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The impact of street lights on spatial-temporal patterns of crime in Detroit, Michigan

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ABSTRACT

The importance of understanding crime in the United States assumed enhanced protrusion in the wake of the increased crime rates year by year in certain cities. Neighborhood social demographic variables have been largely used to measure their associations with crime. Other than those social factors, street lighting is a feature of urban and suburban settlement which is widely thought to be a necessary element in preventing crime. Previous research has drawn mixed conclusions about the relationship between street lighting and crime, and the effect of streetlights on neighborhood crime is not entirely definitive. To address this challenge, we examined the spatial associations between street light density, neighborhood social disorganization characteristics and crime (e.g., burglary, vehicle theft, weapons offenses, etc.) in Detroit, Michigan in 2014. Using the street lighting data from the Detroit Public Lighting Authority, crime data from the City of Detroit, supplemented with Census 2010 data, we conducted a Generalized Least Squares model of neighborhood crime in 879 census block groups to test the random effects of the spatial variables and different hours of day on crime. The results show an inverse relationship between street light density and crime rates across census block groups in Detroit and the effects of time period of a day vary according to different types of crime. These findings provided more credible evidence for researchers and policy makers to effectively optimize scarce public safety resources, such as improving street lighting in disadvantaged neighborhoods.

1. Introduction

Detroit is the largest city in the Midwestern state of Michigan, and has struggled with high crime for decades. There were 1760 violent crimes in Detroit for every 100,000 residents in 2015 which was among the highest in the country, lower only than St. Louis, Missouri (Sauter, Stebbins, & Frohlich, 2016). Research on Detroit crimes and their predictors is needed in order to prevent and reduce crimes in the area. Geographic Information Science (GIS) has been increasingly used in the interdisciplinary fields of geospatial technologies, and spatial analysis. The use of GIS in crime analysis research is now common. By using GIS, we can identify and highlight suspicious incidents, educate the public to clarify crime concerns with visual information, and provide techniques and tools to acquire crime patterns and predict future crime occurrences. In order to further investigate the application of GIS in crime analysis research, more comprehensive concrete examples such as crime statistics are needed (Cantor & Lynch, 2000).

In quantitative crime analysis, the measurement of crime is an important requirement, especially when comparing two or more spatial units. Although crime count is a commonly used measure of crime, crime rates are often used in crime risk assessment to control for the population at risk (Andresen, 2006). The conventionally-used measure of crime rate is based on the number of crimes committed as the numerator, and a measure of the at-risk population as the denominator (Stults & Hasbrouck, 2015). According to Hannon and Knapp (2003), logarithmic transformation of crime rates was able to reduce significant positive skew which is more representative of a normal distribution. In a case study of Chicago, Wang (2005) used the logarithmic transformation of homicide rates at census tract level to measure its relationship with job access. In this research, we adopted the same method to measure crime rates for different types of crime.

A key hypothesis behind spatial crime pattern analysis is that crime rates exhibit correlations with environmental settings, as supported by theories in environmental criminology (Leong & Sung, 2015). Social disorganization theorists link crime rates to neighborhood characteristics such as income level, residential mobility, unemployment rates,

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and ethnic heterogeneity (Patino, Duque, Pardo-Pascual, & Ruiz, 2014). Delbecq, Guillain, and Legros (2013) studied the determinants of violent crime in the city of Chicago between 2009 and 2011. Their work was based on *social disorganization theory*, which suggests that factors such as poverty, residential instability and racial/ethnic heterogeneity result in a lack or a weakening of the social control that communities exert. Sampson, Raudenbush, and Earls (1997) designed a study in 343 neighborhood clusters in Chicago and concluded that residential tenure and home ownership has impacts on the collective effort of communities to ensure social control. In their assessment of the spatial patterns of crime in Lima, Ohio, Ackerman and Murray (2004) found a relationship between low socioeconomic status and high property and violent crime. Following the past practice, we hypothesized that different levels socioeconomic status exhibited an association with different types of crime in this research. In other words, we intended to measure the relationships between a neighborhood's socioeconomic status and the different criminal activities of its residents.

There have been few research reported on the effectiveness of daytime and nighttime of crime. According to the National Crime Victimization Survey, crime happens anytime of the day and night and particular crimes exhibit different patterns. Felson and Poulsen (2003) summarized hour-of-day variations to describe and analyze hourly information of crime, and concluded that crime varies more by hour of day than by any other predictor. On the other side of the spectrum, the characteristics of urban spaces have the tendency to alter the daily flow of people, and research shows that mobile populations can have a significant impact on the crime rate (Malleson & Andresen, 2016). In their study of crime, Stults and Hasbrouck (2015) examined the effect of daytime shifts in population due to commuting. The crime rate was calculated as offenses per 100,000 persons, using the traditional residential population in one instance, and in the other an integrated measure of the residential and commuter-adjusted daytime population. In their study of crime hotspots in London, Malleson and Andresen (2016) also found that ambient population measures such as census workday population offered an improvement in estimating hotspot locations and significance. Therefore, we divided the hour of a day into different classifications to examine how day and night affect crime in this research. Based on the statistical fact that each particular crime has a certain regularity to follow, our research may provide information for local police stations to allocate resources of police assignment according to hourly patterns of crime. Moreover, it will be interesting to extend the study to crime forecasting in the light of data on crime by hour of day.

Different strategies have been used in the past practice. Spicer, Song, Brantingham, Park, and Andresen (2016) introduced a crime mapping technique that is based on crime counts. In their study of crime along a major roadway in Burnaby, Canada, the authors used street profile analysis to analyze spatial and temporal crime patterns. Weisburd, Bushway, Lum, and Yang (2004) also studied trajectories of crime along street segments by using the group-based trajectory model in Seattle over a 14-year period. In their analysis of violent crimes in Irvington, New Jersey, Caplan, Kennedy, and Piza (2012) used point pattern analysis to map the number and density of violent offenses. Barnum, Caplan, Kennedy, and Piza (2017) used a geospatial crime forecasting and diagnostic technique known as risk terrain modeling to identify place features that increase the risk of robberies in Newark, Chicago and Kansas City. However, crimes are usually clustered together in an organized fashion and the hierarchical structured crime data are generally non-normal which may involve random effects. In order to solve this problem, a generalized hierarchical linear modeling strategy was used in this study where the dependent variable is the rate of different crimes in each census block group in each time period of a day.

Researchers have found that street lighting is an important factor in affecting the probability of crime occurrence although their findings are mixed. Murray and Feng (2016) mentioned that street lighting reduces/eliminates opportunities for criminal behavior that can be attributable to urban layout and structure, and also reduces the fear of crime. A substantial majority of women and elderly people avoid going out after dark simply as a precaution against the possibility of becoming a victim of crime. Hendricks, Landsittel, Amandus, Malcan, and Bell (1999) concluded that higher visibility was significantly ($p < 0.01$) correlated with fewer robberies by analyzing over 1400 retail stores in Virginia, suggesting that robbers may choose their targets based on the likelihood of the robbery being witnessed from outside the store. On the other hand, the improved street lighting could increase opportunities for crime in certain circumstances. Some studies found no evidence to support the hypothesis that improved street lighting reduced reported crime (Atkins, Husain, & Storey, 1991; Knuth, Crump, & Elifritz, 2014; Perkins et al., 2015). It may be explained that increased visibility of potential victims may allow potential offenders to make better judgements of their vulnerability and attractiveness, and increased social activity outside the home may increase the number of unoccupied homes available for burglary.

Improved street lighting is associated with greater use of public space and neighborhood streets by law abiding citizens. Especially if well targeted to a high-crime area (e.g., Detroit area), improved street lighting can be a feasible, inexpensive and effective method of reducing crime. The effects of improved street lighting are likely to vary in different conditions. They may vary according to characteristics of the area or the residents, the design of the area, the design of the lighting, and the places that are illuminated. Improved street lighting may have different effects on different types of crimes (e.g., violence versus property) and different effects on day-time as opposed to night-time crime. The methodological quality of these previous studies was considered to be poor, with a high risk of bias. The focus of our work is to collate information from local authorities in Detroit and examine possible disparate impacts of street light on crime rate. If poor street light condition is authentically associated with deviant and criminal behaviors, state and federal government should make more efforts to improve street light facilities, for example, improve the present inadequate illumination in disadvantaged communities.

2. Study site and data sources

The area of the current study is the city of Detroit, which is located in Wayne County, the most populous county in Michigan. Block group is the unit of analysis in this study because we are interested in the effects of community measures of social disorganization on crime, and block group is the smallest level of disaggregation allowing statistical analysis. A census block group, a statistical division of census tract, generally range in population size from 600 to 3000 (Census Bureau, 2012). There are 879 census block groups comprising a study area of approximately 139 mi^2 (Fig. 1).

Street lighting data from the Detroit Public Lighting Authority was formatted and imported into the GIS. Each road segment was classified according to the type of street lighting reduction scheme implemented (e.g., part-night lighting, dimming, part-night lighting and dimming, etc.). The local authority in Detroit was approached in 2014 with a request for the specific locations of all street lights, and recent lighting improvements (already implemented or planned), together with the month and year that changes were made. There are two types of transmission and distribution of electric power systems: overhead and underground system (Allehyani & Beshir, 2016). Generally speaking, the overhead lights are more popular in the residential area while underground lights are mainly located along the main roads and commercial areas. In this study, 58,953 overhead streetlights were used to test the relationship with crime in Detroit. These data were then aggregated to the census block group level and the density of street lights was calculated as total number of lights per square mile.

From the combined data set, counts of crime for each census block group level were generated by month and hour in 2014 in accordance