Understanding Socio-environmental and Physical Risk Factors Influencing Firearm Violence

Final Summary Overview for National Institute of Justice

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Introduction

The United States faces an unprecedented challenge in which firearm-related homicides are on the rise. Research demonstrates that fatal shootings tend to be heavily clustered in specific areas (Aufrichtig et al., 2017; A. Braga et al., 2014; Caplan et al., 2011; J. Eck et al., 2005; J. E. Eck et al., 2007; L. Kennedy et al., 2011; Weisburd et al., 2009, 2017). While research shows that firearm violence is not uniformly distributed throughout the environmental landscape, the geospatial associations between built environment features and gun crime are not well understood. In part, this has been due to the unavailability of geocoded data, processing capacity, and limitations in the necessary computational power. With the open source data movement and advances in parallel computing, researchers now have better access to enormous amounts of geocoded data that RAND leverages to study the relationship between many built features, such as gas stations and convenience stores across four cities of Detroit, Los Angeles, New Orleans, and Pittsburgh.

The built environment and socio-economic associations with firearms violence is an area ripe for more research. One perspective that is needed is community perceptions of the built environment and socio-economic context of firearm violence across multiple cities with differing environments. This would help local city planners and law enforcement 1) understand local perceptions of the built environment and socio-economic role in firearm violence, and 2) develop culturally relevant, local interventions to prevent firearm violence. It would also provide hypotheses for researchers to explore and study using causal methods.

Historical research indicates the built environment is not independent of the social context. Statistical studies are needed to gain a better understanding of the underlying commonalities between built environment features and socio-economic characteristics within different cities, and how these underlying factors may be associated with firearm violence. This has important

implications on how we think about the built environment and how we analyze features going forward.

Against this background, the aim of the RAND project was to provide the cities of Detroit, Los Angeles, New Orleans, and Pittsburgh (and beyond) with vital information on the relationship between built environment features, socio-economic traits, and firearm violence so that law enforcement and urban planners can consider ways to prevent firearm violence. The RAND study has the following three specific aims:

1. Compare and contrast city planning and community views on which socio-economic and built environment factors influence firearm violence and why.
2. Identify types of socio-economic and built environment clusters of firearm violence.
3. Estimate the relative influence of socio-economic and built environment features on firearm violence.

Aim #1: Perceptions in Detroit, Los Angeles, New Orleans, and Pittsburgh

While the urban planning and criminology literatures underscore the importance of coordination between crime control agencies, city planners, and community residents, few studies qualitatively examine community member and urban planner views regarding firearm violence. Furthermore, we are not aware of any studies examining the perceptions of risk and protective factors across socioeconomic and built environments of both local community members and urban planners. As such, the purpose of this Aim is to identify the socioeconomic and built environment factors that community members perceive to be associated with firearm violence and general crime and urban planners would recommend as preventive in their neighborhood across four U.S. cities.

Methodology

Identifying Neighborhoods of Detroit, Los Angeles, New Orleans, and Pittsburgh

We proposed to conduct focus groups in two neighborhoods per city. The identification of relatively higher crime neighborhoods is based on the locations of all reported homicides, robberies and aggravated assaults with a firearm, using local agency data sources as they classified by UCR, between 2016 and 2018 in each of the cities. We use a clustering process called Density-Based Spatial Clustering Application with Noise (DBSCAN; ref) to identify neighborhoods with relatively more crime. Our approach resulted in ten to twelve neighborhoods per city with clusters of reported firearm violence. To select two out of these 10-12 neighborhoods to conduct focus groups, we categorize the crime clusters within areas of relatively low or high density of convenience stores. This would allow us to conduct focus groups among communities with similarly high crime neighborhoods that would have differing built environment features to discuss. Upon selection of the neighborhoods, an expert panel of urban planners - Dr. Alison Linder (Southern California Association of Governments/University of Southern California, Los Angeles), Christine Brill (Studio for Spatial Practice, Pittsburgh), Robert Tannen (Consultant, New Orleans), and Jeffrey Horner (Wayne State University, Detroit) - in each of the cities weighed in on the identified neighborhoods to further validate the selection of the target neighborhoods.

Recruitment Strategy

A total of 3 focus groups were scheduled for each neighborhood at different times of day (i.e., morning, afternoon, and evening) in order to capture a range of different kinds of participants. Focus groups were advertised to community members through a variety of strategies, which varied slightly from city to city. Some of the broader outreach was done by developing ads for local newspapers, radio stations, and social media. We also collaborated with the urban planners from our expert panel and with community leaders to spread the word about the focus groups, and they

received compensation for their recruitment activities. Additionally, we identified community organizations (e.g., education centers, recreational centers, parks, churches, local businesses, libraries, grocery stores, neighborhood organizations, and advocacy groups or organizations) and had them spread the word to about the focus groups as well through the distribution of flyers. Closer to the focus group dates, we also conducted in-person canvassing around the target neighborhoods. Flyers included a toll-free number for interested community members to call and sign up for the focus groups. Eligibility criteria for the groups required that participants be over 18 years of age, that they live or work within one of the target neighborhoods, and that their length of residency or work tenure in the neighborhood be of at least 1 year. The target number of participants for each group was 4-6, with a cap of 10 participants for each group.

Instrument

Prior to each focus group discussion, the focus group moderator read out the consent form and obtained verbal consent from each of the participants. Participants were then asked to complete the short questionnaire that collected demographic information and were also asked to use the map provided, which included landmarks to help with street identification, to draw the boundaries of what they considered to be their neighborhood. Toward the end of the focus groups, we projected the several pictures of high- and low-crime streets inside and out outside of the neighborhood on a screen and asked questions about different aspects of these streets. Some examples of questions asked about the pictures were: what do you consider to be important features or things that stand out to you about this street?; if you could change one thing on this street, what would you change and why?; would you walk down this street during the day or during the night?; is there anything about this street that makes you feel safe?; and is there anything about this street that makes you feel unsafe? The questions were meant to spark a discussion about the street and see whether there

would be any mentions about built environment factors as they relate to safety and gun violence. Sample pictures of high- and low-crime streets can be seen in the figure below.

High-crime Street	Low-crime Street
	

Analytical Strategy

A directed content analysis approach was used to process the focus group data (Hsieh and Shannon 2005). The moderator and notetakers developed and discussed summaries for each neighborhood that included information on the overall number of participants and the key themes that came up for each neighborhood. These summaries and a review of each transcript were used by the senior qualitative researcher to identify the basic topics covered during the focus groups and to develop a preliminary codebook, and two researchers provided feedback on the codebook. Dedoose web application was used for conducting the focus group analysis (2018). The three researchers then separately coded the same transcript and met for a two-hour session to compare code applications, reconcile any coding differences, and make additions and updates to the initial codebook. This reconciliation process was repeated until code application was consistent enough to signal sufficient agreement between coders. One researcher then coded the remaining transcripts and met regularly with the senior qualitative researcher to discuss any further changes or additions that should be made to the codebook. The final codebook included more refined definitions for each code, as well as examples to facilitate further understanding of the codes.

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The coding process yielded a total number of 1,135 excerpts. The excerpts for each code were exported from Dedoose into Excel, and 3 researchers reviewed excerpts for separate codes to identify overarching themes and synthesize the information. The researchers extracted themes at various levels, including within each of the study neighborhoods, across the two neighborhoods for each city, and across all the selected cities. The researchers met to discuss the synthesized results and iterated on them based on the group discussions. Upon completion of the overall synthesis, the researchers created a summary of results for each of the cities, and these summaries were shared with the expert panel of urban planners. The expert panel was given time to review the findings, and to provide feedback. The lead researcher communicated with the panel and had phone calls with all, but one of the experts to obtain their thoughts on the overall findings, as well as their thoughts for how this information could feed into policy recommendations.

Data

The table below shows the sample size we obtained for each group in each neighborhood.

Sample Sizes of Focus Groups, by Group

	Group 1	Group 2	Group 3	Total
Pittsburgh				
Homewood	7	4	7	18
Knoxville	7	10	9	26
Detroit				
Harmony Village	5	4	7	16
Mapleridge	8	6	5	19
New Orleans				
Bywater	2	3	3	8
Treme	4	0	7	11
Los Angeles				
DTLA	3	6	6	15
South LA	3	8	8	19
Total	39	41	52	132

In addition to the information about eligibility, we took note of our best guess of community members' gender to try to stratify our sample of participants for each group by gender and tenure in the neighborhood. Focus group characteristics by city is shown in the table below.

Summary Statistics of Focus Groups

	Pittsburgh	Detroit	New Orleans	Los Angeles	Total
Race					
White American	16.3%	0.0%	10.5%	31.4%	15.2%
Black/African American	55.8%	94.3%	78.9%	34.3%	63.6%
Other	14.0%	2.9%	10.5%	28.6%	14.4%
Missing	14.0%	2.9%	0.0%	5.7%	6.8%
Age					
18-24	18.6%	5.7%	0.0%	8.6%	9.8%
25-34	14.0%	14.3%	5.3%	17.1%	13.6%
35-44	4.7%	8.6%	0.0%	22.9%	9.8%
45-54	16.3%	22.9%	21.1%	8.6%	16.7%
55-64	16.3%	34.3%	26.3%	31.4%	26.5%
65+	20.9%	14.3%	47.4%	5.7%	18.9%
Missing	9.3%	0.0%	0.0%	2.9%	3.8%
Gender					
Male	32.6%	51.4%	42.1%	54.3%	44.7%
Female	58.1%	48.6%	57.9%	42.9%	51.5%
Missing	9.3%	0.0%	0.0%	0.0%	3.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Number of observations	43	35	19	35	132

Results and Discussion

Community members described concerns related to both the physical environment (i.e., layout of streets) and types of places in the community (e.g., residential, public spaces, retail, etc.). In addition, they often associated specific crimes with key neighborhood features (e.g., abandoned buildings are described as havens for drug crime). In manuscripts, we provide details from each city and cross-city comparisons. Given the space limitations here, we provide the cross-city comparisons and lessons.

Whereas some built environment issues tend to be city-specific (e.g., homeless encampments as an issue in Los Angeles and biker clubs are associated with Pittsburgh), common themes and issues are found across cities. Across all cities, participants are concerned with overgrowth, lack of lighting, and loitering. Isolation and crowded areas are both viewed as dangerous, but for different reasons (e.g., tourist areas are dangerous in New Orleans and present robbery opportunities). All cities have perceived issues with prostitution, drugs, and violence, and these activities tend to be perceived as being associated with particular built environment features that lead to firearm violence specifically. Places tend to be avoided by participants during the night, although some residents did not feel safe during the day. Walking is viewed as dangerous. Across all cities, firearm crimes are perceived as occurring where combinations of built environment characteristics are present (e.g., vacant lots with overgrowth, abandoned areas with poor lighting). Abandoned areas are said to be avoided for similar reasons across cities, and areas that lack visibility are said to be avoided.

There were no similarities relating firearm crime to the *built environment* across *all* cities. Participants tended to associate gun crime with particular businesses (e.g., bars) and streets. Across Pittsburgh, New Orleans, and Los Angeles, participants discussed gun violence in relation to poor lighting, but Pittsburgh and Los Angeles participants also associated gun violence with broad daylight. Businesses were associated with gun violence in Pittsburgh (bars, stores that allow loitering, social clubs) and Detroit (gas stations). Participants in Pittsburgh and Detroit discussed gun violence in relation to crowded areas (in PGH, associated with loitering and in DET, associated with people "coming and going"). Across Pittsburgh, New Orleans, and Los Angeles, drug activity was perceived to be associated with shootings. Abandoned houses (and garages in PGH) were discussed in relation to gun violence in Pittsburgh and Los Angeles. In Detroit, robberies and the

high school were related to gun violence. A participant in New Orleans discussed a street corner at a bus stop as a gun violence location, and gun violence was related to prostitution in Los Angeles.

Community members also describe socioeconomic factors perceived to relate to firearm violence and crime. Across cities, residents described several conditions reflective of concentrated disadvantage including a lack of economic opportunities (e.g., limited jobs or training), economic segregation (e.g., differential investment or protection), a lack of essential neighborhood resources including social activities especially for youth, and issues related to behavioral health (e.g., substance use). Community members also associated lack of social capital (e.g.. low educational attainment, a lack of civic engagement or collective efficacy, and low quality of various institutions in the neighborhood) and residential instability (e.g., population decline, turnover, gentrification, and homelessness) with neighborhood crime and the use of firearms during robberies or gang violence.

Lessons Learned and Recommendations

There were no similarities relating firearm crime to the *built or socioeconomic environment* across *all* cities. The implication is that there is not going to be a one-size-fits-all solution to the communities of this study. As such, the results per city are going to be important for urban planners and law enforcement when working on the built and socioeconomic environment solutions to reducing firearm crime.

That said, there were some similarities across cities in the nature of built environment features (rather than feature types, e.g. gas stations) that the communities found concerning and could be improved to reduce firearm crime. In talking about factors that made participants feel safer, a general theme that arose was a sense of neighborliness. Participants across cities described cleanliness, nice homes, city closures of stores and bars that previously were dangerous, and

lighting as feel-safe factors. In addition to solid evidence on the crime prevention impact of lighting, our research suggests it is a type of intervention that makes these communities feel safer and would be welcomed.

Participants across all cities also discussed factors, such as cameras (and green light, a specific intervention in Detroit), police stations, and fences that were meant to lower crime and failed to do so. This suggests that a) research is needed to determine if these elements reduce crime, but 2) even if they do, communities in different parts of the U.S. similarly do not *believe* these measures reduce firearm violence. So if city planners and law enforcement want to show local communities they are doing something to address firearm crime by implementing cameras, police stations, and fences, they will need to a) come up with better strategies for communicating positive evidence on these features, or b) work on other evidence-based strategies to reduce firearm violence that are also culturally acceptable to the community.

In addition, crime reduction strategies should include efforts to address the socioeconomic risk factors raised by community members and urban planner. Residents across all four study cities felt there should be more efforts around creating economic opportunities in their respective neighborhoods, specifically by increasing availability of jobs and training. Increased access to essential resources such as grocery stores and youth programs, as well as availability of services to address issues related to mental health and drug addiction are also vital. Other recommendations include improving the quality of schools and community institutions (e.g., police) and increasing civic engagement and collective efficacy through community gardens, farmers markets, and other public events. Finally, urban planners suggested creating additional housing in blighted properties to create more housing availability and reduce residential instability, and potentially displace crime that occurs in blighted properties.

Aim #2: Patterning of Built Environment and Socio-economic Characteristics and their Influence on Firearm Violence

There is great interest in knowing how the built environment influences crime. Existing research has generated mixed findings. It is difficult to disentangle whether mixed findings reflect different relationships between the built environment (BE) and crime across jurisdictions or over time, or whether they reflect different modeling decisions made by researchers. There is a well-established recognition in criminology research on socioeconomic predictors of crime that multicollinearity is an issue. This Aim uses exploratory factor analysis (EFA) to identify unobservable factors from the observed built and socio-economic characteristics of each city. These unobserved factors are then used to understand the geospatial variation in reported firearm crimes.

Methodology and Data

We summarize our approach in three distinct stages in the table below.

Table 1: Process and Activities of Exploratory Factor Analysis

Step	Summary of Activity	Technical Details
1. Preliminary Analysis	Conduct tests to ensure the selected data and variables are suitable for EFA.	Examine univariate measures of kurtosis and skewness. Compute the correlation matrix for the observed variables to assess singularity, multicollinearity, and sampling adequacy using standard methods from the statistical literature.
2. Factor extraction and rotation	Uncover the unobservable latent constructs in which variables are clustered.	Use several procedures to determine the optimal number of factors, including Onatski's test, scree test, and Horn's parallel analysis test (because simultaneous use of multiple decision rules considered superior to assuming a single criteria). Explore a variety of factor extraction and rotation methods to assess the robustness of results, and consider implementing the relatively new method of Bayesian EFA.
3. Factor interpretation	Define the conceptual meaning for each factor.	Examine which variables (of the larger set) are associated with each extracted factor and the strength of the association, and take into account theoretical understanding of relationships. Correction procedures for correlated factors will be used to determine significance of relationships and to protect against Type I error.

Table 1 provides summary statistics of the data used in the analyses across the three cities. The table shows the mean annual reported crimes with a firearm across census tracts, as well as built environment feature mean counts per census tract. Detroit has the largest number of mean reported crimes (43), followed by Los Angeles (17), and Pittsburgh (9). In terms of their top three counts of built environment features, all cities, although slightly more in Detroit and Pittsburgh (585 and 566 respectively), than Los Angeles (463). Detroit has a much larger mean count of vacant lots than in Pittsburgh (this feature was not coded in Los Angeles).

The neighborhood characteristics generally suggest that Detroit and Pittsburgh are more like each other than Los Angeles. For example, the mean proportion of non-citizen people is quite a bit greater in Los Angeles, 0.37, than the other two cities 0.01 in Detroit and 0.04 in Pittsburgh. Although the unweighted median proportion of black people per neighborhood is significantly larger in Detroit (0.96) than in Los Angeles (0.06) or Pittsburgh (0.18). The size of the neighborhoods in terms of population are similar in Detroit (2,149) and Pittsburgh (2,104), but larger in Los Angeles (3,835). A larger proportion of people are unemployed in Detroit (17%) than in Los Angeles (7%) and Pittsburgh (6%). In sum, while several features may be similar across some cities, no two cities are the same and we can use this variation to understand something about their underlying structures and the relationship to firearm violence.

Table 2: Summary statistics of analytical data, Census Tract, 2013-2018

	Detroit	Los Angeles	Pittsburgh
Annual reported crimes with a firearm	43	17	9
	(25.7)	(35.3)	(14.3)
Top 3 built environment features+			
Single family homes	585	463	566
	(491)	(525)	(422)
Vacant lots	302		63
	(369)		(122)
Multi-family units	32		61
	(90)		(64)

	Detroit	Los Angeles	Pittsburgh
Apartments 5 or more		27	
		(36)	
Duplex		19	
		(59)	
Neighborhood Characteristics			
Education (years attained)	15.93	15.91	17.47
	(1.25)	(2.48)	(1.54)
Income* ($)	21085	23017	30724
	(16149.03)	(18317.32)	(22070.64)
Rent* ($)	799	1342.5	872.5
	(178.3)	(533.96)	(258.33)
Percent poverty 150	0.53	0.29	0.29
	(0.15)	(0.17)	(0.19)
Race and ethnicity (median %)			
Asian	0.00	0.11	0.03
	(0.06)	(0.12)	(0.07)
Black	0.93	0.06	0.18
	(0.25)	(0.13)	(0.30)
Native American	0.00	0.01	0.01
	(0.01)	(0.03)	(0.02)
Pacific Islander	0.00	0.00	0.00
	(0.00)	(0.01)	(0.00)
White	0.06	0.56	0.76
	(0.19)	(0.21)	(0.28)
Non-citizen (%)	0.01	0.37	0.04
	(0.10)	(0.13)	(0.07)
Total population	2149	3835	2104
	(1158.45)	(1328.45)	(1326.06)
Unemployed (%)	0.17	0.07	0.06
	(0.08)	(0.04)	(0.06)
Female (%)	0.53	0.50	0.51
	(0.06)	(0.05)	(0.10)
SNAP (%)	0.24	0.21	0.16
	(0.08)	(0.08)	(0.10)
Observations			
Number of Census tracts	293	1003	138
Number of built environment features	369880	788636	123215

Notes. + Due to the large number of built environment features, we present statistics on the top 3 feature counts. *Median values.

Results

Regression results in tables 1 to 3 show the how the factors load on residential, non-residential built environment and/or neighborhood characteristics, and the relationship between the and the count of gun crime per census tract.

Los Angeles

To address this multicollinearity problem we found, we obtain factor scores from factor analysis and use the factors as explanatory variables in the regressions. Factor scores are determined from factor loads, which indicate relationships between observed variables and factors, given in Table 1. For clarity, we provide loadings with absolute value 0.30 or greater correlation. We find four of eleven factors had loadings with both BE and NC variables. Factors 1, 2, and 3 load on residential features and neighborhood context characteristics, and factor 4 loads on non-residential and neighborhood characteristics. Specifically, factor 1 shows an underlying commonality between low numbers of single-family homes, low proportion of white residents, low SES, and high proportion of non-citizens. This latent factor is positively associated with reported firearm crime incidents at the 1% level, and explains more of the firearm violence in Los Angeles than the other latent factor zones of this analysis. Factor 2 has large loadings for both total population (an NC variable) and single-family homes (a BE variable). This seems to capture the long-standing promotion and protection of the single-family zones in California (Anderson et al, 2013). This underlying factor is positively associated with reported firearm crime incidents. Factor 3 loads on more dense housing (i.e. 5 or more apartment units, quadplexes) and low food assistance (i.e. low SNAP). This is the only latent factor with a statistically significant, negative associate with reported firearm violence. Factor 4 is the only factor that loads on both non-residential features (i.e., few animal shelters or auto sale services) and neighborhood context (i.e. higher unemployed). This latent factor is unrelated to firearm violence.

Most of the factors indicate single use zoning, i.e. either residential or non-residential features, but not both. Only two factors, 5 and 6, load on both residential and non-residential features and could be considered, therefore, "mixed use". These appear to capture the practice of having multiple kinds of parcel zones in close proximity. While Jane Jacobs promoted such mixed land uses (cite), "this kind of zoning was considered undesirable in traditional zoning practice which generally sought to segregate residential uses from other uses" (Anderson et al., 2013 p. 710). These two latent factors are positively associated with firearm crime, factor 5 more than factor 6.

Three factors load on types of non-residential features. Factor 7 loads heavily on industrial buildings, open storage, and petroleum gas, which may suggest an underlying commonality around zoning for industries and utility companies. We find no statistically significant relationship with reported gun crime. Factor 8 shows an underlying commonality between retail stores, wholesale outlets, and commercial parking lots, which seems indicative of commerce or shopping areas. This factor is positively associated with reported firearm crime. Factor 9 loads on manufacturing plants, warehousing distribution, utility plant, and industrial parking lots, which would suggest a latent clustering of manufacturing trades. We find a statistically significant positive relationship with firearm crime.

Two factors load exclusively on demographic characteristics. Factors 10 and 11 load on demographic characteristics and are indicative of placed-based exclusion, isolation, or segregation. These latent factors are positively and negatively associated with firearm crime, respectively.

Table 3: Factor Loading and Negative Binomial Regression Estimates of Relationship between Environmental Factors and Gun Crime in Los Angeles

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11
Coefficient	0.600**	0.211**	-0.104**	-0.029	0.418**	0.192**	0.030	0.080**	0.130**		
Standard error	(0.019)	(0.019)	(0.018)	(0.018)	(0.018)	(0.018)	(0.019)	(0.017)	(0.017)		
					Factor Loading						
Residential											
Apartment 5 Plus Units			0.674			0.326					
Duplex					0.857						
Quadplexes			0.373		0.668						
Single Family Home	-0.702	0.427									
Triplex					0.866						
Non-residential											
Animal Shelter				-0.415							
Auto Sale Service				-0.389		0.352					
Banks						0.463					
Churches					0.501						
Commercial Building					0.351	0.452					
Department Store						0.300					
Food Processing Plants								0.568	0.578		
Heavy Manufacturing Plants									0.738		
Hotels/Motels						0.482					
Industrial Buildings							0.931				
Manufacturing Plants								0.319	0.711		
Mineral Processing							0.470				

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11
Movie Theaters						0.422					
Multiple Retail Stores								0.952			
Office Buildings						0.718					
Open Storage							0.877				
Parking Lot, Commercial						0.558		0.498	0.397		
Parking Lot, Industrial							0.572		0.600		
Petroleum Gas							0.986				
Professional Building						0.441					
Restaurants						0.589					
Split Retail Stores					0.564	0.476					
Utility Plant							0.360		0.657		
Warehousing Distribution								0.534	0.775		
Wholesale Outlet								0.795			
Neighborhood Context											
Educational Attainment, mean	-0.851										
Non-Citizen	0.743									-0.340	
Population, total		0.963									
Poverty 150, percent	0.831										
Race, as a Proportion											
Asian											0.915
Black										0.965	
White	-0.727									-0.398	-0.325
Rent, Median	-0.764										
SNAP	0.418		-0.417								-0.360

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11
Unemployed, percentage				0.301							

Standard error in parentheses. Statistically significant: ** p < 0.01; * p < 0.05.

Detroit

We provide the Pearson correlations and regression results using each environmental feature of Detroit in the supplement. Table 3provides factor loadings with absolute value 0.30 or greater correlation, and the coefficients and standard errors of a negative binomial regression analysis with firearm crime counts in Detroit as the dependent variable.

We find five of eight factors had loadings with both BE and NC variables, and four of those five had loadings with both residential and non-residential features. Specifically, factor 1 shows an underlying commonality between Airbnb units, multi-family homes, vacant lots and poverty. This latent factor is unrelated to firearm violence in Detroit. Factor 2 has large loadings for condos, boarding houses, hospitals, schools, and neighborhood economic or enterprise zones[1]. This seems to reflect "Eligible Distressed Communities" where a local governmental unit can provide for the development and rehabilitation of residential housing. This underlying factor is negatively associated with reported firearm crime incidents. Factor 3 loads on mixed use land with higher proportions of white, non-citizens. The latent commonality between these features is negatively associated with reported firearm violence. Factor 4 loads on mixed use land, commercial garages, gyms, hotels/motels, offices, parking lots, and higher proportions of Asian residents. The unobserved commonality among all these features is unrelated to firearm violence.

One factor includes only residential features and neighborhood characteristics. Factor 5 loads on single-family homes, high population, and higher proportion of people receiving SNAP. This is perhaps like Factor 2 in Los Angeles which also loaded on single-family homes and population,

[1] Provides tax exemptions for the development and rehabilitation of residential housing located within eligible distressed communities. http://www.michigan.gov/documents/taxes/NEZ_FAQs_Final2_490111_7.pdf

but not SNAP, and also had a statistically significant and positive relationship to reported firearm violence.

Two factors load on types of residential and non-residential built features and no neighborhood characteristics. Factor 6 loads on elderly homes, dormitories, and casinos. We find no statistically significant relationship with reported gun crime. Factor 7 loads on mixed use land and 24 of the non-residential features, the largest of which are retail stores, restaurants, and parking lots. This factor is positively associated with reported firearm crime. This latent factor is, perhaps arguably, most like factor 6 in Los Angeles, which is also statistically significant and positively associated with reported firearm crime.

The final factor in Detroit loads entirely on non-residential buildings, particularly industrial buildings, manufacturing, tool shops, and warehouses. The underlying factor of commonality between these features is negatively associated with firearm violence.

Table 4: Factor Loadings and Negative Binomial Regression Estimates using Built and Neighborhood Characteristics in Detroit

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
Coefficient	0.043	-0.066*	-0.172**	-0.002	0.325**	-0.009	0.097**	-0.116**
Standard Error	(0.026)	(0.026)	(0.026)	(0.025)	(0.025)	(0.026)	(0.025)	(0.026)
				Factor Loading				
Residential								
Airbnb	0.439							
Apartment 4 Or Less Units		0.330						
Condo		0.578						
Dormitory						0.657		
Elderly Home						0.788		
Mixed Use			0.367	0.376			0.465	
Multi Family Unit	0.365							
Single Family Homes					0.676			
Non-Residential								
Auto Sale Service							0.606	
Banks							0.507	
Barber Beauty							0.653	
Bars							0.693	
Boarding House		0.860						

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
Carwash							0.457	
Casino						0.955		
Churches	0.392							
Clubs Fraternal Orgs							0.404	
Commercial Building				0.338			0.390	0.387
Drug Store							0.702	
Dry Cleaner							0.698	
Fast Food							0.498	
Garage Commercial				0.821				
Garage Residential			0.349					
Gas Station							0.587	
Gyms				0.620				
Heavy Manu-facturing Plants								0.387
Hospitals		0.599						
Hotel/Motel				0.436			0.420	
Industrial Buildings								0.642
Industrial Plant							0.508	0.376
Laundromat							0.352	
Light Manu-facturing Plant								0.873
Movie Theaters								
Office Building				0.751			0.523	
Parking Lot				0.507			0.708	
Private Medical Practice							0.626	
Railroad								0.441
Repair Service Shop							0.575	0.392
Restaurant							0.774	
Retail Store							0.914	
Schools		0.331					0.333	
Scrap Yards								0.541
Spec Act		0.372		0.678				
Strip Mall							0.421	
Supermarkets							0.335	
Tool Shop								0.632
Utility				0.338				
Vacant Lot	0.584							0.309
Veterinarians							0.482	
Warehouse								0.674
Neighborhood Characteristics								
Neighborhood Economic Zone		0.308						

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
Non-citizen			0.886					
Poverty 150, percent	0.714							
Race, as a proportion								
Asian				0.375				
White			0.944					
SNAP	0.321				0.431			
Total Population					0.629			
Unemployed	0.444							

Note. For clarity, loadings with absolute value <0.30 were omitted. Statistically significant: *** $p < 0.01$; ** $p < 0.05$.

Pittsburgh

We provide the Pearson correlations and regression results using each environmental feature of Detroit in the supplement. Table 4 provides factor loadings with absolute value 0.30 or greater correlation, and the coefficients and standard errors of a negative binomial regression analysis with firearm crime counts in Detroit as the dependent variable.

We find five of six factors have loadings with both BE and NC variables, and three of five have loadings with both residential and non-residential features. Specifically, factor 1 shows an underlying commonality between public housing, government buildings, religious buildings, vacant lots, and higher proportions of Black residents living in high poverty and unemployment. This latent factor is positively associated with firearm violence in Pittsburgh. Factor 2 has large loadings for apartments, universities, and neighborhood characteristics of high educational attainment, higher rent, higher population, and more Asian, non-citizen residents. The underlying commonality between these environmental features is unrelated to reported firearm crime incidents. Factor 3 loads on mixed uses of condos, multi-family units, single-family homes, as well as 13 non-residential features (the largest of which is banks, convenient stores, and supermarkets), and greater population. The latent commonality between these features is positively associated with reported firearm violence. Factor 4 loads on mixed use buildings and several non-residential

buildings; the greatest loadings are on hotels/motels, office buildings, restaurants, and movie theaters. Reported firearm violence is positively associated with the unobserved commonality among these features. Factor 5 is very similar to factor 1 in that it has higher loadings on the same residential (public housing) and non-residential features (government building, religious building, vacant lot), as well as development parcel, but factor 5 does not load on any neighborhood characteristics; this factor is also similarly positively associated with reported firearm violence.

One factor, factor 6, loads only on non-residential features, the greatest of which are warehouses, 'uncategorized', manufacturing, and marine buildings. This is perhaps like the other two cities that each had a factor loading on mostly manufacturing-type buildings. The factor is unrelated to firearm violence in Pittsburgh, whereas the factor is negatively associated in Detroit and positively related in Los Angeles.

Table 5: Factor Loadings and Negative Binomial Regression Estimates of Relationship between Environmental Factors and Gun Crime in Pittsburgh

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Coefficient	0.532***	-0.119	0.495***	0.202***	0.414***	0.124
Standard error	(0.061)	(0.065)	(0.059)	(0.057)	(0.058)	(0.063)
			Factor Loading			
Residential						
Apartments		0.581				
Condos			0.384			
Multifamily Units			0.693			
Public Housing	0.306				0.588	
Single Family Homes			0.485			
Mixed Use Buildings			0.706	0.454		
Non-residential						
Banks			0.556	0.337		
Bars			0.400	0.308		
Car Washes						0.366
Club Fraternities			0.440			
Commercial Buildings			0.445	0.316		0.534
Convenience Stores			0.557			
Development Parcel					0.529	
Fast Food				0.319		
Funeral Home			0.357			
Government Buildings	0.327				0.849	
Hotel/Motels				0.925		

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Manufacturing Building						0.685
Marine Building						0.652
Movie Theaters				0.787		
Office Buildings				0.877		0.390
Parking Lots				0.694		
Pharmacies			0.304			
Private Practices			0.497			
Public Parks				0.339		
Public Transit				0.393		0.341
Religious Building	0.305		0.325		0.452	
Restaurants				0.866		
Retail Building			0.388	0.370		0.589
Right of Way			0.315			
Shopping Centers			0.326			
Supermarkets			0.512			
Uncategorized						0.779
Universities		0.366				
Vacant	0.393				0.835	
Warehouses						0.908
Neighborhood Characteristics						
Educational Attainment, mean		0.482				
Rent, median		0.350				
Poverty 150, percent	0.666					
Race, as proportion						
Asian		0.979				
Black	0.926					
Non-citizen		0.815				
SNAP	0.532					
Total Population		0.350	0.497			
Unemployed	0.595					

Aim #3: Accounting for Socio-Economic Context in the Distance between Built Environment Features and Firearm Violence

While there is research demonstrating firearm crimes happen closer to some types of built environment features, there are some gaps in research that we address in Aim #3 of this project. First, research has been done in small set of select cities, typically in the U.S. northeast, and more research is needed in other cities where the built environment differs. As such, we study cities throughout the U.S., including: Detroit, Los Angeles, New Orleans, and Pittsburgh. Second, the set of features studied has been perhaps small. So in this aim, we study 40 different types of built environment features. Third, it is unclear whether socio-economic conditions help explain the *distance* relationships identified between built environment features and firearm crime. We develop a way to include neighborhood socio-economic status in a Network Cross-K Function analysis. Finally, the direct comparison between features would be helpful for comparing and contrasting features and further understanding the relationships in a city. Therefore, we develop a normalized density metric that allow for such comparisons.

Methodology

Using the Network Cross-K function approach also used in this study, Xu and Griffiths (2016) demonstrate that liquor stores, grocery stores, bus stops, and foreclosed properties are risk factors of firearms violence in Newark, New Jersey. The application of the Network Cross-K Function (Okabe & Sugihara, 2012) was an important contribution to the literature because previously, almost all research measured Euclidean distance (‘as the crow flies'), rather than the street network. By organizing networked spatial data along a street network plane, one reduces measurement bias and improves the accuracy in the estimated relationship between features and crimes. Importantly, this approach more closely models the experience and decision-making of firearm violence perpetrators and victims (Lu & Chen, 2007; Yamada & Thill, 2004). Although beyond the scope

of their study, potential reasons for the proximal relationships identified, such as socio-economic characteristics, were not explored.

The fundamental equation used is the Network Cross K Function, which is defined as

$$K^f(t) = \frac{l_T}{n_f n_S} \sum_{i=1}^{n_f} P_{ft} \ ,$$

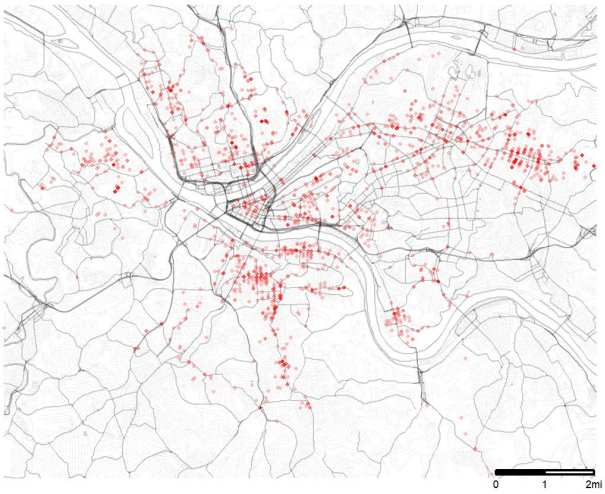
where F is the set of physical features, n_f is the number of physical features of type $f \in F$, S is the set of gun crime locations, n_S is the total number of gun crime, T is a set of discrete network distances, l_T is the cumulative length of all streets in the network, and P_{ft} is the number of gun crimes within network threshold $t \in T$ of a physical feature of type f.

In order to quantify trends in influence dissipation over distance, we perform piecewise linear regression on the firearms incident density for each feature, where breakpoints between segments are determined through Pruned Exact Linear Time (Pelt), a penalized change-point detection algorithm (Wambui et al., 2015), which identifies statistically significant changes in the pattern of influence.

Data

Crime datasets are available within each city's open data portal, but time coverage and type of crime reported are not uniform across cities. We use Part 1 crimes types of homicide, robbery, aggravated assault; the type of weapon was not available for crime of rape, filtered based upon string searches for terms such as "Gun" or "Shooting". All reported firearms crimes are defined using the Uniform Crime Reporting (UCR) hierarchy. Figure 3 illustrates the spatial distribution of firearms incidents for each city over the study timeframe. Our dataset includes only reported incidents with a firearm that occurred within city limits. Only these edges are included in the simulation to prohibit simulated firearms incidents to occur anywhere outside of the observed data.

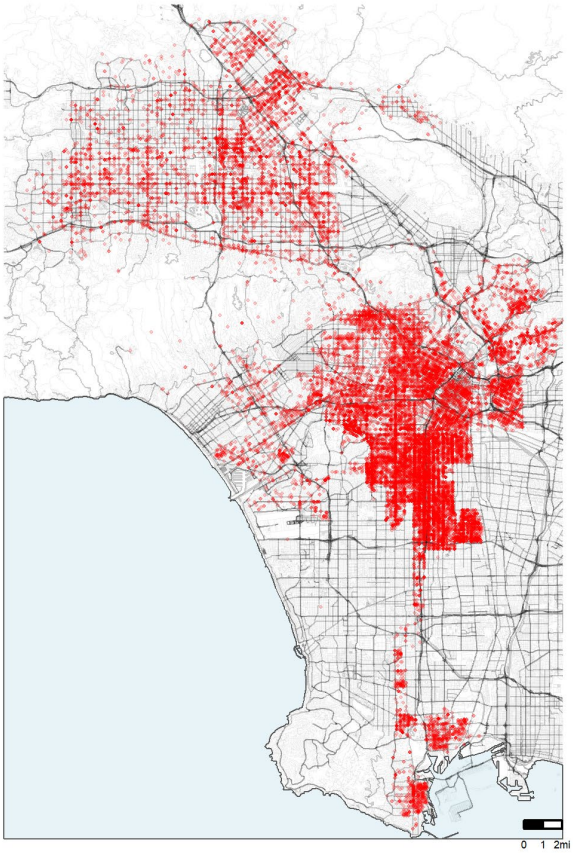
FIGURE 1 Spatial distribution of reported crimes with a firearms in A)Pittsburgh (2015-2017), B) New Orleans (2015-2017), C) Detroit(2014-2016), and D) Los Angeles (2013-2017)



A) Pittsburgh

B) New Orleans

C) Detroit



D) Los Angeles

From each city, we leverage the corresponding open data portal to collect any relevant, geocoded dataset. The table below shows presents the number of feature types, the number of recorded firearms incidents, and the studied years for each city. All features are self-reported, meaning that the owner of a property designates the type of feature that they own and each location may only be one feature type. If located outside of the street network, the location of each feature is snapped to the nearest road segment according to Euclidean distance.

Features and Firearms Incident Characteristics from Pittsburgh, New Orleans, Detroit, and Los Angeles

City	Years	Number of Feature Types	Total Number of Features	Number of Firearms Incidents
Pittsburgh	2015-2017	36	5,315	11,535
New Orleans	2015-2017	27	3,116	7,656
Detroit	2014-2016	25	6,277	14,141
Los Angeles	2013-2017	25	17,160	29,348

Results and Discussion

Methodological Advances

This Aim makes two key methodological advances in studying built environment and firearm crime. First, we develop a Firearms Incident Density measure, $S^{ab}(t)$, which represents a measurement of risk as a function of distance from features. This allows researchers to compare the propensity for firearms violence incidents to occur from different features. This measure counts the number of firearms incidents that occurred within distance *t* of an average feature, capturing the dissipation of influence with increasing distance (Equation 1).

$$S^{ab}(t) = \frac{\sum_{i=1}^{n_a} \sum_{j=1}^{n_b} p_{ij}^{t}}{n_a t} \quad (1)$$

Our framework diverges slightly from Xu & Griffiths (2016) who exclude n_a from the denominator of $S^{ab}(t)$. We include this component to account for the fact that the number of features of a certain type will have some natural association with the number of proximal firearms

incidents. That is to say, given two feature types with similar influence, the feature type with a high number of locations will naturally be near more firearms incidents than a feature type with a small number of locations. Similar to the Cross-K function, if a firearms incident node is within t of multiple features, it is only counted once. To serve as an example, suppose there exists one location ($n_a = 1$) for a particular feature *a.* Suppose further that one firearms incident had occurred at a 250ft. distance. Then, the firearms incident density reaches its maximum at 250ft, where $S^{ab}(250) = \frac{1}{1(250)} = 0.004$ and declines with increases in *t*. Had there been two locations for feature *a*, and the firearms incident occurred near only one of them, then $S^{ab}(250) = \frac{1}{2(250)} = 0.002$, which reflects the fact that fewer firearms incidents occurred *per location*.

Second, we developed a method for including socio-economic status (SES), which has been shown to drive firearms violence (Mills et al., 2019; Sampson & Groves, 1989; Shaw & McKay, 1942). To explore the extent to which SES explains or adds depth to our results, we apply the *NCFSSE* to subsets of feature locations according to the socio-economic status of the census tract in which the feature is located. Each census tract is designated a socio-economic index score based upon the methods of Aim #2, which incorporates indicators such as median household income, housing vacancies and unemployment from the American Community Survey ("American Community Survey, 5-Year Estimates," 2018)**.** We compare results for features located in census tracts corresponding to the upper and lower 25th percentile of SES index in each city, analyzing the extent to which results vary from their city-wide presentations in the previous section.

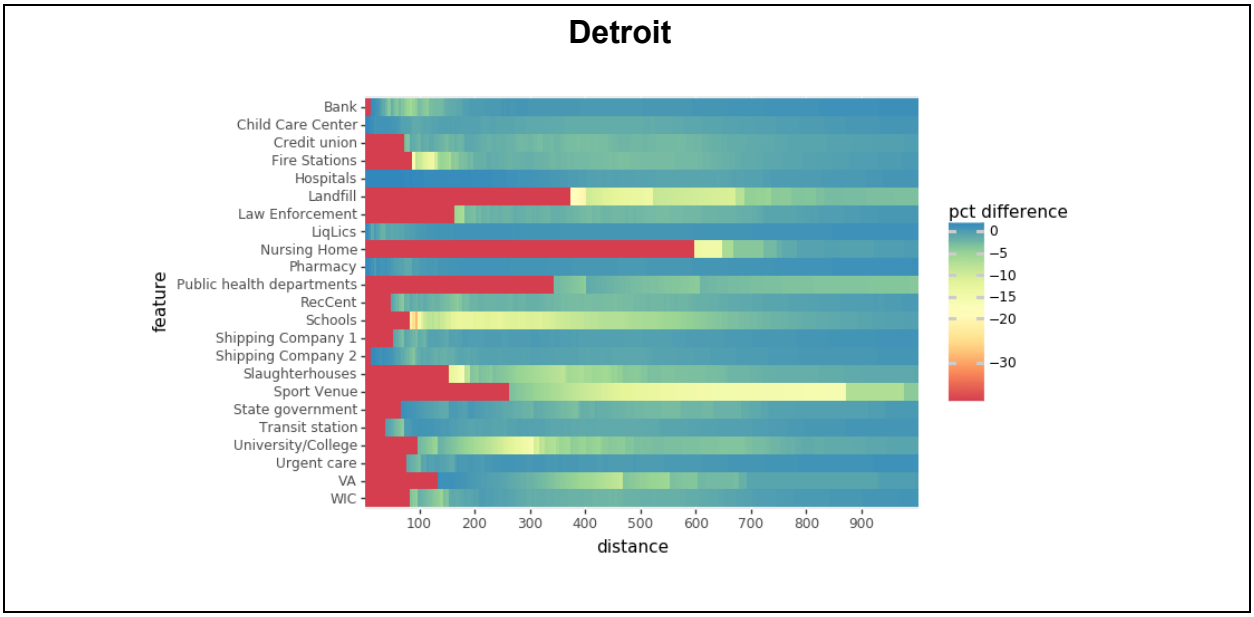
Attractors, Repellants, and Neutral Features: Lessons Learned and Recommendations

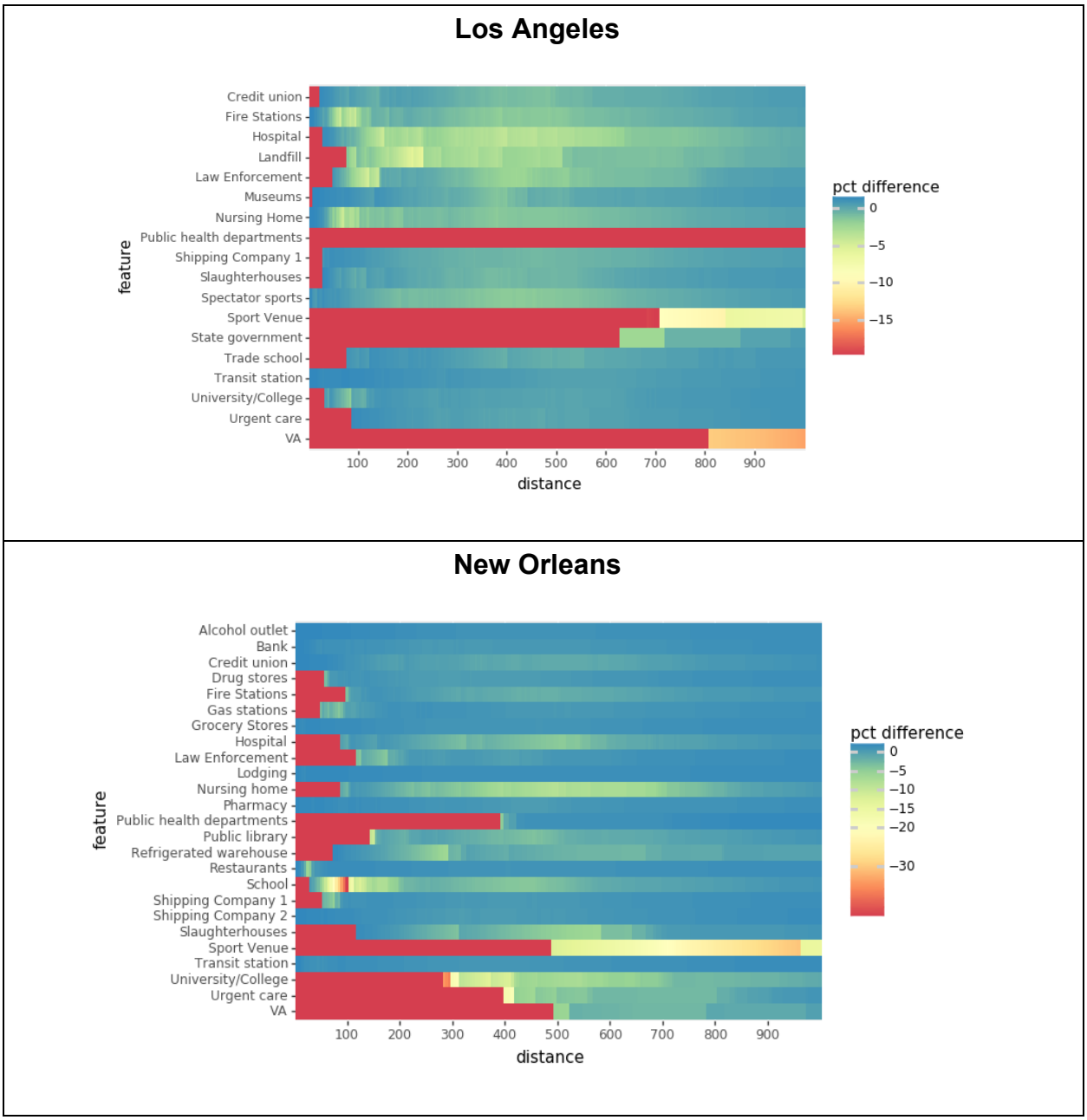
By embedding street networks within geospatial analyses of built environment features on reported crimes with a firearm, we find both similarities and dissimilarities across our four cities and compared to previous research. We are able to highlight the benefits of our proposed metric

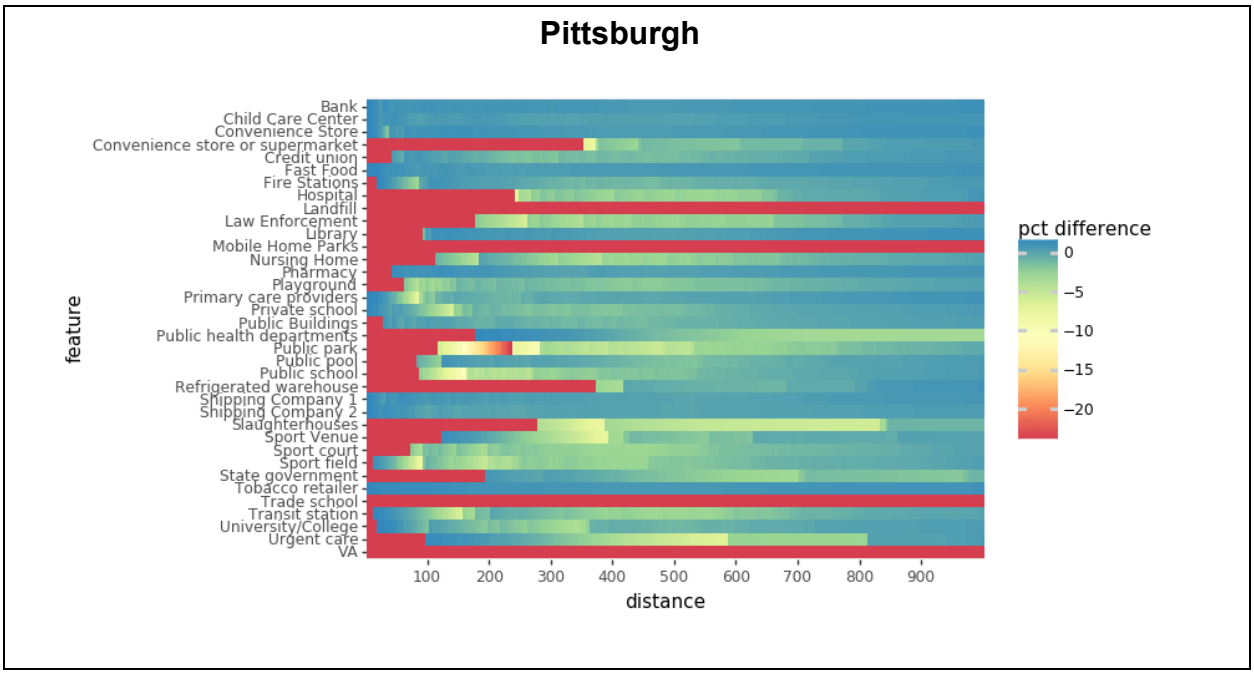
to normalize incident density values because we are able to make comparisons that were not possible before.

When features are examined in aggregate, no single feature (for which we have data in every city) exerts attractive influence in all four cities. In Detroit, we find that none of the tested features exert a strong attractive influence at an aggregate level, possibly due to the relatively uniform distribution of firearms incidents across the city. But, we do find attractors when examining within lowest (25th percentile) and highest (75th percentile) SES neighborhoods.

We present a summary of results in the form of a "heat map". We calculated the percent difference between the observed and simulated Network Cross-K functions at distances from 0-1,000ft from a feature. A positive value indicates an attractive influence and a negative value indicates a repellent influence. To facilitate interpretation, positive values (attractors at a particular distance) are shown in shades of blue. Neutral features are in shades of green. Negative values (repellants at a particular distance) are shown in shades of yellow and orange, with solid red if there are zero observed, reported firearms incidents at the corresponding distance.







Impact and Dissemination

While we were hindered by COVID-19, we presented some of the work before the shut-downs and made every effort to present in virtual conferences more recently. We presented Aim #1 research at the American Society of Criminology Annual Meeting in November 2019. We presented at the RAND Drug Policy Research Center brown bag in May 2020, which included an audience of statisticians, economists, criminologists, and PhD students at Pardee RAND Graduate School. We presented virtually at APPAM's international conference on July 23rd, 2020. Results were also presented to urban planner experts in each city. We are scheduled to present at the American Society of Criminology Annual Meeting in November 2021.

For Aims #1 and #2, we have two papers under review at journals. For Aim #3, we have a revise and resubmit at a journal, and await final decisions and reviewer comments. We will post reviewed documents on the RAND website, and highlight the research on RAND social media (Twitter, facebook). We archive the data at ICPSR.