transference effects to surrounding areas caused by the installation of CCTV was not found and the results were insignificant. On the other hand, it was identified that crime rates in surrounding areas are likely to decrease due to CCTVs, even though the decline of crime was not great to the extent of the decrease in direct crime cases.

These results were confined to the case areas, but more scientific studies, which can trace back to the crime occurrence, and efforts to improve the CCTV effects through continual evaluation, are needed to maximize the effect of CCTV installation. In terms of research, methodological development which can evaluate the installation effect of CCTV is required. In other words, evaluation methods should be developed from the spatial and economic perspectives such as GIS space analysis and cost-benefit analysis. For the appropriate installation and operation, such evaluation methods need to be

distributed to local governments.

The study results have a limit in their generalization because this study analyzed only one case area. Therefore, additional crime occurrence data before and after the CCTV installation in more diverse areas are needed for further analysis. However, in Korea, it is very difficult to acquire such data for the privacy concerns. Therefore, this matter should be resolved in a timely manner.

ACKNOWLEDGMENT

This study was supported by MOLIT 13AUDP-B070066-01, NRF 2012R1A1A4A01019803, BK21PLUS Project.

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