Can Environmental Design and Street Lights' Retrofit Affect Crime Incidents in San Antonio?

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ABSTRACT: The neighborhood planning and street design are two major contributors to the physical environment's implications on safety measures. Natural surveillance, including glazing, lighting, and positioning of non-private areas and access paths inside and outside of buildings, has been studied ever since Oscar Newman and Jane Jacobs writings on successful design of streets with community spaces and observer's control of outside spaces. Various methods and data processing tools are used in the literatures to examine the location's capacity for natural surveillance as a major player in Crime Prevention Through Environmental Design [CPTED] and criteria such as space formation, nighttime lighting and its intensity, and visibility are used to identify crime hotspots. This paper is part of a broader project that examines environmental variables acting as crime generators at the public realm in the City of San Antonio [CoSA], and it focuses on drug, property, and violent [DPV] crimes reported for the period from 2012 to 2016. The study area is comprised of ten-neighborhood alongside the historic corridor of Fredericksburg Rd. Using geoprocessing tools of Geographic Information Systems, the method included univariate analysis of five environmental design variables: land use, street network, major transportation corridors, public spaces (parks and bus stops buffers), and street lights. Variables were triangulated with crime hotspots and the results showed that two neighborhoods (Gardendale and Five Points) have endured perseverance of crime hotspots from 2012 to 2016 in areas where multiple variables non-grid street network, parks, highway underpass, and a mix of commercial, industrial and multifamily land use were detected. When these variables exist in one location, they acted as crime-generators and created situational crime areas with intensity of crimes in public open space. The study provides a pathway for further examining -through qualitative data and micro scale analysis- to intervene in policy and design of public space in order to mitigate the likelihood of crime occurrence and endurance.

KEYWORDS: Crime, Environmental Design, Land Use, Street Network, and Street lights

INTRODUCTION

The neighborhood planning and street design are two major contributors to the physical environment's implications on safety measures. The modern interpretation of crime prevention through environmental design [CPTED] has been discussed in published scholarly work in the fields of urban and environmental design, criminology, and social theory (Ekblom, 2011; Cozens and Love, 2015; Sakip et al., 2012; Minnery and Lim, 2005; Marzbali et al., 2012; Lee et al., 2016). In most literature, elements defining CPTED stemmed from the Jane Jacobs' narrative on what made a city safe including high pedestrianism and clear public private distinction, and from Oscar Newman's defensible space which suggests different urban design tools for leveraging crime prevention. Some studies (Lee et al., 2016 and Marzbali et al., 2012) defined several elements of the CPTED that would significantly reduce perception of fear of crime including: access control, surveillance, maintenance, parks and community centers, and territoriality. According to the National Guidelines for CPTED of New Zealand's Ministry of Justice (2005), there are seven qualities that characterize well designed and safe places. These qualities are: 1) access through safe movement and connections; 2) surveillance and sightlines; 3) layout: clear and logical orientation; 4) activity mix; 5) sense of ownership through caring for the place; 6) well-designed environments; and 7) physical protection using active security measure.

In urban planning and design, territoriality has been applied by Jacobs, and then by Newman to places with close social networks can develop voluntary community guardianship. According to Newman, residents' territorial attitude could deter potential crimes because of the theory of natural surveillance. Newman's concept also addressed that semi-public community space surrounded by residential buildings would be important for developing territoriality through increased visibility of public spaces. His concept is that spaces controlled by its own residents with the sense of community are more effective in maintaining safe neighborhood than police enforcement. Natural surveillance, including glazing, lighting, and positioning of non-private areas and access paths inside and outside of buildings, has been thoroughly studied ever since Newman and Jacobs writings.

The literature also discussed another, equally important, contributor to crime prevention attributes, which is land use. Researchers have also warned that the unplanned growth without studying the implications of land use may increase crime rates. The works of Hirschfield (2008), Ludin et al. (2013), Sypion-Dutkowska (2017), and Loukaitou-Sideris et al. (2001) have also discussed land use as a factor that could influence crime opportunity, and some studies suggested that policy-makers should examine potential areas of growth using GIS technology to strategically plan for future growth. Hirschfield (2008) also discussed the need to study the areas with ease of accessibility as they increase crime opportunities, and thus act as crime generators. These areas encompass the following elements: bus stations, road junctions, and the edges of urban areas according to crime pattern theory (Hirschfield, 2008). Changes in these elements are referred to as situational crime prevention approach, which is defined by Clarke (1997) as a strategy that focuses on crime settings, rather than those committing the crimes. It is therefore an approach that seeks to anticipate the occurrence of crime based on the analysis of environmental design elements, and thus can make the environment less appealing to offenders.

Beside CPTED physical components, sociologists have discussed social development theory, which support the role of urban lighting in providing a milieu for human interaction and feelings of safety at night time. During night time, street lights has a greater weight in natural surveillance measures and therefore it could impact the sense of safety and contribute to crime prevention endeavors. Kyttä et al. (2013) studied the impact of both the social qualities and design characteristics of the neighborhood on perceived safety of residents as well as perceived levels of crime. The study concluded that, because of their density and design qualities, and access to smaller open spaces, urban infills could help change distressed development by increasing the level of perceived safety.

Improvement of street lighting has been a popular strategy for improving community safety and reducing the fear of crime. This reflects a shift towards situational crime prevention using environmental improvements to reduce the fear and eliminate opportunities for crime. Nonetheless, studies by Gilling (1997), Koskela and Pain (2000), and Walklate (1989) criticized this approach by indicating that it evades the deeper implications of socio-economic causes of crime, yet it can reduce crime and fear in certain areas (Clarke, 1992; Oc and Tiesdell, 1997). Other studies argued that improvements of street lights is resulted in both day-time and night-time crime reductions, which might not be due to deterrence, but because of an increased sense of ownership and community pride (Pease, 1999). This argument is supported by other findings as Farrington and Welsh (2002) explained that street lights normally work best in stable and well-maintained communities.

Improvement of street lights was incorporated in the UK as a nationwide initiative that involved six cities, where the effect of retrofitting lighting sources was examined for its potential effect on crime and sense of safety. Herbert and Davidson's (1994) research focused on two of these six cities, Hull and Cardiff, where in both the type of light sources and location of the street lighting poles increased the sense of safety in the two areas of study. In the same study, the authors divided the types of social problems into four categories: incivilities, crimes, insecurities, and services, where the effect of street lights changes was measured.

In San Antonio, a crime rate of 56 per one thousand residents (82,784 total crimes) made the city one of the highest crime rates in America compared to all communities of all sizes - from the smallest towns to the very largest cities (Neighborhood Scout, 2017). One's chance of becoming a victim of either violent or property crime in San Antonio is one in 18, which is higher than 96% of communities across Texas.

This paper is part of a broader project that looks into the changes in reported crime incidents in the inner city and urban corridors of the (City of San Antonio CoSA, Texas. Nonetheless, it focuses on crimes reported between 2012 and 2016. The paper focuses on a geographic area along one of the historic corridors, named Fredericksburg Road. To determine the study variables, a thorough review of the literature discussing crime prevention through/and association with environmental design variables was conducted. 20 papers were reviewed in this process, which resulted in two approaches of analyzing nighttime street lights. While in one approach adopted by several authors (i.e. Katyal, 2002 and Loukaitou-Sideris et al., 2001), street light was a component of environmental design variables, other authors (i.e. Shaw, 2014 and Steinbach et al., 2015) separated street light from other environmental design variables. It is worth mentioning that this disparity is due to the complexity of nighttime street lights impacts on crime.

In the first approach, street lights were considered with regard to the physical domain of light poles and their characteristics (i.e. location, height, source type, wattage, etc.), all of which are physically-measurable attributes through the utility companies or the municipalities and, thus, were part of the environmental design variables. In the second approach, street lights were considered a factor contributing to the sense of safety and reduced fear of crime, and therefore they were separated from environmental design variables. In this paper, physical attributes of street lights (i.e. location and wattage) are integral part of environmental design variables. With this decision, the approach of Ostrom (1976), Lee et al. (2016), Marzbali et al. (2012), Kim and Park (2017), Herbert and Davidson (1994), and Kyttä et al. (2013) was adopted.

1.0 METHOD

There are various methods and tools to examine the location's capacity for natural surveillance as a major player in crime prevention through environmental design. Both quantitative and qualitative methods including surveys and interviews were used to assess environmental design of the context of crime locations, and various criteria pertaining to space configuration, nighttime lighting intensity and light source type, and building and street configurations comprise primary features contributing to the creation of crime hotspots in specific locales. The geographic scope of the inner city of San Antonio, where most of older developments and variations of transit corridors exist, was selected to examine the impact of retrofitting street lighting and other environmental design facets on crime incidents. The new LED for street lights were installed in San Antonio throughout 2013, and thus for examining the impact of street light transitions, 2013 data was excluded from the analysis. Crime data CoSA was obtained from the year of 2012 through 2016 and were split into two categories: 1) crimes occurred before installation date of LED source, and 2) crimes occurred after installation.

1.1. Study Area

This paper focuses on the selected neighborhoods representing the geographic scope of 16 neighborhoods along the Fredericksburg Road. Selection criteria for the pilot neighborhoods were based on built environment attributes deemed associated with situational crime theory discussed in the literature. These attributes include: 1) availability of data on street lights by installation dates; 2) balance between mix of non-residential uses within the residential-only areas; 3) proximity to major transportation corridor (i.e. Interstate-10 or Interstate-410); and 4) proximity to areas with concentration of night life activities.

1.2. Study Variables

In their studies of the association of built environment variables including land use, Canter (1999), Ludin et al. (2013), and Sypion-Dutkowska and Leitner (2017) have praised the importance of using reliable data sources and tools that can identify patterns and spatial distributions of crimes. These three studies utilized Geographic Information Systems (GIS). Canter (1999) also discussed how the careful analysis of crime pattern, situation, and trend can be utilized to support policy decision making and allocate resources to determine the effectiveness of crime deterring strategies. Several spatial analysis models were also used in crime analysis.

Five themes comprising all variables discussed in more than 20 studies were concluded. The five themes are: 1) land use and zoning, 2) transportation and transit routes, 3) urban form and territoriality, 4) surveillance and crime generators, 5) socio-economic status, and 6) nighttime lighting. With the exception of the socio-economic status, selected variables in each of these themes, as shown in figure 2, were selected for this paper and were mapped using GIS. Socio-economic status was considered controlled variables for this paper, leaving only selected CPTED variables to be examined. In future, the authors will be integrating socio-economic variables as dependent variables. Variables used in this study encompassed the following:

Independent Variables

1) Land use: residential, commercial, industrials, etc.;
2) Street network: grid vs. non-grid/diagonal
3) Territoriality and major transportation corridors: interstates/highways;
4) Public open spaces: community parks, and bus stops buffers;
5) Natural surveillance: street lights (type of source and pole location)

Dependent Variable

Crime incidents that are likely to take place in the public view. Thus, only reported drug, property, and violent crimes [DPV were selected for this analysis. Areas with low -and no- counts of DPV crimes were omitted from the geographic scope of the 16 neighborhoods, which yielded only ten neighborhoods identified as the pilot study area (see Figure 1).

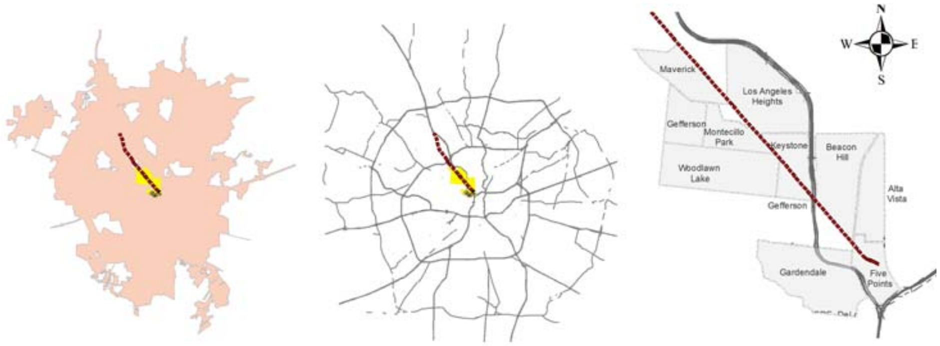

Figure1: Fredericksburg corridor and the ten selected neighborhoods for the study area in San Antonio, TX.

1.3. GIS for mapping variables and crime hotspots

All selected variables were mapped individually using ArcGIS 10.5.1 (ESRI, 2017) and a univariate analysis was conducted for each variable: land use, street network, bus stops buffers, parks buffers, highways buffers, street lights, and DPV crime incidents for 2012, 2014, 2015, and 2016. The analysis encompassed the following tools and measures, which are also illustrated in the workflow shown in Figure 2:

- A vector polygon layer of land use was analyzed by using ordinal measures of the standard Land-Based Classification Standards (LBCS) developed by the American Planning Association.
- A vector line layer of street network was classified using ordinal scale- into three categories: 1) grid, grid-edge, 2) non-grid intersection, 3) non-grid edges.
- Vector point layer of bus stops and polygon layer of parks were analyzed using geoprocessing tools of GIS. A 250 m (820 ft) buffer for parks and a 100 m (328 ft) buffer for bus stops were created to examine likelihood of crime occurrence in the vicinity of these features as public open spaces.
- Highways (transportation corridors with high traffic volume) were analyzed using a 250 m (820 ft) buffer around the two major highways adjacent to the study area: Interstate 10 (IH-10) Interstate 410 (Loop 410).
- Street lights' vector point layer was analyzed to create a heat map using kernel-density spatial analyst tool, and a seven-class categorical raster output was created. Kernel analyst was chosen for this analysis because its use of algorithm that allows for better weighting of highly dense points and its associated smoother outputs.
- Vector point layers of the DPV crime incidents reported in 2012, 2014, 2015, and 2016 were analyzed to create a heat map using kernel-density spatial analyst tool. Only crimes occurred during nighttime, between 6:00 pm to 6:00 am, were included, and crimes reported outside of this time were excluded. Seven-class categorical raster output was created. 2013 data was removed from the analysis due to the major LED lights retrofit that took place during 2013.

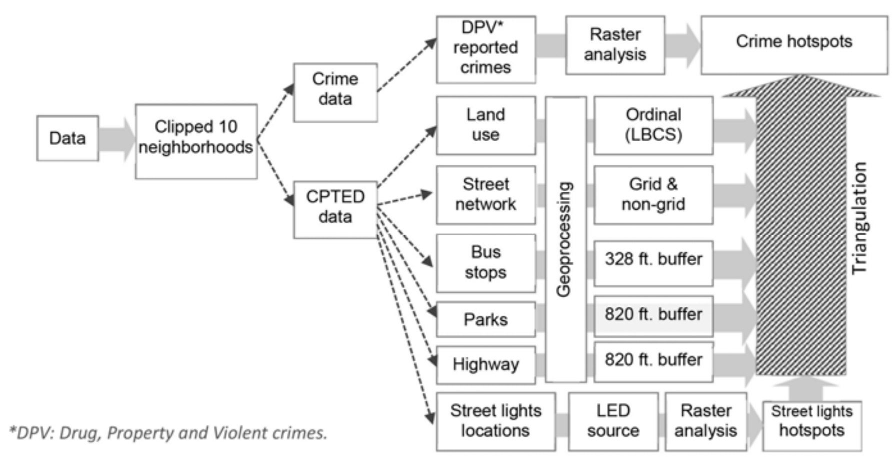

Figure 2: Workflow of the analysis and processing models of environmental design and DPV crime incident variables.

Following the univariate analysis using vector and raster data processing tools, cross examinations of the environmental design variables (land use, street network, highways, parks and bus stops/buffers) with the heat map of crime incidents was conducted. To assess the relationship between LED street lights and the location of crime hotspots, we cross-examined compared the crime heat maps of 2012 (pre-LED retrofit) with crime heat maps of 2014, 2015, and 2016. With this triangulation, it was possible to observe patterns, including perseverance and shifts, of some locations of crime hotspots as well as their relationships with different environmental design variables including nighttime street lights as discussed in the following section.

2.0 RESULTS AND DISCUSSIONS

2.1. Univariate Analysis

The univariate analysis of the selected environmental design variables revealed the following characteristics of the study area (see Figure 3). Univariate analyses were cross-examined with the raster outputs of DPV crime hotspots:

Land use: A concentration of commercial land uses is evident on both sides of Fredericksburg Road. along Maverick, Los Angeles Heights, Montecillo Park, Keystone, and Gefferson neighborhoods. Other areas where commercial activities are concentrated are: 1) south side of Alta Vita neighborhood, 2) North-west portion of Five Points neighborhood, where commercial and mixed land-use dominates land uses, 3) around Interstate 10 in Gardendale neighborhood, 4) intersection of Gefferson, Woodland Lake, and Monticello Park neighborhoods, and 5) west side of Gardendale neighborhood, and 5) north and east edges of Beacon Hill and Alta Vista neighborhoods respectively.

Street network and Highways: Most of residential blocks of the study area are stemmed from a grid network, however, in Five Points and Maverick neighborhoods, non-grid system represented the majority of street network. These two neighborhoods are located in the north and south sides of the study area. At Gardendale's east side as well as the intersection of Keystone, Monticello Park, and Woodlawn Park neighborhoods, street network was also based on non-grid system. The latter had a big box structure of the local grocery store, known as HEB.

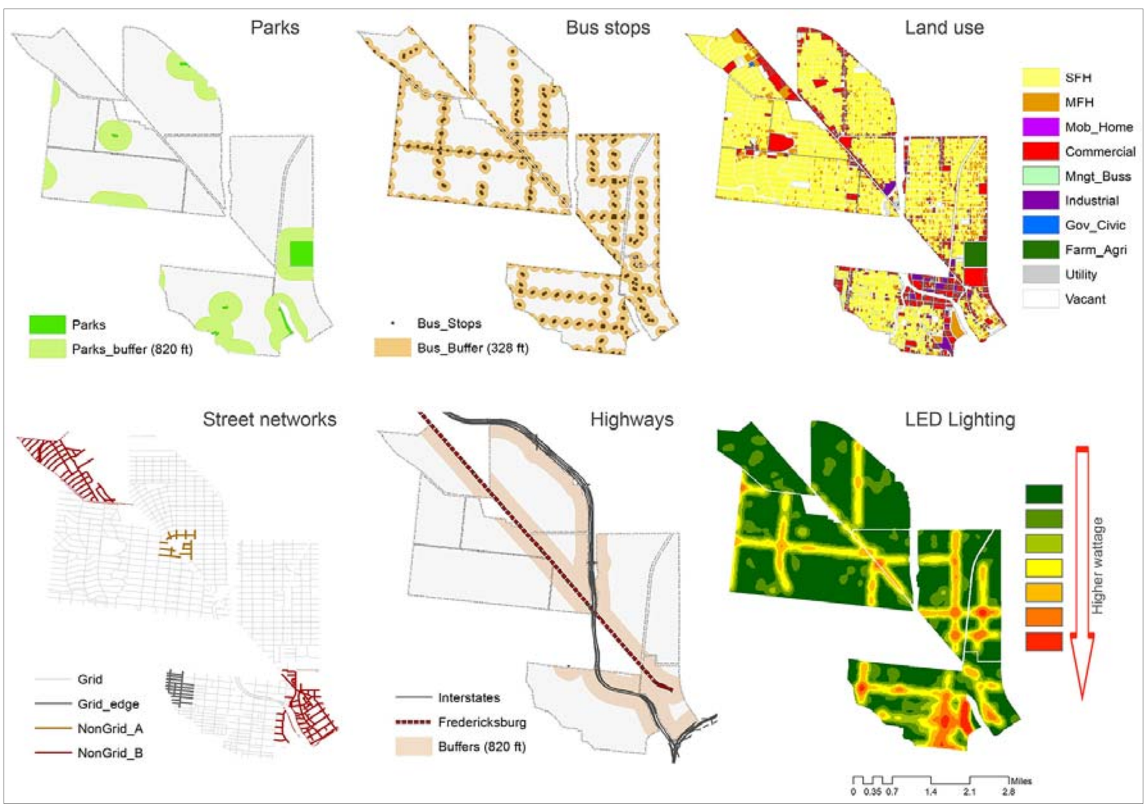

Figure 3: Univariate spatial analysis results for CPTED and street lights around Fredericksburg Corridor

Public open spaces: There are three parks inside the study area, and six parks on its edge. A 250 m (820 ft.) buffer around parks and a 100 m (328 ft.) buffer around bus stops was also created using ArcGIS geoprocessing tools (see Figure 3). Based on Anderson et al. (2013), these buffers normally act as crime generators, and thus create a situational crime opportunity as discussed in the introduction section of this paper. Therefore, the buffers were cross-examined with DPV crime hotspots and the results are discussed in the data triangulation section.

Interstates: There are two interstates, IH-10 and IH-410, pass-by and intersect with the study area. A 250 m (820 ft.) buffer around each was created using ArcGIS geoprocessing tools.

Street lights: Focusing on the watt-value of each LED street light source, a raster dot kernel-density analysis was performed on street lights layer. Figure 3 shows the aster output of this analysis including an overview of the concentration of LED lamps along main commercial and mixed-use streets, with higher wattage detected in the commercial areas, west of IH 10 in Gardendale as well as along the commercial corridor in Beacon Hill neighbourhood. It's worth mentioning that LED lamps was ranging from 100 to 400 watts. LED raster output was cross-examined with crime heat maps as discussed in the triangulation section.

2.2. Crime Hotspots

Using GIS spatial analyst tools, kernel-density analysis was performed on the point data of the DPV crimes (for 2012, 2014, 2015, and 2016) to create crime heat maps using seven-class scale to show areas with least crime concentration to areas with maximum concentration of crimes. In Figure 4, crime heat maps show a scale ranges from green to red, where red indicates the highest crime concentration in a cell size of 50 ft, and dark green is designated for the least concentration of crime incidents for the same cell size. The maps present a location-based profiling for areas with tenacious DPV crimes, which are indicated in red and orange- within the study area.

By comparing the location and intensity of crime hotspots across the study area from 2012 to 2016, an overall decline in the magnitude of DPV crimes reported at the intersection of Montecillo, Los Angeles Heights, and Keystone was evident. It is also noticed that both south portion of Five Points and south-east sides of Gardendale are obstinate with relatively high crime magnitude despite the drop in severity of crime concentration (from red to orange according to the crime concentration scale). Area located on the northwest portion of Gardendale showed a persistence of crime concentration, despite a slight drop in 2015. Along different segments of Fredericksburg Road, it was clear that a low to moderate crime magnitude was evident, and a drop in severe hotspots was detected particularly in 2014 and 2015.

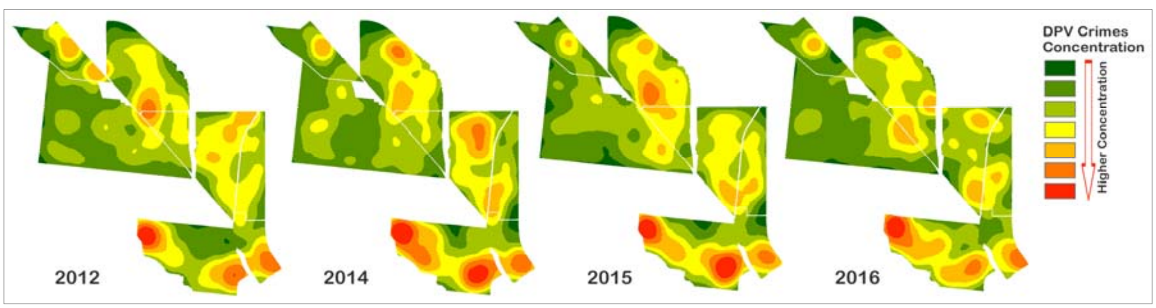

Figure 4: Heat maps of DPV crimes in the study area around Fredericksburg Corridor.

2.3. Data Triangulation

The univariate analysis maps were cross-examined with the raster output of DPV crimes hotspots. Each univariate map was separately examined for association with severe to moderate hotspots (shown in Figure 4 in red, orange and yellow respectively). Areas of the univariate map that proved a strong association with crime magnitude were designated as crime generators. Applying this triangulation process on the six univariate maps (land use, street network, bus stop buffer, park and park buffer, highway buffer, and LED street lights) showed that when a single variable coincide with the crime analysis, not clear evidence of association between both was detected. Only when commercial and/or mixed-use areas were examined, a partial association between commercial/mixed-use area and moderate crime hotspots was evident mostly in southeast and northwest portions of Gardendale. Additionally, LED wattage concentration had an inverse-association with moderate to severe DPV crime hotspots. Primary areas where high and moderate crimes from 2012 to 2016 were identified encompass:

- Northwest and east portions of Gardendale
- South portion of Five Points

Gardendale and Five Points neighborhoods are located north of the intersection of I-10 and I-410. Areas within the two neighborhoods where multiple variables overlapped resulted in severe to moderate crime hotspots. These hotspots are associated with the interstate I-10 buffer, non-grid street network, park and bus stops buffers, and mixed-use area. However, in the two neighborohoods, there is no evidence of the association of these hotspots with LED wattage. In Five Points, LED higher wattage concentration was associated with moderate to low crimes, however, in this part of the neighbourhood (Five Points), there were other variables exist including interstate buffer, bus stops buffers, and non-grid. In the south portion of Gardendale, LED wattage concentration was associated with high to moderate crime hotspots, however, in this area there was also mixed-use and bus stops buffers.

It is worth mentioning that even though the utility company has retrofitted the light sources across the study area from High Pressure Sodium Vapor to LED during 2013, changes in crime severity were not detected in 2014, rather in 2016 with one persistently high crime area located in the northwest portion of Gardendale. This portion of the neighborhood encompassed a concentration of commercial and mixed-use areas, park buffer, bus stops buffers, yet, it is a grid street network with lower wattage LED sources. From this analysis, it is clear that a significant association of environmental design variables and DPV crime is detected when multiple variables overlap, and thus act as crime generators.

CONCLUSION

The study provides evidence that when multiple environmental design variables exist in an area, they validate the crime generators theory of Katyal, N. K. (2002) and Hirschfield, A. (2008), and thus act to incite drug, property, and violent crimes. LED street lights, particularly with higher wattage showed less association with severe to high crimes across the study timeline. Only in southeast portion of Gardendale neighbourhood, LED street lights were associated with the magnitude of crime that continued to decrease (from high in 2014 and 2015 to moderate in 2016). When combined, the following variables showed significant associations with high to moderate crime incidents: commercial and mixed-land use, open spaces around parks and bus stops, non-grid street network, highway buffers, and sparse LED street lights. A further analysis is needed through allocated a different weight for each variable to identify variables with higher association with crime.

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