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CCTV Evaluation in Cincinnati within GIS Environment for Crime Prevention.

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CCTV Evaluation in Cincinnati within GIS Environment for Crime Prevention

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By

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Abstract

This paper evaluates the newly installed Closed-circuit television (CCTV) at selected sites in Cincinnati, OH, for one year before and after camera installation dates to understand its effectiveness in crime deterrence. In order to determine the expected crime control area a viewshed study was conducted with 2D and 3D GIS mapping. To measure relative impact, the Corryville study area was compared to two other local CCTV areas in Cincinnati. There was minimal total crime reduction after CCTV installation in two selected comparison sites relative to the Corryville study area. To evaluate the different results, this paper analyzes evaluates not only the camera’s location but also social and physical characteristics of the sites to understand other possible factors affecting crime rates. The paper concludes that CCTV is not very effective in deterring certain types of crime. Moreover, the effectiveness is different depending on the physical and social characteristic of a given neighborhood. However, it is still effective in reducing some types of crime, even more so if the study area is a residential area with less mobility and limited accessibility from other high density neighborhoods. It is almost impossible to conclude that crime is reduced by CCTV because this study only considers a one year period and there are many other factors and limitations. Thus, future observation in crime rates for these areas is necessary to determine if there is a lagging effect of CCTV installation.
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1. Introduction

High crime rates in the United States have a considerable effect on residential location and their property values (Cook 2008). Therefore, the concentration of crime in specific locations (hot spot) is a significant public safety problem which threatens the quality of urban life. In areas with endemically high crime rates, an unpleasant and unsafe urban environment remains a serious problem, causing economic decline as a result of the loss of businesses. In terms of sustainable development, safe streets are a necessary platform for neighborhood growth and prosperity (Cook 2008). In order to increase usability, management of crime prevention is a necessary challenge to overcome.

The goal of this study is to evaluate a previously proposed crime prevention technique and to understand its impact on crime reduction. CCTV is popular because when the cameras are installed properly, they can be a problem-solving tool in the fight against a wide range of crimes (Brown 1995). However, recent evidence indicates that very few of CCTV installations have been systematically evaluated. Nearly half of all metropolitan and non-metropolitan cameras are not analyzed for effectiveness in crime reduction (Brown 1995). Evaluating recently installed CCTV is critical to understanding its effectiveness as a crime prevention tool and finding a better practice in the future. As a result, findings from this paper should help law enforcement officials to make decisions in regard to their plans for existing CCTV and future CCTV installation.

In Cincinnati, there were 34 public open-street CCTV cameras operated by the City of Cincinnati Police Department for public safety in 2011. However, the cameras have not been evaluated since their installations. Accordingly, evaluating the installed CCTV is important in understanding its effect on crime prevention in Cincinnati. Literature review indicates that
CCTV works best in small area, so that this paper focuses on three different neighborhoods individually which are differentiated by their land use as residential and commercial, or residential. These neighborhoods are separated by diverse social contexts, which is important for measuring the direct impact of cameras on crime in a ways that maximizes the validity and reliability of the result. Therefore, comparing those different study areas is important because every neighborhood has different social contexts and they influence on crimes differently. In this paper, 12 selected cameras in different neighborhoods are compared based on crime incidents before and after the CCTV installation.

Crime mapping and hot spot analysis were performed for all study areas for four consecutive years to analyze crime incident patterns. The crime hot spot maps were able to understand high and low crime rate areas and see the crime changes visually. From the crime maps, it was possible to propose different causes of crime changes after CCTV installation.

A Viewshed was analysed to determine an appropriate study area to select crime incidents occurring in the CCTV monitoring range for quantitative analysis.

1.1 Report Structure

In this paper, the following contents were mentioned to conduct the research:

(1) Statement of Problem: Crime prevention in urban areas is important for public safety. CCTV has been popular for crime prevention, and it is necessary to evaluate its effectiveness with better spatial analysis methods including three-dimension (3D) techniques.
(2) Research Objectives and Questions: The hypothesis is, “Does CCTV really affect to crime reduction?” If not, “What are the possible causes of the results?”

(3) Literature Review: Crime and Environmental Criminology are reviewed to understand the crime prevention with physical environment. CCTV is used as a situational crime prevention tool. Contextual theory explains why people behave differently from people in different social contexts regions. For crime analysis, crime mapping and GIS are useful to visualize and analyze it.

(4) Methodology: Social and physical analysis, spatial analysis, and quantitative techniques are used to evaluate the CCTV.

(5) Study Background and Setting: Crime data, CCTV characteristics, physical and social characteristics of study areas are described.

(6) Crime Mapping and Spatial Analysis: A large scale of crime hot spot map is generated to visualize the crime incidents. A daytime and nighttime bar graph shows the crime numbers in order to explain the findings from Corryville study which resulted in no significant crime reduction.

(7) Viewshed and 3D Spatial Analysis: A small scale hot spot map is developed to show the crime changes in 300ft buffer. In order to conduct quantitative research, counting crimes occurring in the buffer and the viewshed is important to describe crime changes in numbers. The viewshed is also examined in 3D.

(8) Conclusion: All 12 CCTV were installed with the same method but the result in crime reduction is different due to different social contexts and geographical differences.
However, CCTV in two study areas show that crime decreased after CCTV implementation in vehicle theft, assault, and robbery.

(9) Limitation: There are limitations such as lack of data about criminals’ understanding of CCTV location, different numbers of pedestrians in different study areas, geocoding inaccuracies, difficulty of statistical testing due to the limited frequency of crimes, and possible lagging effect.
2. Statement of Problem

2.1 General Problem of Crime

Crime in urban areas, especially in or adjacent to poorer neighborhoods, is high and crime in those areas has been spreading to other adjacent areas where they end up creating other high crime regions. Ultimately, it is important to prevent possible crime events to protect a healthy community from other adjacent high crime regions. The study area, Corryville, is situated next to the University of Cincinnati; students live, shop, and walk through the region where high crime incidents occur compared to other study areas.

2.2 Efficiency of Surveillance Camera

According to the American Civil Liberties Union, an increasing number of American Cities and towns are currently investing millions of taxpayer dollars in surveillance camera systems. But, few are closely examining the costs and benefits of those investments, or creating mechanisms for measuring those costs and benefits over time (Biale 2011). In order to use the investments effectively, more studies in crime location and video surveillance system should be conducted for the benefits of crime prevention and reduction of costs of installation before CCTV systems are put in place.

2.3 Need for Three-dimensional Spatial Analysis

The two-dimensional (2D) urban area coverage-based location models were developed with the limited information of real location information. There were many difficulties in presenting
three-dimensional (3D) environments into two-dimensional methods. Specifically, previous research has not included findings at the level of individual neighborhoods within the three-dimensional viewing area “viewshed”, which is important for measuring the direct impact of cameras on crime in a way that maximizes the validity and reliability of results. For this purpose understanding of preexisting urban conditions is important to the analysis of crime patterns and the determination of the ultimate solutions with regard to crime prevention. In this research, 3D maps will be constructed to a better view and present accurate geospatial coverage areas of surveillance cameras.

2.4 Social and Physical Analysis on CCTV Evaluation

Preliminary studies on CCTV were conducted in different locations and these differ in camera types, monitoring range, operation system, social and physical character of region, management, location, and action on CCTV. Moreover, in order to find the result or generalize the impact of CCTV, it is common to use statistic methodology to evaluate the effectiveness. According to the literature review, most of the research shows no statistically significant effect on crime reduction (Biale 2011). Those studies have been focused on individual cameras and measure the crime changes between the pre-installation and post-installation period. This paper studied current CCTV installed in Cincinnati within the context of neighborhood characteristics.
3. Research Objectives and Questions

3.1 Main Objective

The goal of this project is to evaluate the recently installed local open-street CCTV for crime prevention based on 2D and 3D GIS environment. To achieve this goal, the following objectives are followed.

3.2 Sub-objectives Questions and Methods

Social and physical analysis of each study areas are needed before CCTV location analysis, and then quantitative analysis should be followed to the different findings on crime changes.

1. Why different study areas are required to be observed for CCTV evaluations?
   
   a. Explain the selected study areas’ location importance as residential and commercial, residential.
   
   b. Understand crime patterns and influences to the neighborhoods.
   
   c. Evaluate crime changes before and after CCTV installation.

2. What kinds of data and how can the data be studied?
   
   a. Acquire recent crime data, surveillance camera location, and the geographical information system (GIS) of the study area, and review of the data.
   
   b. Examine the data within a 2D GIS environment and finding the hot spot.
c. List the problems of 2D GIS location analysis and suggesting 3D GIS location analysis for better geospatial analysis.

3. How can the viewshed visualization be useful to analyze crime changes?

a. Create 300ft buffer and viewshed to calculate the crime incidents over four years, and analyze the differences.

b. Compare the results in Corryville to other selected sites to evaluate the CCTV effectiveness.

c. Find areas hidden from the buildings.

d. Compare the finding in Corryville to other selected sites to evaluate the CCTV effectiveness.

e. Evaluate the crime changes in Price Hill and Millvale with the same evaluation methodologies used in Corryville.

f. Find different results from the compared sites.

g. Why are the results of crime reduction in Corryville different from the other sites?

h. Explain the possible factors, which might affect the locale.

i. Analyze the social and physical characteristic of these differences.
4. What suggestions are followed after this evaluation to increase the influence of the CCTV?

   a. Propose that more CCTV in Corryville as required
   b. Other crime prevention methodologies are needed to improve the walkability of the area, such as CCTV signage, lighting and public participation in surveillance.
   c. Future study on CCTV evaluation is necessary to see the lagging effect of CCTV installation.
4. Literature Review

This research project is focusing on three main areas including crime and crime patterns in terms of environmental criminology, crime mapping within geographic information system (GIS), and contextual theories of Crime. For the research project, there are four different literature reviews had to be done for each study area. First, literature of crime patterns and theoretical models based on designing physical environment are introduced to understand how to reduce crime and fear of crime. Second, the effectiveness of closed circuit television (CCTV) is reviewed from previous studies. Third, GIS crime mapping and three-dimensional visualization are suggested for a better crime analysis tool and find CCTV’s impact on crime. Finally, a contextual theory of crime is reviewed to understand how social, cultural, and physical or geographical context affect crime patterns in urban area.

4.1 Crime patterns in Urban Societies

According to the Uniform Crime Reports (UCR), Part I offense classification includes Criminal Homicide, Forcible Rape, Robbery, Aggravated Assault, Burglary, Larceny-theft (except motor Vehicle theft), Mother Vehicle Theft, and Arson (Federal Bureau of Investigation 2004). Collecting this crime data, finding the high crime location, and controlling the places are essential to prevent crime activities. To prevent the crime, thousands of local law-enforcement agencies keep records of crime information according to definitions and guidelines provided by the UCR (Cook 2008). Based on the UCR’s crime types, this paper categorized the major offense to Assault, Theft, Robbery, and Auto related crime due to majorities of crime types in the study areas.
From the crime report, the volume, trend, and patterns of crime are easy to identify. The geography of crime tends to be rather stable and predictable in spite of its voluntary nature (Cook 2008). According to Cook, therefore, crime rates are high in those neighborhoods, which is characterized by a high concentration of disadvantaged minorities, joblessness, single-parent household, drug abuse, substandard housing, inadequate public services, and high population turnover (Cook 2008). Eventually, areas where poor people live in high crime rates become hot spots perhaps because of declining social and economic conditions.

Crime hot spots are an identified area where certain crime types occur more frequently than in other areas. In hot spots, there is high crime incident opportunity because there is a high opportunity to commit criminal activities. That can be identified by “opportunity theories”: Routine Activity Theory, Rational Choice Perspective, and Crime Pattern Theory that are interlinked (Liu & Eck 2008).

Routine Activity Theory by Marcus Felson explains on offender requires following three essential elements: a motivated offender; a suitable target; and the absence of a capable guardian (Cohen & Felson, 1979). However, this theory has been argued by its focusing on the criminal event and not the offender, which is difficult to predict and analyze criminal events (Clarke 1983).

The Rational Choice Theory by Cesare Beccaria describes offenders as rational decision-makers who think about their behavior before committing their crimes: a bounded rationality (Liu & Eck 2008). The potential offenders commit crime when their reward is maximized (Liu & Eck 2008). The Rational Choice Theory is also arguably used independently because offender’s decision-
making process cannot be fully explained without considering the environmental information (Liu & Eck 2008).

Crime Pattern Theory by Patricia and Paul Brantingham focuses on how offenders find suitable targets and crime places within the environment (Liu & Eck 2008). Potential offenders know the best place to commit their criminal behavior within their personal awareness space. For example, home, workplace, activity, and the paths between them can be their awareness spaces (Brantingham & Brantingham, 1984, 1993). In other words, potential offenders plan on criminal activity in the area within better awareness than others, which then becomes a hot spot. This also supports following explanation on how smaller hot spots are created by other existing hot spots because of knowing the areas. This crime pattern theory is a better explanation to understand the relationship between crime and space, which explains how offenders select the site for their crime.

4.2 Crime Prevention Methods Based on Environmental Criminology

A crime occurs when the following four elements come together: a law; an offender; a victim or target; and a place (New South Wales Government 2011). To reduce crime, controlling places have become important because we can predict the hot spot and control the space rather than offenders or victims. Environmental Criminology is based on the place element by using urban design that improves public safety by deterring crime and reducing the fear of crime (Atlas et al. 2008). There are two primary crime prevention methods based on environmental criminology. One is Situational Crime Prevention and another is Crime Prevention Through Environmental Design (CPTED). Both crime prevention practices introduce how to use the space in order to reduce crime.
4.2.1 Crime prevention through environmental design

Crime Prevention Through Environmental Design (CPTED) had been introduced by criminologist and sociologist C. Ray Jeffrey (1971) and was inspired by Jane Jacobs’s theory (1961) “eyes on the street.” From Jacobs’s book “The Death and Life of American Cities”, “she suggests residential crime could be reduced by orienting buildings toward the street, clearly distinguishing public and private domains and placing outdoor spaces in proximity to intensively used areas” (Jacobs 1961). According to Jeffrey’s studies, he found that most street crime is influenced by physical surrounding environment (Jeffrey 1971). In short, well-maintained places reduce crime, but inappropriate street design with lack of surveillance provides criminal opportunities. Defensible Space by Oscar Newman (1971, 1973) is another well known theorist who proposed CPTED that protects private property by considering strong visual barriers and improving surveillance.

From Newman’s study on defensible space and Jeffrey’s study on CPTED, surveillance is important to reduce opportunities of crime by observing potential offenders. In terms of environmental design for crime prevention, design with high surveillance can deter crime. This theory leads to other crime prevention practices such as Situational Crime Prevention derived from CPTED.

4.2.2 Situational Crime Prevention

Situational crime prevention was introduced by in the late 1970s and early 1980 influenced by CPTED and Defensible Space. However, situational crime prevention focused more on “highly specific forms of crime that involve the management, design, or manipulation of the immediate
environment in as systematic and permanent a way as possible so as to reduce the opportunities for crime and increase its risks as perceived by a wide range of offenders.” It is obvious that situational crime prevention through environmental change reduces the opportunity for crimes to occur, but the approaches should be carefully designed not to be unattractive while using target hardening. Thus, appropriate use of a tested situational prevention tool is required to address public safety with the best effectiveness and minimizing installation of target hardening. For the purpose of suggesting situational prevention requirements, CCTV was selected and studied for the best recommendation of situational crime prevention tool. Previously, there are successful case studies involving surveillance cameras result in crime reduction.

4.3 CCTV for crime prevention

CCTV is one type of situational crime prevention tool that the use of public security CCTV has been widely used in law enforcement agencies in Great Britain, France, Monaco, Spain and other Countries (Nieto 1997). Numbers of U.S. municipalities have begun using CCTV to monitor public areas, schools, and residential districts by law enforcement (Nieto 1997). The advantage of CCTV is reducing crime by increasing surveillance and reducing the rewards of crime. According to Armitage et al. (1999), she describes the mechanisms of CCTV:

1. **Caught in the act** – perpetrators will be detected, and possibly removed or deterred.

2. **You’ve been framed** – CCTV deters potential offenders who perceive an elevated risk of apprehension.
3. NOSY PARKER – CCTV MAY LEAD MORE PEOPLE TO FEEL ABLE TO FREQUENT THE SURVEILLED PLACES. 
   THIS WILL INCREASE THE EXTENT OF NATURAL SURVEILLANCE BY NEWCOMERS, WHICH MAY DETER 
   POTENTIAL OFFENDERS.

4. EFFECTIVE DEPLOYMENT – CCTV DIRECTS SECURITY PERSONNEL TO AMBIGUOUS SITUATIONS, WHICH 
   MAY HEAD OFF THEIR TRANSLATIONS INTO CRIME.

5. PUBLICITY – CCTV COULD SYMBOLIZE EFFORTS TO TAKE CRIME SERIOUS, AND THE PERCEPTION OF 
   THOSE EFFORTS MAY BOTH ENERGIZE LAW-ABIDING CITIZENS AND/OR DETER CRIME.

6. TIME FOR CRIME – CCTV MAY BE PERCEIVED AS REDUCING THE TIME AVAILABLE TO COMMIT 
   CRIME, PREVENTING THOSE CRIMES THAT REQUIRE EXTENDED TIME AND EFFORT.

7. MEMORY JOGGINGS – THE PRESENCE OF CCTV MAY INDUCE PEOPLE TO TAKE ELEMENTARY SECURITY 
   PRECAUTIONS, SUCH AS LOCKING THEIR CAR, BY JOGGING THEIR MEMORY.

8. ANTICIPATED SHAMING – THE PRESENCE OF CCTV MAY INDUCE PEOPLE TO TAKE ELEMENTARY 
   SECURITY PRECAUTIONS, FOR FEAR THAT THEY WILL BE SHAMED BY BEING SHOWN ON CCTV

9. APPEAL TO THE CAUTIOUS – CAUTIOUS PEOPLE MIGRATE TO THE AREAS WITH CCTV TO SHOP, LEAVE 
   THEIR CARS, AND SO ON. THEIR CAUTION AND SECURITY-MINDEDNESS REDUCE THE RISK.

10. REPORTING CHANGES – PEOPLE REPORT (AND/OR POLICE RECORD) FEWER OF THE CRIMES THAT OCCUR, 
    EITHER BECAUSE THEY WISH TO SHOW THE [DESIRABLE] EFFECTS OF CCTV OR OUT OF A BELIEF THAT 
    “THE COUNCIL IS DOING ITS BEST” AND NOTHING SHOULD BE DONE TO DISCOURAGE IT (ARMITAGE ET AL).

Due to such advantages of CCTV, many studies have been conducted to understand the 
effectiveness of CCTV with different evaluation. However, its effectiveness of crime prevention
is still controversial because the findings are different. For example, each study comes up with different result by using different methodology applied to different social and physical characteristics of the study areas. In general, however, studies shows that CCTV decreases crime to a small degree, and it is the most effective in reducing vehicle crime in car parks (Brandon et al 2002).

4.4 CCTV in United Kingdom

During the literature review, many CCTV studies from UK indicate it is very effective in crime rate: in the small town of Berwick burglaries fell by 69 percent; in Northampton overall crime decreased by 57 percent; and in Glasgow, Scotland crime decreased by 68 percent (Montalbano 1996). Moreover, In Liverpool, crimes such as shoplifting, prostitution, graffiti, and other nonviolent crimes have decreased by 25 percent over the last three years (Marcus Nieto 1997). According to the Liverpool study, the city has installed on of the largest CCTV surveillance system and the residents report that they feel safer downtown, even at night (Marcus Nieto 1997).

According to Noam Biale, he describes that meta-analysis which is combined the results of multiple researches on CCTV evaluation that all have similar hypotheses and methodological criteria; it shows no statistically significant impact on crime rates in UK when using meta-analysis (Noam Biale 2011).

Yet, there are varying results of CCTV’s impact on crime, UK has the largest number of surveillance cameras in the world as a crime-fighting tool (Privacy International 2011). The number of surveillance cameras in England and Wales surpasses 4.2 million or one for every 14
persons in 2002 (Privacy International 2011). The British Home Office spent 78% of its criminal justice budget in the 1990’s on surveillance cameras\(^1\), and is estimated to have spent over a $1 billion in between 1995 and 2005 (Biale 2011).

### 4.5 CCTV in Untied States

Public CCTV surveillance system began to make a mark from events such as the World Trade Center Bombing, the Oklahoma City bombing, and the closure of Pennsylvania Avenue at the White House have raised public concerns about security (Nieto 1997). However, fewer studies of video surveillance have been conducted in the United States. Therefore, those studies conclude that CCTV reduces crime to a small degree in city centre or public housing, public transport; but CCTV can be most effective in reducing crime in car parks (Welsh and Farrington 2002). Welsh and Farrington also suggests that cameras can be effective when used in specific environments and using other interventions might help to increase the effectiveness of CCTV for crime prevention.

From the two CCTV studies in UK and USA, it is hard to make a common conclusion from the previous studies that CCTV has a significant effect on crime rates or not. However, the literature explains that the CCTV target study area should be small and then the outcomes would be better than the in the wider area outside. In addition, CCTV has to be evaluated at the local level with similar living environments not by city or national level because CCTV’s effectiveness is also affected by the surrounding environmental characteristics.

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4.6 Contextual theory

There are high crime rate regions called crime ‘hot spots’ where relatively high crime incidents occur in specific regions with social or physical problems such as high population density, low income, and low education. Individuals in these similar social context regions behave differently in regards to some specific type of behavior from other regions with different social contexts. (Benson). The contextual theory was supported by statistics, showing a correlation between some types of context and some types of behavior (Benson). Therefore, people commit crime in high crime areas more than people who live in other low crime areas (Benson). An understanding of social and physical characteristics in neighborhoods is so important to explain why people behave differently from people in different social context regions. Eventually, contextual theory would help to support why there are different results of crime prevention with CCTV in different social contexts.

4.7 Crime Mapping and Analysis Using GIS

Crime mapping is widely used to show the crime location and analyze the crime pattern for criminal justice practitioners. The mapping technique and tool has been drastically improved and it can show comprehensive data with accuracy and deliver the reliable information to decision makers (Johnson 2000). The high productivity and effective utilization of Geographic Information System (GIS) as an interface for integrating and accessing massive amounts of location-based information and enhance the implementation of various policing methodologies to reduce overall crime and disorder (ESRI 2011). The benefit of GIS crime mapping is important to understand where and how many crimes occurred. Therefore, the GIS is useful to visualize and analyze the crime event quickly for fast response from law enforcement and criminal justice
operations. Interactive visualization methods are required to present the viewer with an accurate and intuitive view of the criminal activity in a cityscape (Bruer et al 2008).

### 4.8 Three-Dimensional Visualization for Better Spatial Analysis

Since 1980, two-dimensional (2D) maps have been used to describe crime (Bruer et al. 2008). However, analyzing three-dimensional (3D) spatial information in the 2D projected crime map is limited to simulate all. Three-dimensional visualizations are widely used for showing virtual reality. As computer software for spatial information technology is being developed, the 3D visualization is getting more realistic and convenient to simulate real spatial information into cyber-space, it significantly helps researchers to test their projects much cheaper, faster, and easier.

There are several computer design tools to create 3D virtual images with GIS such as AutoCAD, 3DS Max, and SketchUp which are complementary technologies to develop 3D modeling. Using such an advantage graphic computer software with geographic information systems (GIS) provides a wider range of applications for city planners, researchers, designers, and engineers.

As increasing the demand and democratization for richer information and communication moving from analog to digital, 2D to 3D, to 4D, highly informed maps have been required for local businesses and the public sectors (Eberhard, D 2009). It can be expected that 3D mapping with GIS and 3D design tools can satisfy the needs of for better planning, design, construction and maintenance a more sustainable world today and in the future.
Analyzing 3D spatial information is critical to evaluate further studies on CCTV location and its monitoring range. It is certain that 3D visualization enables crime analysts to easily interpret the data and find actual monitoring sites to evaluate the CCTV’s effectiveness on crime prevention.

4.9 Findings from Literature Review

CCTV studies from literature reviews found that CCTV is not significant to reduce crime; but it has some effect on specific locations such as parking lots. However, more studies are required on the effectiveness of CCTV in crime prevention in the United States because there is a relatively small number of studies conducted compared to funding-for CCTV cameras. Moreover, the CCTV target study area should be small and separated by similar living environment due to different social contexts affecting the CCTV.

There are relatively many CCTV studies using statistical method instead of social characteristics of target areas. According to the contextual theory, understanding social context is important because crime occurs in different ways in different places. In order to evaluate the CCTV in different places, finding different social contexts would help to find different results from the CCTV evaluation.

According to the advantages of GIS, the ability to access and process geographical information with simple mapping allows us to visualize spatial information quickly and analyze it effectively to understand crime patterns. Therefore, 3D geospatial information allows better understanding of sensing ranges and capacities of CCTV from the typical geographical conditions because previous research includes a viewshed in 2D that is not enough to find the actual monitoring range without calculating an elevation of the camera and its surroundings. Three-dimensional
visualization is very useful to evaluate the CCTV monitoring area. The advanced visualization can designate better CCTV location allocation for adequate CCTV installation sites for future installation.
5. Methodology

To develop a set of analyses, spatial analysis, qualitative and quantitative techniques were used. First, social and physical analysis was performed in different study areas to define the social contexts because a small crime change may be a result of the social disorder than the installation of CCTV. Second, spatial analysis was conducted to show the hot spots or “risky places” in and out of the study areas to visualize the crime changes over four years. Moreover, viewshed or line of sight, which identified CCTV monitoring range, was developed to count the crimes influenced by CCTV. The third quantitative techniques provide the numerical information to create a time-series graphs for three years before and one year after CCTV installation.
6. Study Background and Setting

6.1 Crime data

The crime data came from the City of Cincinnati Police Department. The crime report includes street address, neighborhoods, date and time of reported crime, start and end of crime, location description, incident time, and types of crimes. For the purpose of spatial analysis with the crime data, GIS has been used.

The crime data was geo-coded with North America Geocode Service (ArcGIS Online). The special accuracy is 99 percent accuracy out of 100 percent, 1 percent for tie score.

From June 2007 to May 2011, Cincinnati crime data has been analyzed and divided into five major crime types as follows: Assault\(^2\) (aggravated assault, aggravated vehicular assaulted, assault, felonious assault), Criminal Damaging Endangering\(^3\), Robbery\(^4\) (aggravated robbery, robbery, Theft\(^5\); grand theft, petit theft, theft), Vehicle Theft\(^6\) (theft-license plates, unauthorized use of motor vehicle, vehicle theft, vehicular vandalism). Those crimes were selected by outside locations in order to count the crimes only monitored by CCTV. Outside locations are as follows:

\(^2\) Aggravated assault: An unlawful attack by one person upon another for the purpose of inflicting severe or aggravated bodily injury. This type of assault usually is accompanied by the use of a weapon or by means likely to produce death or great bodily harm. Simple assaults are excluded. (FBI)

Other assaults (simple): Assaults and attempted assaults where no weapon was used or no serious or aggravated injury resulted to the victim. Stalking, intimidation, coercion, and hazing are included. (FBI)

\(^3\) No person shall cause, or create a substantial risk of physical harm to any property of another without the other person’s consent (codes.ohio.gov)

\(^4\) Robbery—The taking or attempting to take anything of value from the care, custody, or control of a person or persons by force or threat of force or violence and/or by putting the victim in fear. (FBI)

\(^5\) Larceny-theft (except motor vehicle theft)—The unlawful taking, carrying, leading, or riding away of property from the possession or constructive possession of another. Examples are thefts of bicycles, motor vehicle parts and accessories, shoplifting, pocket-picking, or the stealing of any property or article that is not taken by force and violence or by fraud. Attempted larcenies are included. Embezzlement, confidence games, forgery, check fraud, etc., are (FBI)

\(^6\) Motor vehicle theft—The theft or attempted theft of a motor vehicle. A motor vehicle is self-propelled and runs on land surface and not on rails. Motorboats, construction equipment, airplanes, and farming equipment are specifically excluded from this category. (FBI)
Yard; Construction Site; Lake/Waterway; Field/Woods; Street; Parking Lot; Park/Playground; Cemetery; Public Transit Vehicle; Other Outside Location; Others. To identify the crime incident date, ‘Date From’ was used for the crime incident rather than ‘Date Report’ from the crime report attribute table to limit the possibility of the report crime happening after the crime occurred.

### 6.2 CCTV Characteristics

City of Cincinnati Police Department installed a total of 34 CCTV cameras around Cincinnati in 2011. According to a City of Cincinnati Police Department officer, those existing CCTV were installed based on crime statistics, community input, donations, police officer inputs, and CCTV technology. Security personnel in the police department monitoring room, monitor the cameras and dispatch the officers if needed. Because of privacy issues, officers monitor or manually operate the cameras when they have received crime reports from the 911 call centers. Usually, The CCTV captures video automatically 360-degrees around the camera during the day. It can monitor approximately 1000ft from the camera at maximum; in addition, it can identify license plate numbers within a 300ft range and recognize objects and color within a 1000ft.
6.3 Study areas

6.3.1 Corryville

Figure 1. Corryville Location Map

Corryville has been selected for this research study because many University of Cincinnati students reside in this high crime area. It is the main study area and is the focus of this thesis to evaluate CCTV in crime deterrence. However, because the findings were not clear supporting data was sought for the result. Thus, CCTV in Price Hill and Millvale were scrutinized to
compare to the CCTV in Corryville. In evaluating the data and conclusions of this paper, it is important to bear in mind that CCTV can be more effective within selective social and physical contexts. With this consideration in mind, and therefore understanding each study area is the most important part in evaluating the CCTV.

Corryville is the place where University of Cincinnati students live, and go for entertainment and shopping in Cincinnati (Uptown Cincinnati). It is located in the north side of downtown and close to the Over-the-Rhine neighborhood to the south and University of Cincinnati to the west. The neighborhood has a high accessibility to roads systems within Cincinnati neighborhoods; I-75 is to the west and I-71 is to the east, and major arterial roadways such as Vine Street and Reading Road are accessible. According to the 2010 US Census data, there are 3,327 residents and the population density is 6,412 persons per square mile. Cincinnati population density is 3,809 persons per square mile. The population density of the southern part of Corryville should be higher because the University of Cincinnati Hospital is situated in the northern part of Corryville, which is almost half of Corryville’s area. Majority of residents are between 18 to 24 years nonfamily households (39.7%) and rent houses. Medium house hold income is $12,808. On an economic perspective, there have been several new or remodeled residential and commercial constructions in the southern part of Corryville with geographic proximity to the University.

Although Corryville is in a school district, there is a high crime rate. Corryville is infamous for its high crime, and students and residents feel unsafe when walking in this place. In 2010, the City of Cincinnati Police Department installed public open-street CCTV in southern part of Corryville for crime prevention.
6.3.2 Price Hill

Price Hill is one of the earliest settlements of Cincinnati, which is mainly a residential area that has various cultures and economic levels (Cincinnati.Com). It is situated in the west part of Cincinnati, across the railroads from downtown. The region was settled away from the crowded inner city in the 19th century. For geographic reasons (high hill, highway and railroad) accessibility without car from the east part of Cincinnati is low. However, it was thriving upper-middle-class suburb containing businesses in the 19th century and well known for its “incline.”

Price hill is subdivided into East Price Hill, West Price Hill, and Lower Price Hill. According to the 2010 Census, there are 15,340 residents in East Price Hill and 15,320 residents in West Price Hill. The population density is 5,552 persons per square mile. The first two major resident brackets are between 25 to 34 years (15.8%) and 45 to 54 years (13.8%). Population in family households (76.4%) is higher that nonfamily households (21.5%). Renter occupied housing is 60.7%. Medium household income is $ 28,393.
6.3.3 Millvale

Millvale is a small neighborhood, apartment complexes, situated along the Mill Creek that single family and multi-unit residential structures are located. To the east, past and present light industry and a preponderance of railroad activity along the Mill Creek” (Cincinnati.Com). It is only a residential area that there is no business, but some dilapidated light industrial buildings are still in existence. The 2010 Census indicates that, Millvale contains 2,399 residents; population density is 5,404 per square mile. As of 2010, 39.5% of the residents are as male and 60.5% as female. Twenty two percent of residents are under 5 years and 16.8% are between 18 to 24 years,
according to the 2010 Census. Most of residents are in family households (85.3%) and the medium household income is $15,526. The neighborhood has low accessibility from the east and no attraction from other neighborhoods.

Figure 3. Millvale Location Map

6.4 Demographics

This demographic map shows population density with race. According to the map, Corryville is placed in between high population density of different ethnicity with diverse ethnicity compared to Price Hill; relatively high population density with whites, and in Millvale, most of people are black. The lowest population in between the highway in red and the strip n light cyan to the
north is because railroad and old light industry were located there. According to US census data, Table 1, Corryville is a high population density neighborhood with ethnic diversity where young people around 18 to 34 years live in rented houses as a nonfamily household. Price Hill is the place where a middle age group between 25 to 34 and 45 to 54 years lives in their own house with family. Millvale includes 90 percent of young black people with a high female population living with children. These findings from the demographics and geographical location will be important factors of CCTV evaluation in spatial analysis.
Figure 4. Demographic Map of Study Areas

Figure 5. Income Map of Study Areas
<table>
<thead>
<tr>
<th>Social and Physical Characteristics</th>
<th>Cincinnati</th>
<th>Corryville</th>
<th>West Price Hill &amp; East Price Hill</th>
<th>Millvale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population (Density) person/per square mile</strong></td>
<td>296,943 (3,809)</td>
<td>3,327 (6,412)</td>
<td>30,660 (5,552)</td>
<td>2,399 (3,744)</td>
</tr>
<tr>
<td><strong>Ethnicity (%)</strong></td>
<td>White (49.3) Black (44.8)</td>
<td>White (48.7) Black (43.1)</td>
<td>White (52.4) Black (40.1)</td>
<td>White (5.1) Black (90.9)</td>
</tr>
<tr>
<td><strong>Sex (%)</strong></td>
<td>Male (48.1) Female (52.0)</td>
<td>Male (57.5) Female (42.5)</td>
<td>Male (47.8) Female (52.2)</td>
<td>Male (39.5) Female (60.5)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>25 to 34 years (16.6%) 18 to 24 years (14.6%)</td>
<td>18 to 24 years (39.7%) 25 to 34 years (22.2%)</td>
<td>25 to 34 years (15.8%) 45 to 54 years (13.8%)</td>
<td>Under 5 years (22%) 18 to 24 years (16.8%)</td>
</tr>
<tr>
<td><strong>Nonfamily households (%)</strong></td>
<td>53%</td>
<td>77%</td>
<td>44%</td>
<td>32%</td>
</tr>
<tr>
<td><strong>Occupied housing units (%)</strong></td>
<td>Owner (38%) Renter (61%)</td>
<td>Owner (11%) Renter (88%)</td>
<td>Owner (39%) Renter (60%)</td>
<td>Owner (11%) Renter (88%)</td>
</tr>
<tr>
<td><strong>Employment (%)</strong></td>
<td>White (93%) Black (81%)</td>
<td>White (97%) Black (86%)</td>
<td>White (91%) Black (82%)</td>
<td>White (94%) Black (85%)</td>
</tr>
<tr>
<td><strong>Medium Household Income (dollar)</strong></td>
<td>$33,425</td>
<td>$12,808</td>
<td>$28,393</td>
<td>$15,526</td>
</tr>
<tr>
<td><strong>Accessibility from outer region</strong></td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td><strong>Median Year Structure Built</strong></td>
<td>1945</td>
<td>1939</td>
<td>1939</td>
<td>1948</td>
</tr>
<tr>
<td><strong>Median Gross Rent (dollar)</strong></td>
<td>$605</td>
<td>$670</td>
<td>$625</td>
<td>$319</td>
</tr>
<tr>
<td><strong>Occupancy Status (units)</strong></td>
<td>Occupied (78%) Vacant (21%)</td>
<td>Occupied (77%) Vacant (22%)</td>
<td>Occupied (79%) Vacant (21%)</td>
<td>Occupied (73%) Vacant (26%)</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td>LHS (7%) HSG (92%)</td>
<td>LHS (9%) HSG (27%) SC (24%) BD (14%)</td>
<td>LHS (22%) HSG (34%) SC (26%) BD (11%)</td>
<td>LHS (43%) HSG (21%) SC (30%) BD (0%)</td>
</tr>
<tr>
<td><strong>Land use</strong></td>
<td>Mixed Use</td>
<td>Mixed Use</td>
<td>Residential</td>
<td></td>
</tr>
</tbody>
</table>
7. Crime Mapping and Spatial Analysis

7.1 The Importance of Crime Hot Spot Map

Crime can occur everywhere and anytime, but it is impossible to predict the future crime location. However, it is possible to know which crimes and places would happen more in certain places than others using hot spot maps. With hot spot map, people can realize where the high crime locations are, and they can avoid the locations. In this chapter, crime hot spot maps show the change in crime rates before and after CCTV installation.

7.2 Developing Crime Hot Spot Map

To generate a crime hot spot map around the CCTV, it is necessary to zoom in to the specific site around the CCTV to predict the high crime location based on the same geographical region. The reselected site generated the same scale for better reading. In order to create a hot spot map, there were three steps undertaken using ESRI GIS program. First, geocoding had been done to displace the crime report from spreadsheet onto the map based on address. Second, to sum the multiple crime events on the same address, Collect Event tool calculated the number of crimes in each address. Finally, Kernel Density tool generated a hot spot map. According to Chainey, kernel density estimation is the most accurate prediction of where crime occurs (Chainey 2008).
7.3 Four Consecutive Crime Hot Spot Map in Regional Scale

Looking at the regional scale of crime hot spot maps is critical to understanding the general idea of crime changes around the study areas to check CCTV effectiveness in crime deterrence. Moreover, to visualize the crime changes effectively, four crime hot spot maps were generated, three consecutive crime maps for the local crime changes before CCTV installation, and one map for showing the crime hot spot after CCTV installation. For crime mapping and analysis, kernel density estimation was used to generate the hot spot. It is critical to understand the kernel density estimation, which is predicting high crime locations based on the number of incidents in the selected area. However, it can be misleading to compare the crime density to other different years of crime maps because each map only shows the crime pattern not the crime numbers to compare to the other crime maps. For example, the fourth map in Figure 7, the after CCTV installation map of Corryville is a light yellow (crime density), which doesn’t mean that
Corryville had less crime than the previous year because the map was generated within that selected area.

7.4 Corryville Hot Spot Maps

According to Figure 8, there are two major hot spots: the primary one is at the bottom of the map, Over-the-Rhine (OTR), where the most severe crime incidents occurred in Cincinnati, and secondary one is in the middle of map where business districts are placed along the University of Cincinnati corridor. The two major hot spots spread widely over Corryville and other adjacent areas, and they are all connected to other small hot spots. In general, the secondary hot spot spreads over part of Corryville – the half that includes businesses and residential area. Therefore, the highest crime density of Corryville showing in red has been reduced, but the size of the hot spot in OTR increased after CCTV installation. From the maps, it might explain that Corryville has been affected in the primary hot spots where crowds of potential offenders look for the targets in other business districts with high walk-ability. The map shows that the primary hot spot is very dense in OTR (shown all in red), and it needs more crime target areas, so and it spreads to the north since there was no place to go because of physical and geographical barriers such as railroads in the west and highways in the East. Moreover, Corryville might become a hot spot due to many college students living independently and walking alone at night. According to Laura J. Horn and Jennifer Berktold, approximately 86 percent of college and university students are defined as commuter students, that is, students need to walk (Laura et al. 1998). In 2010,
there were 50 crime incidents at nighttime\textsuperscript{7} and 26 crimes at daytime\textsuperscript{8} in a 300ft buffer around the CCTV after installation.

Figure 7. Daytime and nighttime crime number 12 month before and 12 month after CCTV Installation in a 300ft buffer

Figure 7 shows that Corryville has more nighttime crimes than daytime crime compared to Price Hill and Millvale. The bar graph shows that there are high crimes during night because many young independent college students walk at night, but the CCTV cannot monitor crime during the night.

\textsuperscript{7} Nighttime is between 19:00 to 06:59.

\textsuperscript{8} Daytime is between 07:00 to 18:59.
Figure 8. Corryville crime changes over for years. Yellow (low crime density), Red (high crime density)

Note: Yellow represents high crime density and red represents very high crime density.
### 7.5 Price Hill Hot Spot Maps

Figure 9. Price Hill Crime changes over for years.

Note: Yellow represents high crime density and red represents very high crime density.
According to Figure 9, the center of the hot spot with high crime rates is the commercial district placed along Price Hill’s main business corridor, Glenway and Warsaw Avenue, and the outer hot spot with low crime rate is a residential area. The high density of hot spot has been steadily decreasing over three years. The critical difference between the Corryville and Price Hill hot spot maps was that there is no severe hot spot connected to Price Hill’s hot spot, which is very important when evaluating the CCTV accurately because there is no crime influence from the outer study areas. It is evident that the highest crime density area has been reduced after CCTV implementation. The result supports the CCTV’s effectiveness in crime reduction.

7.6 Millvale Hot Spot Maps

Millvale has a small and low-density hot spot in the middle of its residential area. The size of the hot spot is small because there is a small number of residential units without commercial activities. It is very unique that this study area is isolated from the other regions and activities. In addition, the CCTV was installed very close to each other in a small area. In result, it is a notable crime reduction after CCTV installation. This small-scale study area revealed that crime could be decreased in such environments, no crime influxes from other high-density crime areas, residential, and high number of CCTV in small area. In other words, CCTV is effective in small residential areas away from other severe hot spots. However, in order to reduce crime in wide mixed-land use areas with less CCTV installation, it is important to evaluate the existing CCTV individually with spatial analysis to propose better techniques for CCTV in crime prevention.
Figure 10. Millvale Crime changes over for years.

Note: Yellow represents high crime density and red represents very high crime density.
8. Viewshed and 3D Spatial Analysis

8.1 Corryville

To conduct the research, the important thing is finding crimes that occur in the CCTV viewshed or influence area. As noted earlier a 300ft buffer around CCTV was developed as an influence area: high-quality images that identify face and license plates. Viewshed was generated individually to find real monitoring areas in GIS. However, the real CCTV’s monitoring range was set by the Cincinnati Police Department manually so that the real viewshed might be different from the generated viewshed in this paper. Furthermore, a small-scale of hot spot maps is needed to show the crime changes within the 300ft buffer and viewshed. The following crime density maps show the different crime rate between before and after CCTV implementation.

Figure 11 indicates that the crime density in a 300ft buffer increased once CCTV had been installed. This result does not answer the hypothesis that CCTV reduces the crimes. Thus, more studies are required to examine the CCTV to find the reasons of inefficiency in crime prevention, and the findings shall compare to other study areas to find the differences if the CCTV effect on crime reduction in other sites.

Following methods were conducted to evaluate the CCTV for the study areas: first, selecting crimes in the viewshed as a direct impact on crimes; second, lists the crime numbers based on major crime types in 300ft and viewshed to understand the crime changes after CCTV installation; third, examine the CCTV sites to evaluate the surrounding barriers; fourth, crime changes in the city, neighborhood, and the 300ft buffer to evaluate the overall crime patterns, which is helpful to check other timely or seasonal crime patterns.
Figure 11. 300ft Buffer in Corryville and Hot Spot Changes After CCTV Installation.

Before CCTV Installation

After CCTV Installation
According to the hot spot maps (Figure 11), crime occurred more in the two buffers on Vine Street and Jefferson Avenue. It was an unexpected result that crime actually increased after CCTV implementation. However, the viewshed map (Figure 12) suggests that the crime on Vine Street was not decreased due to having a smaller viewshed than the other two buffers. Although CCTV on Jefferson Avenue has a wide viewshed to monitor the crimes around the camera, the crime density increased after installation. To find the answer for the question, more studies of CCTV on Vine Street and Jefferson Avenue are necessary. Three-dimensional special analysis
would help to explain why crime occurred more after CCTV installation on Jefferson in Figure 14 and 15.

Table 2. Corryville Crime Changes in 300ft Buffer and Viewshed

<table>
<thead>
<tr>
<th>Corryville</th>
<th>Crimes in 300ft Buffer</th>
<th>Crimes in Viewshed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N crime before</td>
<td>N crime after</td>
</tr>
<tr>
<td>Theft</td>
<td>25</td>
<td>33</td>
</tr>
<tr>
<td>Assault</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Criminal Damaging Endangering</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Robbery</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>Vehicle Theft</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Overall Crime</td>
<td>67</td>
<td>72</td>
</tr>
</tbody>
</table>

Table 3. Individual Crime Changes by Total Crime in Viewshed

<table>
<thead>
<tr>
<th>Corryville</th>
<th>Individual Crime Changes by Total Crime in Viewshed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before Viewshed (%)</td>
</tr>
<tr>
<td>Theft</td>
<td>41(%)</td>
</tr>
<tr>
<td>Assault</td>
<td>13(%)</td>
</tr>
<tr>
<td>Criminal Damaging Endangering</td>
<td>15(%)</td>
</tr>
<tr>
<td>Robbery</td>
<td>15(%)</td>
</tr>
<tr>
<td>Vehicle Theft</td>
<td>17(%)</td>
</tr>
<tr>
<td>Overall Crime</td>
<td>100(%)</td>
</tr>
</tbody>
</table>

It is significant to list crime numbers in a 300ft buffer and viewshed in order to explain the crime changes based on crime numbers with major crime types. Table 2 includes five major types of
crimes with numbers and percent of changes. It is a general result that total number of crime in the buffer should be greater than the number of crime in viewshed due to different sizes of selected areas. According to the table, the total crime incidents after CCTV installation in the 300ft buffer increased to 7 percent before CCTV. The result counters the hypothesis that CCTV might reduce crime or does not affect to crime. In contrast, the total crime change after CCTV in the viewshed is not significantly different with only a one per cent increase. However, the individual percentage of crime changes in the viewshed showed big differences from the 300ft buffer in assault, theft, and robbery. To prove the different results in crime changes by types, further studies were necessary with nonparametric statistics, which accounts for the correlation between CCTV and each crime type. In Table 2, the results on percentage of crime change from the 300ft buffer and the viewshed are different; theft in the viewshed decreased by almost half a percent for crimes in 300ft buffer after CCTV installation, assault increased 5 times more than the number in the viewshed, and robbery in the viewshed was one third of crimes in the 300ft buffer. The results are big differences in certain crime types. The possible reason would be a small size of the viewshed, which is small and would not be the similar crime incident pattern as the buffer. To avoid counting crime outside of real monitoring CCTV sites, it is suggested that evaluating CCTV with the viewshed is more accurate than the 300ft buffer. According to table 3, the percentage changes of each crime in the viewshed partially support the theory that CCTV reduces or has no impact on crime. However, before drawing this conclusion, the 2D viewshed has to be examined against the 3D viewshed since the findings are not expected from the hypothesis.
In Figure 13, crime changes after CCTV installation is varied by crime types. The findings proposed that CCTV in Corryville has an effect on crime prevention in criminal damaging endangering and vehicle theft. Yet, there should be more studies on those increasing numbers of crime types. Site visiting for the CCTV installation and advanced visualization can determine the CCTV’s location allocation.

To identify the CCTV installation sites, site visiting was necessary. Figure 14 shows the CCTV location on street and a building. The cameras are not well recognized from the street and are also hidden from the trees on the sidewalks. Two CCTV on Vine Street are in the middle of two different arches installed at a second story height. However, the CCTV on Daniels Hall is installed on 12-story high building. It is barely seen from the street, and the camera is placed on the secondary rooftop where is set back from the edge of the rooftop. Such a high camera could be due to a camera system that signal should be high enough for transmission and reception from the other cameras and the base station. However, it should be visually scrutinized for its function.
on crime prevention. Therefore, a three-dimensional spatial analysis was conducted to compare to the viewshed in two-dimension for better research.

Figure 14. CCTV location and The Surroundings

![CCTV on Vine Street](image1)
![CCTV on Vine Street](image2)
![CCTV on Daniel Hall](image3)

Figure 15 shows the geocoded crimes and the line of sight in 300ft buffer areas in SketchUp, which is a 3D computer drawing program from Google. This visualization can help to count the crimes and examine the existing viewsheds. There are lines connecting from the CCTV to the each crime location, some lines are disconnected when it penetrates through the buildings. It helps to select which crimes are in viewshed.

Except for one CCTV on a high building, Daniels Hall, other CCTV and buildings are similar height and that elevation does not change the viewshed in 2D.

According to Figure 16, collected crime numbers within the viewshed in 2D spatial analysis were not accurate enough that many crimes were not in the real viewshed. Moreover, the camera was installed very high, above 120 feet from the ground that cannot be easily recognized from the pedestrians or offenders. See Figure 17.
Moreover, this small-scale of 3D map is able to find a significant limitation of this study that geocoded crimes are only marked on the streets and not behind or beside of buildings. This limitation is critical because crimes occur all around. For instance, high numbers of crime around the biggest building on the map, Kroger (grocery shopping center), placed in an entire block has one geocoded dot, which poorly explains the real crime location. Although the 3D visualization enables us to overcome the limitation, the crime report has no such detailed location information. For better study on CCTV evaluation, specific crime location in a crime report is essential.
Figure 15. Three-dimensional Spatial Analysis of CCTV in Corryville

<300ft buffer around CCTV>

<CCTV Viewshed>
Figure 16. Two-dimensional Spatial Analysis of CCTV on Daniels Hall

<300ft buffer around CCTV>

<CCTV Viewshed>
Figure 17. Three-dimensional Spatial Analysis of CCTV on Daniels Hall

Note: Red represents invisible line of sight, blue represents visible line of sight.

It is possible that trees are another significant obstacle to block the view from the CCTV, but they are not considered so in this study because of the seasonally changing size and shape of trees. However, it is also possible that the viewshed would be smaller in the summer compared to winter.
Figure 18. A time-series analysis of city, neighborhood, and 300ft buffer areas.

Figure 18 shows a time-series of crimes within the different target areas. The three areas follow a similar trend overall with a low crime rate in the winter and high rate in the summer. It is also determined from the neighborhood that a crime has been decreasing slightly since July 2007. However the time-series also shows that crime rates in the 300ft area were not decreased significantly after camera installation, and it is not similar to the neighborhood’s crime rate patterns. This means that CCTV did not affect to crime in Corryville.

**Findings from the Corryville Studies**

CCTV in Corryville is not effective on overall crime reduction. However, criminal damaging endangering and vehicle theft were reduced after CCTV installation although other types of crimes were increased. There are several possible reasons why the cameras have not been effective. First, there are other severe hot spots outside of Corryville, which are close enough to attract the offenders with high accessibility via walking or automobiles. Second, there are a lot of
easy targets such as college students who are living independently in a high walk-ability environment area carrying valuable goods such as phones and laptops. Third, CCTV was not properly installed with one CCTV on a high building rooftop and two cameras on Vine Street are not easily recognized from the sidewalks. Moreover, there is a small viewshed, which is not enough to control the crime around the CCTV. Fourth, four cameras are a minimum to monitor the entire study area: one camera on Daniels Hall has a very limited function. Fifth, there are big trees planted along the sidewalks that create hidden spaces for offenders. Finally, CCTV is only useful to reduce certain types of criminal activities that are small portions of overall crimes in the study area. More studies on crime changes in other study areas by crime types would explain that CCTV is effective on crime deterrence only on certain types of crime.

8.2 Price Hill

The same research methodologies for CCTV from the Corryville studies were conducted to find the effectiveness of CCTV in Price Hill. The following practices explain how the CCTV in Price Hill has been effective based on camera installation and geographical reasons with visualizations.

Figure 19 indicates that overall crime around the CCTV had been reduced after CCTV installation. This is the expected hypothesis that CCTV will have meaningfully less numbers of crime incidents within its influence areas (300 feet buffer). The result is different from the Corryville studies that the crime increased post-installation. The most possible reason is the size of viewshed. Figure 20 shows a viewshed within 300ft buffer and the viewshed is bigger than the viewshed in Corryville: area size of viewshed in Corryville is 465,190 square feet; Price Hill is 650,559 square feet; and Millvale is 327,511 square feet.
Figure 19. 300ft Buffer in Price Hill and Hot Spot Changes After CCTV Installation.

Note: Light-grey represents low crime density and dark-grey represents high crime density.
Table 4 compares number of crimes occurring within viewshed and 300ft buffer. As shown in Table 4, as seen from the hot spot maps, total crime had been decreased. Therefore, assault, robbery, and vehicle theft were decreased notably in both areas: only theft had not been reduced. Incidents of this crime rose in both the area from Price Hill and Corryville indicate that CCTV has no influence on theft. Since the viewshed and 300ft buffer has same trends of crime changes, it is not necessary to find individual crime changes by total crime in viewshed.
Table 4. Price Hill Crime Changes in 300ft Buffer and Viewshed

<table>
<thead>
<tr>
<th>Price Hill</th>
<th>Crimes in 300ft Buffer</th>
<th>Crimes in Viewshed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N crime before</td>
<td>N crime after</td>
</tr>
<tr>
<td>Theft</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Assault</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>Criminal Damaging Endangering</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Robbery</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Vehicle Theft</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Overall Crime</td>
<td>56</td>
<td>43</td>
</tr>
</tbody>
</table>

Figure 21. Change of Crime Incidents in 300ft Buffer and Viewshed in Price Hill
Figure 22 represents that all four CCTV in Price Hill are exposed to public view and that they can be well recognized by pedestrians. Moreover, there is minimal vegetation or trees along the sidewalks that block the view from the CCTV. The modeled viewshed is accurate that most of buildings are two to three story heights, which is a similar height from the CCTV. There is no unusual locations of CCTV.

Figure 22. CCTV location and the Surroundings

![CCTV on Gleneway Ave.](image1)
![CCTV on Gleneway Ave.](image2)
![CCTV on Gleneway Ave.](image3)

Figure 23 presents the seasonal crime changes before and after CCTV implementation. The occurrence of crime changes within Price Hill and Cincinnati is akin to the high crime rate in the summer and low crime rate in the winter. However, the crime movement in the 300ft buffer has less seasonal pattern due to small incidents, which changes the graph sharply with small numbers.
Figure 23. A time-series analysis of city, neighborhood, and 300ft buffer areas.

Findings from the Price Hill Studies

The result presented above was the expected findings that CCTV can impact upon crime reduction. This is clearly seen in the viewshed map (Figure 19) and images of CCTV locations (Figure 22). The cameras were installed effectively to secure a clear view. Another notable finding is no crime reduction on theft. It suggests that cameras have no significant impact on theft. According to the demographic and geographic data and GIS maps, therefore, it would be proposed that CCTV is effective in the area where middle aged people living with families without any adjacent severe hot spots around it.
8.3 Millvale

Figure 24. 300ft Buffer in Price Hill and Hot Spot Changes After CCTV Installation.

Note: Light-grey represents low crime density and dark-grey represents high crime density.
Pre and post-installation hot spot maps of Millvale present crime changes clearly. Figure 24 shows that the overall crime had been decreased remarkably after CCTV installation. The buffers cover the entire high density hot spots. Compared to the buffer in Corryville, the Millvale buffer covers the crime location sufficiently even though the geocoded location is slightly off from the accurate location, which is very important in influencing entire hot spots. In addition, the viewshed in Figure 25 covers all the roads and sidewalks to access the hotspots. All cars and visitors from outside of the neighborhood are monitored by the CCTV.

Figure 25. Viewshed in 300ft Buffer in Millvale
Table 5. Millvale Crime Changes in Viewshed

<table>
<thead>
<tr>
<th>Millvalel</th>
<th>Crimes in Viewshed</th>
</tr>
</thead>
<tbody>
<tr>
<td>N crime before</td>
<td>N crime after</td>
</tr>
<tr>
<td>Theft</td>
<td>4</td>
</tr>
<tr>
<td>Assault</td>
<td>16</td>
</tr>
<tr>
<td>Criminal Damaging Endangering</td>
<td>10</td>
</tr>
<tr>
<td>Robbery</td>
<td>10</td>
</tr>
<tr>
<td>Vehicle Theft</td>
<td>1</td>
</tr>
<tr>
<td>Overall Crime</td>
<td>41</td>
</tr>
</tbody>
</table>

Note: All crimes were occurred within viewshed, which is the same numbers of crime in 300ft buffer.

Figure 26. Change of Crime Incidents in 300ft Buffer and Viewshed in Millvale

According to Table 5, total crime in Millvale decreased to 36 percent. The crime reduction considers not only the viewshed but also the CCTV location. The existence of CCTV is obvious.
that every resident knows there is CCTV in their neighborhood. As seen from Figure 27, three CCTV cameras are on apartment complexes rooftop and one is on the sidewalk signal pole. There are a few trees in the apartment complexes.

Figure 27. CCTV location and the Surroundings

Figure 28 shows a time-series of crime in different scale. Both Millvale and the 300ft buffer graph follow a similar trend overall and it is clear that they correlate to each other. In other words, most crimes in Millvale had occurred in the buffer area during pre-installation and the buffer could affect to most crimes in the study area after camera installation. Crime reduction after CCTV implementation is seen on the graph.
Findings from the Millvale Studies

Millvale is a residential area that many young female mothers live with their children. The study area is small and four CCTV cameras could monitor all the hot spots. Therefore, CCTV is highly exposed to the public that can be shown to anyone in the area. Consequently, CCTV could reduce crime remarkably. The results find that CCTV with wide monitoring range covers most crime location in small residential areas and are highly efficient in crime prevention.
Figure 29. A time-series analysis of 300ft buffer in three study areas

Figure 30. Total Change of Crime Incidents in 300ft Buffer and Viewshed
9. Conclusion

The research was designed to understand the impact of CCTV on crime prevention. Crime is a complex phenomenon, which requires various methodologies to understand it. Understanding social contexts in each study area enables to explain why CCTV is effective in Price Hill and Millvale but not in Corryville. Visualizing crime trends over four consecutive years in two different scales is important for identifying general crime patterns and specific crime changes in the cameras’ influence area. Three-dimensional spatial analysis is also useful to evaluate the CCTV system to find its actual viewshed.

There is no statistical difference between before and after CCTV installation with respect to the number of crimes. Moreover, the results also show that there is no statistical difference by crime types (theft, robbery, assault, criminal damaging endangering, and vehicle theft). The possible reason is from selecting a small number of CCTV in three neighborhoods, which makes it difficult to demonstrate the findings from the statistical analysis. However, non-parametric statistical analysis was able to attest to the unexpected results from crime changes in Corryville that explains that CCTV affected to certain crime reduction while total crime was increased.

From the quantitative analysis total crime reduction in the viewshed was shown from two study areas after CCTV implementation and no changes from one study area: Total crime in Corryville increased to 1 percent; Price Hill decreased to 18 percent; Millvale decreased to 36 percent. CCTV is very useful in preventing vehicle theft, but theft. Vehicle theft was decreased in all study areas noticeably while theft was increased.

Social and physical analysis explains why CCTV in Corryville were not significantly effective to reduce the crimes compared to other study areas. Corryville has different social contexts and
geographical characters from Price Hill and Millvale. According to the spatial analysis and visualization from Corryville studies, it can be carefully explained that offenders in Over-the-Rhine need more targets, that offenders in OTR cause a very high crime rate and tend to expand to Corryville due to its high accessibility. The Corryville hot spots map can suggest this explanation that very dense hot spots in OTR spread to the north, and Corryville hot spots are connected to the OTR hot spots (Figure7).

Therefore, three-dimensional spatial analysis shows that why the CCTV on Daniels Hall has very limited viewshed and its impact on crime might be very small compared to other CCTV.

Possible causes of ineffectiveness of CCTV in Corryville compared to Price Hill and Millvale that can be cautiously drawn are:

- A limited public participation on crime prevention: High numbers of residents are student and they temporarily reside in the area resulting in low interest in public activities.

- Less communication: Due to short period of residency, there might be not enough time to communicate with other neighborhood.

- Less guidance: Young independent students living without guidance.

- Low home ownership: 88% of residents are renters who may have low responsibilities to managing outdoor living environments.

- High walkabilities: Students prefer to walk to the campus due to short distance from Corryville.
• High accessibilities: Corryville has high pedestrian and transportation accessibility from the Cincinnati downtown, Over-the-Rhine, and other adjacent neighborhoods.

• Vulnerable targets with valuable goods: Students carry laptops, mobile phones, and some money.

• Influences from other hot spots: Other hot spots are located around Corryville

• High nighttime crime: CCTV cannot monitor or control the nighttime crimes

• Low public acknowledgment of CCTV: one CCTV was installed 12-story high building and it is hard to be seen from the sidewalks.

In sum, CCTV can be highly effective on crime reduction in certain circumstances such as possessing a wide viewshed to cover the hot spots, placing it in residential area with fewer visitors from outside, placing it in remote regions from the existing other severe crime hot spots, making it highly exposed to the public, with no big trees blocking the view of it, and low accessibilities from other neighborhoods.

For crime prevention using CCTV in Corryville, the following suggestions would reduce the crime. 1. Placing signage for informing the CCTV to public. 2. Relocating the CCTV on Daniels Hall on the corner of the rooftop. 3. More CCTV cameras are recommended to be installed around the Kroger in order to create a viewshed around the highest crime area.

However, further studies are necessary to overcome the limitations. A survey on committed offenders’ recognition of CCTV in the viewshed is important. Therefore, reviewing future crime changes for legging effect of CCTV installation is also required.
10. Limitations

The followings are the limitation of this research.

• The study started with expectation of potential offenders’ deterrence of crime activities are being monitored by CCTV. CCTV in Corryville is not easy to recognize by commuters.

• There is no data about the committed criminals' understanding of CCTV location in the 300feet buffer area.

• The number of walking people in those selected sites is different.

• Due to lack of information about the crime location, the geocoded location is showing on the streets not on the actual position.

• Low crime location is hard to make statistical testing due to the limited frequency of crimes.

• All the CCTV was installed recently, and there might be a lagging effect.

• CCTV cannot capture images at night although Corryville has high nighttime crime.

• Looking for proactive crime prevention tool rather than reactive prevention practice.

• A Small sample size, number of CCTV and crime incidents, in statistical analysis could not support the results of CCTV effectiveness.
11. Future Studies

In order design proactive crime prevention rather than reactive, real-time action on CCTV, other multiple crime prevention techniques such as lighting and alarms are necessary. A faster reaction is also needed to fill in the time gap between crime activities and police dispatch. Thus, improving public awareness of the importance of surveillance and communication with other residents is important to prevent possible crimes because there should be someone nearby to help.
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