



# The spatial dynamics of commercial burglary during the COVID-19 lockdown in San Francisco

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## Abstract

**Purpose** This paper investigated the impact of COVID-19 stay-at-home regulations on the spatial distribution of commercial burglary in San Francisco.

**Method** Geocoded commercial burglary data for 2003–2021 from San Francisco were analyzed using the Andresen Spatial Point Pattern Test to examine potential spatial movement in commercial burglary.

**Results** Concentrations of commercial burglary spatially shifted following the emergence of COVID-19 and the subsequent stay-at-home orders. Original hot spots experienced a relative decrease in commercial burglary, and crime spread out throughout the city. These spatial changes in commercial burglary appear to be related to variations in guardianship and criminal opportunity.

**Conclusion** These findings suggest that the dramatic shifts in routine activities resulting from the COVID-19 policies could disrupt spatial burglary patterns, especially burglary clustering. Law enforcement should consider the spatial dynamics of commercial burglary, as well as land use heterogeneity, to effectively respond to crime during periods of social distancing and business shutdowns.

**Keywords** COVID-19 · Crime trends · Spatial crime patterns · Commercial burglary · Hot spots

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## Introduction

In the Spring of 2020, the spread of the novel coronavirus SARS-Cov2 (COVID-19) led to governors and mayors issuing stay-at-home orders in states and cities in the USA. Along with such orders came concerns of increased risks to domestic violence victims, higher levels of unemployment, and general unrest as the pandemic settled in around the world. These were felt all across the nation, with nearly every jurisdiction subjecting residents to these orders to prevent the spread of COVID-19. Daily routines were disrupted, with people spending more time at home. Non-essential businesses were forced to close, potentially leaving these locations unsupervised for long periods of time.

Citywide changes in routine activities have been linked to changes in criminal activity, including and especially burglary in the context of the routine activity framework (Felson et al., 2020). Under COVID-19-related stay-at-home orders, residential burglaries might be expected to decline as people are likely to be at home and able to act as guardians of their property. In contrast, it can be expected that commercial burglaries increase because non-essential businesses were left unattended and thus lacking capable guardians. Several studies have found declines in residential burglary and increases in commercial burglary following COVID-19 lockdown orders across several cities in different states (Abrams, 2021; Ashby, 2020; Carter & Turner, 2021).

While this is certainly a promising start to understanding the effect of stay-at-home regulations on burglary, very little is known about whether burglary spatially shifted due to changes in the routine activity of human behavior during the COVID-19 lockdown orders. From a routine activity perspective, drastic changes in routine activities within a city in response to COVID-19 are expected to disrupt long-term crime clustering patterns, thus leading to new or different areas having higher concentrations of burglary (Felson et al., 2020). To date, few studies have directly examined whether COVID-19 lockdown orders affected the spatial distribution of crime, including burglary (Campedelli et al., 2020; Yang et al., 2021), and such work has not disentangled burglary by its type of location, which may limit our nuanced understanding of the spatial dynamics in burglary.

The present study addresses these shortcomings by testing whether commercial burglary spatially shifted throughout San Francisco in response to lockdown orders. San Francisco presents itself as an intriguing case study for the effect of COVID-19 regulations on crime because of the duration that it was under stay-at-home orders. San Francisco phased in and out of different regulations but maintained stringent lockdown orders on businesses with regulations beginning March 17, 2020, and the citywide reopening process starting June 15, 2021 (City and County of San Francisco Department of Public Health, 2020, 2021). The focus of this paper is on commercial burglary because of its rise in San Francisco during the pandemic. Using geocoded commercial burglary data for 2003–2021 from San Francisco, Andresen's Spatial Point Pattern Test was used to identify any spatial shifts in commercial burglary during the COVID-19 lockdown period. The following sections review the relevant literature, describe the current study's data

and methods, report our results, and discuss the policy and theoretical implications of our findings.

## Literature review

### COVID-19 and burglary

During the pandemic, there were high levels of unemployment as many businesses closed and others laid off workers in the USA (Bureau of Labor Statistics, 2021). One might expect higher levels of property crime during periods of increased unemployment (Raphael & Winter-Ebmer, 2001), but weekly property crime rates were found to decrease during the pandemic in many large cities across the USA (Lopez & Rosenfeld, 2021). As noted by Felson et al. (2020), the extreme shift in people's daily routines could best explain why US cities did not experience increases in crime during the earliest stages of the pandemic. Specifically, residential and non-residential burglary rates decreased overall from the onset of the pandemic to the end of 2020 in a sample of 18 cities, a sample that included San Francisco (Lopez & Rosenfeld, 2021). Still, findings from other studies have detected mixed effects of the pandemic on burglary (Abrams, 2021; Carter & Turner, 2021; Mohler et al., 2020).

Separate analyses of Indianapolis and Los Angeles resulted in mixed findings on the effect of social distancing guidelines on daily calls for service for burglaries (Mohler et al., 2020). Difference in means tests revealed no statistically significant change from their baseline period (January 2 to March 16, 2020) to the treatment period in Indianapolis (March 24 to April 21, 2020), but a statistically significant decrease was detected for Los Angeles (March 20 to April 18, 2020). It could be that differing findings on the effect of social distancing policies on burglary may be attributed to the failure to distinguish between residential and commercial burglaries.

For example, in a study of four Michigan cities, including Detroit, Grand Rapids, Kalamazoo, and Lansing, Carter and Turner (2021) conducted interrupted time series analyses using weekly counts of residential and commercial burglary from 2018 through the end of 2020. Detroit and Grand Rapids exhibited declines in residential burglaries during the stay-at-home period but only Detroit experienced increases in commercial burglaries (Carter & Turner, 2021). In the analysis of aggregated daily crime rate data for 25 US cities, Abrams (2021) also found differential effects of stay-at-home orders across types of burglary, with a 23.5% decrease in residential burglary offset by a 37.8% increase in non-residential burglary.

### Theoretical explanation for changes in burglary

The theoretical mechanism for juxtaposing changes in commercial and residential burglary is rooted in routine activity theory. Routine activity theory states the convergence in time and space of a motivated offender, suitable target, and lack of a

capable guardian are necessary for crime to occur (Cohen & Felson, 1979). The COVID-19 pandemic and accompanying stay-at-home orders drastically changed everyday life and people's daily routines. Instead of leaving home to go to work during the day, many people began working from home, and during the evening hours on the weekend, people were no longer able to go out for dinner or frequent bars. The combination of these factors greatly increased the level of guardianship for residences, suggesting residential burglary would decrease during the height of the pandemic. In turn, non-residential locations were no longer frequented by customers or employees if they were designated as non-essential businesses. This would greatly decrease the guardianship at and around such locations and potentially increase the risk of crime occurring.

Felson et al.'s (2020) work investigated rapid changes in burglary for 879 Detroit block groups and described the stay-at-home process and its effects on crime. By breaking March into pre-lockdown, lockdown transition, and lockdown periods, they were able to compare block groups with more than 90% of their parcels designated as residential areas to those with less than 90% of their parcels designated as residential parcels. Results from their descriptive analysis suggested a potential shift of burglary out of primarily residential areas and into block groups with more mixed land use (Felson et al., 2020). Their findings suggest that during the early stages of the pandemic, a routine activity perspective could explain these shifts in crime. This theoretical explanation assumes the potential spatial shift in commercial burglary following the emergence of a stay-at-home order; however, no research to date has examined whether a stay-at-home order influenced spatial burglary patterns, especially effects on burglary clustering.

### **Crime clustering and the context of COVID-19**

Crime has been found to cluster non-randomly in locations (Sherman et al., 1989), and to be stable in hot spot areas over long periods of time (Weisburd et al., 2004). Specifically, crime has clustered at the street segment level of analysis in Seattle, WA (Weisburd et al., 2004), Vancouver, BC (Curman et al., 2015), and Albany, NY (Wheeler et al., 2016). In the context of commercial burglary, there is some evidence that it also clusters the way other crime does. For example, Andresen et al. (2017) investigated property crime clustering from 2003 to 2013 in Vancouver and found crime became more evenly distributed across micro-places, even while crime decreased overall in the city. Their findings held true for multiple property crimes, including commercial burglary.

With such a great disruption to routine activities during lockdown periods, it is possible the distribution of crime would also become disrupted, thus causing new or different areas to host higher concentrations of commercial burglary. Drastic changes to everyday routines of people within a city (i.e., COVID-19-related lockdowns) could disrupt long-term crime clustering patterns, with mixed land use areas experiencing increases in crime due to decreased guardianship from businesses being closed.

Overall, there is some evidence that crime diffused or was dispersed across cities during lockdown periods and did not cluster in the same way it did prior to the pandemic. In Miami, Moise and Piquero (2021) were not able to detect significant violent crime arrest clusters during their 3-month study period in 2020 as compared to 2018 and 2019. Campedelli et al. (2020) and Yang et al. (2021) found evidence of shifting concentrations of crime, including burglary, in Chicago, and hot spots of child abuse and neglect were found to intensify or cool off through Los Angeles (Barboza et al., 2021). Conversely, Drake et al. (2022) did not find evidence to suggest the spatial distribution of shootings shifted during the stay-at-home period.

Although these studies are helpful in illuminating the effects of COVID-19 restrictions on the spatial distribution of crime, they do not fully describe the specific effects of closing businesses on commercial burglary. For example, while a few studies have considered the effect of the pandemic on citywide levels of commercial burglary, no studies have examined whether commercial burglary spatially shifted in response to changes in the routine activity of human behavior following lockdown order implementation. Furthermore, the studies assessing the impact of COVID-19-related regulations on spatial burglary patterns have not disaggregated burglary into residential and commercial categories. All of these constraints limit the field's understanding of how the COVID-19 policies influenced spatial patterns of commercial burglary.

## Current study

Although the field has examined trends in burglary after the emergence of COVID-19 and subsequent containment measures, one lingering question that has received comparatively less attention is how COVID-19 lockdown orders have influenced the spatial patterns of burglary. From a routine activity perspective, it is expected that drastic changes in the routine activity of human behavior can disrupt long-term crime clustering patterns. However, no studies at this time have specifically assessed whether commercial burglary concentrations spatially shifted in response to COVID-19-related restrictions. This study addresses these shortcomings by examining potential spatial pattern changes in commercial burglary.

The current study narrows its focus to San Francisco to test for changes in the spatial distribution of commercial burglary. San Francisco presents itself as a unique case study due to the duration and intensity of their COVID-19-related regulations, with the city being largely locked down or highly restricted for most of 2020 and the first half of 2021.<sup>1</sup> We rely on nearly 18 and a half years of crime data sourced from San Francisco's website to consider the historical spatial burglary

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<sup>1</sup> In San Francisco, CA, non-essential businesses were ordered to stay-at-home beginning at midnight on March 17, 2020. The conditions of this order lasted nearly two and a half months until June 1, 2020, when Mayor London Breed began to slowly and partially allow some businesses to re-open and larger gatherings to take place. After multiple delays in re-opening indoor dining and retail, Mayor Breed officially rolled back the minor re-openings in November and re-enacted a stay-at-home order that went into effect on December 6, 2020, at 10 o'clock PM. Finally, in June of 2021, the city was allowed to re-open businesses and activities, aligning itself with the state and Governor Newsom's plan.

patterns and test for the effects of stay-at-home orders on burglary patterns in San Francisco.<sup>2</sup>

## Data

This study analyzes commercial burglary in San Francisco, CA. As of 2020, the city had a population of about 880,000 individuals, making it the seventeenth largest city in the USA.<sup>3</sup> The city of San Francisco is 46.9 square miles, making it the second most densely populated large US city.<sup>4</sup>

The data for the analyses are police incident data from the San Francisco open data portal. The crime type of focus for this study is commercial burglary. Our study period includes data from January 1, 2003 (the earliest date crime incident data were available) through June 15, 2021, the date that San Francisco began re-opening along with the state of California. Crime incidents were geocoded to the street intersection level by the San Francisco Police Department, and the geographic information given in the data were the latitude and longitude for the crime location. After eliminating the cases that were not geocoded or were missing the date the incident was reported to the San Francisco Police Department, the total number of commercial burglaries over the study period is 22,333, with an average of approximately three commercial burglaries occurring per day.

To examine the impact of COVID-19 on the spatial distribution of commercial burglary, we partition our data into pre- and post-COVID-19 lockdown regulations. The city of San Francisco adopted a stay-at-home order (SAHO) on March 17, 2020. All non-essential businesses were forced to close, and residents were directed to remain at their place of residence. After periods of lighter restrictions and a return to a “lockdown” state, the SAHO ended on June 15, 2021, and restrictions on businesses were lifted. With this in mind, we consider the post-COVID-19 period as the time window from March 17, 2020, to June 15, 2021.<sup>5</sup> The pre-COVID-19 period is defined as the time frame from January 1, 2003, through March 16, 2020.

<sup>2</sup> The historical data permalink: <https://data.sfgov.org/Public-Safety/Police-Department-Incident-Reports-Historical-2003/tmnf-yvry>

The 2018 to present permalink: <https://data.sfgov.org/Public-Safety/Police-Department-Incident-Reports-2018-to-Present/wg3w-h783>

<sup>3</sup> <https://worldpopulationreview.com/us-cities>

<sup>4</sup> <https://worldpopulationreview.com/us-cities>

<sup>5</sup> A longer time window prior to COVID SAHO was considered as a baseline period for reasons. First, a longer baseline period allows for a rigorous test of spatial shift in crime by considering the historical volatility of crime. Crime is a rare event and thereby its ups and downs over short time intervals may be a result of random fluctuations. This pattern may be evident at micro-places (Hinkle et al., 2013). Given the spatial consistency of crime over long periods of time in different sites and contexts (Curman et al., 2015; Weisburd et al., 2004; Wheeler et al., 2016), one can reasonably determine a spatial shift in crime at micro-places by comparing crime in the post-COVID period to its historical patterns that occurred prior to COVID SAHO. Second, a longer time frame provides a large baseline of crimes enough to detect changes in SPPT. By having a large sample size, one can have sufficient statistical power to find the treatment effect (here the COVID SAHO effect). One may question the validity of the results from comparing a short time period with a longer time window because higher counts of crime in the baseline period are likely to bias the results. This concern may not be substantial as SPPT examines proportions of crime in each area in pre- and post-COVID period, not crime counts of the spatial patterns.

**Fig. 1** Commercial burglary trend in San Francisco 2003–2021

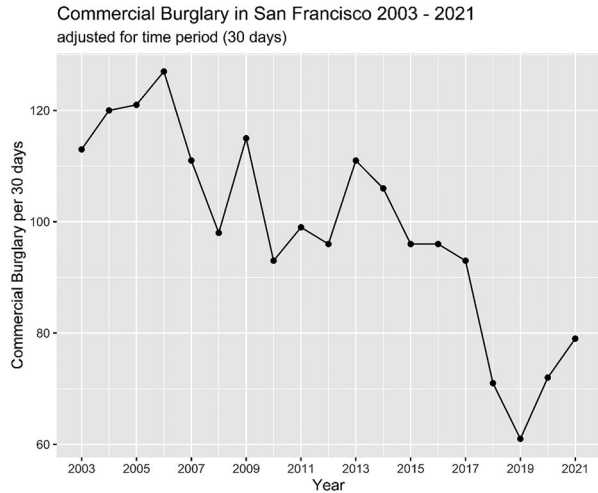


Figure 1 shows the temporal trend of commercial burglary, standardized per 30 days in San Francisco. San Francisco experienced an increase in commercial burglary during the early 2000s, with a peak of 127 commercial burglaries per 30 days in 2006. Then, there is fluctuation during the early 2010s until commercial burglary began to decrease through the mid-2010s until 2019. The years 2020 and 2021 provide evidence of an overall increase in commercial burglary compared to 2018 and 2019.

## Method

This study focuses on two different analyses. To identify spatial clusters of crime in the pre-COVID-19 period and whether there is a spatial shift in the post-COVID-19 period, we used quadrat analysis, specifically a grid thematic mapping technique. With this method, we displayed spatial patterns in both pre- and post-COVID-19 periods to get a general picture of spatial crime patterns and clusters over time. Additionally, these maps will show differences in commercial burglaries between pre- and post-COVID-19 periods to examine the absolute increase in the commercial burglary intensity in each grid cell. This allows for testing whether hot spots of crime remained stable or intensified, or if crime clusters shifted to other locations.

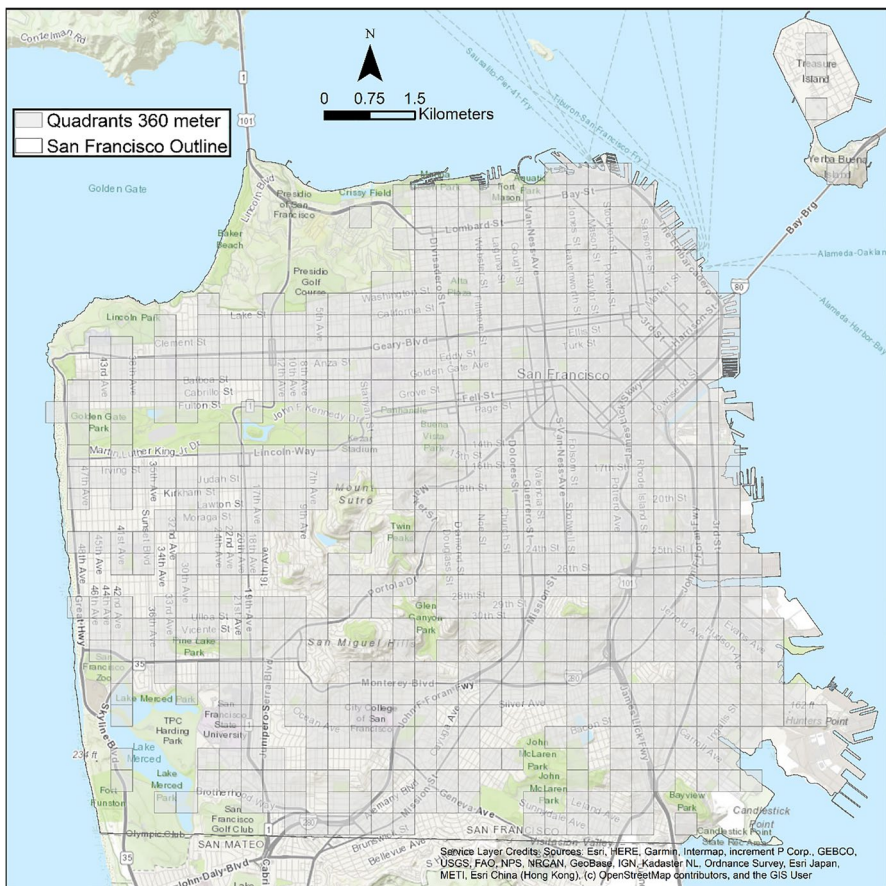
A grid of  $360 \times 360$  m squares was constructed to overlay San Francisco for the quadrat analysis.<sup>6</sup> Grid cell analysis has several advantages. First, it can address the problem of inconsistency of the geocoding between two point patterns. Second,

<sup>6</sup> The  $360 \times 360$ -m grids provide a power of over 0.7 to detect changes in the relative distribution of commercial burglary. Smaller areas would not allow for the same statistical power, and larger areas would likely mask the heterogeneity of crime clustering. In San Francisco, most city blocks are smaller than  $360 \times 360$  m, so a larger grid cell would run counter to what is known about crime clustering non-randomly in very small (within-city blocks) spatial units (Andresen et al., 2017; Curman et al., 2015; Sherman et al., 1989; Weisburd et al., 2004; Wheeler et al., 2016).



this sized area provides enough observations to estimate differences in proportions between two point patterns in many areas. Specifically, building on the power analysis logic suggested by Wheeler (2021), this sized area provides a power of over 0.7 to detect a change in relative distribution from a location at the 98th percentile to median percentile, assuming the spatial data follows a Poisson distribution with slight overdispersion. If the areas are too small, one would lack the power to detect changes because each area will have a smaller percentage of total cases, and thereby larger standard errors will emerge in the analysis. We examined grid cells that have at least one commercial burglary over the entire study period, resulting in a total of 655 grid cells. Figure 2 displays these grid cells with a background map of San Francisco.

For the second analysis, we examined the relative differences of proportions of commercial burglaries between pre- and post-COVID-19 time periods using Andresen's Spatial Point Pattern Test (SPPT). Andresen's SPPT is designed to examine the



**Fig. 2** San Francisco study area, with 655 360 by 360-m grid cells that had at least one commercial burglary over the 19-year study period



similarity or differences in proportions of two spatial patterns. Assuming there is a hypothetical area A that has 6% of total burglaries in one time point and then has 9% of total burglaries in another time point, the SPPT compares the two spatial distributions of crime to examine whether the difference of the proportions is statistically significant. The test does the same statistical analysis for each location over the study area, testing a null hypothesis that the two proportions are equal. An overall index of similarity, referred to as the S index, indicates the proportion of areas that are considered equal. Additionally, spatial patterns of overall differences between two samples can be mapped out to identify particular spatial patterns such as clusters or shifts of differences.

Andresen's SPPT has several advantages. First, the SPPT allows one to identify a change in the relative ranking of the highest crime places (Drake et al., 2022). For example, if the area with the most crime has 8% of the total crime incidents in the pre-COVID-19 period and in the post-COVID-19 period has 4% of the total crime incidents, it is assumed that its relative ordering is likely to decrease. This situation can occur if crime spreads out or other areas eclipse that hot spot in relative importance. Either way, a change in the relative ranking of hot spots implies a spatial shift in crime density related to COVID-19-related restrictions. Also, with the SPPT, one can identify areas that experience higher crime that were not originally hot spots, which may not be clearly identifiable using a hot spots clustering approach. Additionally, using the updated version of Andresen's SPPT, one can identify the areas with a substantial change in the proportion of crime by constructing the absolute size of the differences in proportions. Some areas may experience a proportional change in crime that is statistically significant but substantially trivial (Wheeler et al., 2018). By measuring the sizes of the proportional differences and mapping the output, one can focus on areas with a higher proportional increase of crime, which is useful for police agencies in terms of prioritizing hot spots of crime. Andresen's SPPT has been widely used in several publications to examine changes in crime distribution over time (Andresen & Malleon, 2013, 2015; Andresen et al., 2017; Hodgkinson & Andresen, 2019; Hodgkinson et al., 2016; Linning, 2015).

The current study employs the procedure described by Wheeler et al. (2018) to test differences in proportions in each grid cell directly. This technique helps overcome the limitation of the original SPPT. The original SPPT required selecting one of two point patterns as a base set and another as a test set (Andresen, 2016). The assignment of point patterns to base and test sets is likely to lead to bias in the results (Wheeler et al., 2018). For example, when some areas have zero observations in the test set and small proportions (but non-zero) in the base set, the original SPPT approach will falsely identify that the patterns are significantly different as the confidence interval for the proportion in the test set will always be zero. Our method directly tests differences in proportions in each grid cell using the chi-square test with Yates continuity correction. This approach does not require assigning our point pattern shapefiles to a base and test set, so the results are invariant to our assignment choice. Additionally, we use multiple comparison corrections to adjust a  $p$ -value to limit false positive rates using the procedure discussed in Benjamini and Yekutieli (2001). As there are a lot of individual statistical tests (655 in our case, with a test comparing a pre and post for each quadrant), some differences in proportions can be

statistically significant simply by chance. This issue can be minimized by correcting  $p$ -values based on a false discovery rate.

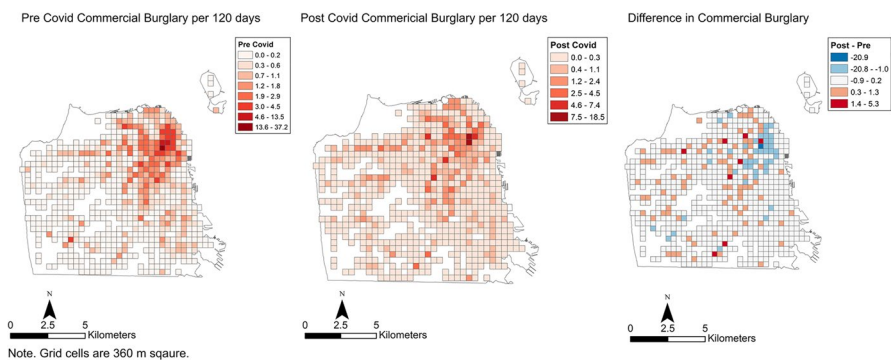
## Results

Spatial patterns in the pre- and post-COVID-19 period and differences in commercial burglary are plotted in Fig. 3. As one can see in the left panel, in the pre-COVID-19 period, commercial burglaries have historically clustered around the northeastern part of San Francisco in the area defined as the central business district. The highest densities of commercial burglaries are located in Union Square, which is the main shopping district. This spatial pattern is expected because these areas are collections of department stores and upscale boutiques with high-end goods, which may be suitable targets for burglary. However, there is no apparent commercial burglary cluster around the original hot spots in the post-COVID-19 period.

The decline in commercial burglaries occurred in most grid cells in the central business zone; however, the grid cell with the most crime experienced the highest drop in commercial burglary. The map of differences in commercial burglary indicates that several grid cells that were not initially considered hot spots experienced higher crime post-COVID-19 compared to pre-COVID-19. The analysis implies that spatial patterns in commercial burglary shifted, meaning that original hot spots have fewer commercial burglaries per 120 days, and crime appears to have spread out over San Francisco. The question is whether this spatial shift is statistically significant or a result of random variation.

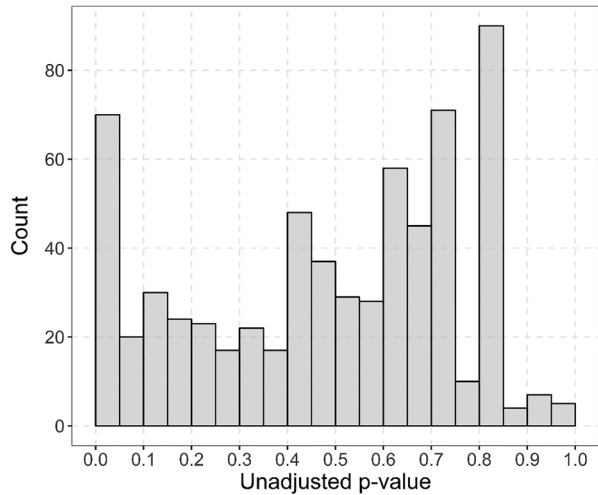
### SPPT results

Figure 4 displays a histogram of unadjusted  $p$ -values resulting from the SPPT. The analysis identified that there are a total of 70 grid cells with statistically significant



**Fig. 3** Spatial patterns of commercial burglary in pre- and post-COVID periods and the comparison of the difference

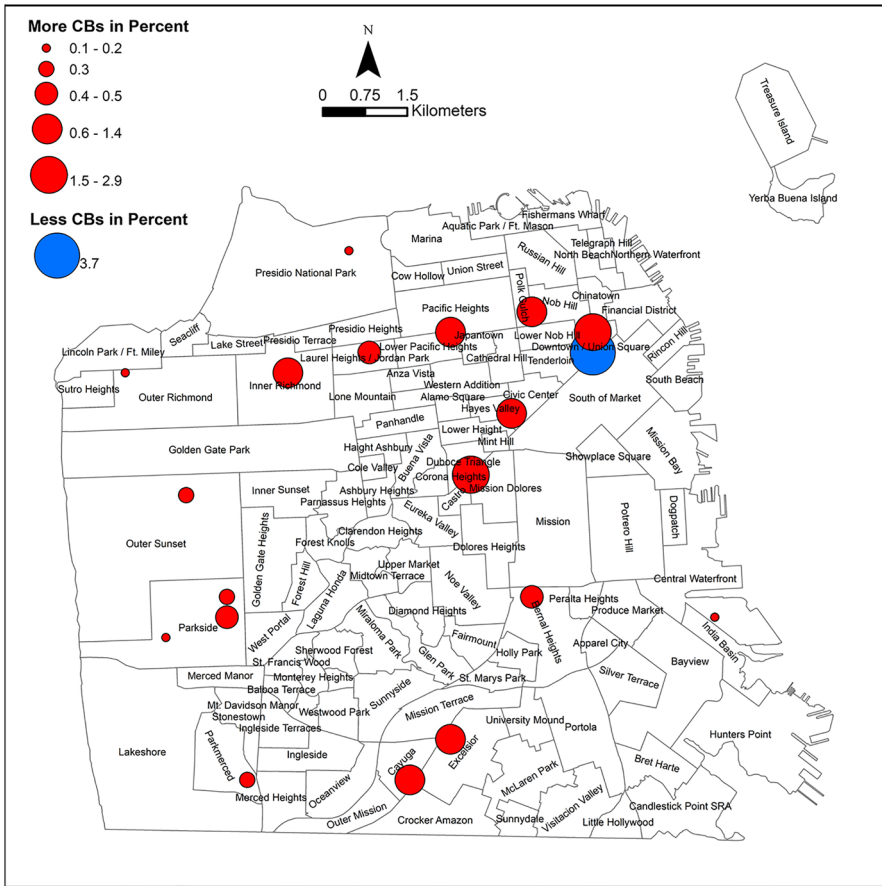
**Fig. 4** Histogram of 655 unadjusted  $p$ -values from SPPT analysis



differences in the proportion of crime that occurred within their boundary (for an  $S$  index of 89%), but this does not account for multiple comparison corrections. With 655 tests, one would expect around 32 grid cells under the typical 0.05 threshold simply by chance without adjustment. After using multiple comparison corrections that assume the tests are correlated, the analysis detected 19 grid cells below the 0.05 alpha level (for an  $S$  index of 97%).

Figure 5 shows grid cells having either a higher proportion or a lower proportion of commercial burglary after correcting for multiple comparisons using the false discovery rate. Grid cells with statistically significant increases or decreases in commercial burglary are represented with circles and overlaid on a map of the neighborhoods in San Francisco. The map displays grid cells with an increased proportion of commercial burglary as red circles, while a blue circle indicates a grid cell with an overall decrease in the proportion of commercial burglaries. One can see that the results of the SPPT are consistent with those from the quadrat analysis.

Downtown San Francisco, the neighborhood which historically has contained grid cells with the highest level of commercial burglary contains a grid cell with the greatest decrease in the proportion of commercial burglary in the post-COVID-19 period. Commercial burglary spread out to 18 other areas throughout San Francisco. The place just north of the highest crime area experienced a greater proportion of commercial burglary, a grid cell also located in the downtown or Union Square neighborhood. There is also a proportional increase in commercial burglary in grid cells within the Nob Hill, Pacific Heights, and Hayes Valley neighborhoods, which are close to the downtown area. Additionally, the proportion of commercial burglary increased in some grid cells distant from original hot spots, including those in Inner Richmond, Laurel Heights/Jordan Park, Duboce Triangle, Bernal Heights, Excelsior, Cayuga, Outer Sunset, Parkside, Parkmerced, and Central Waterfront, suggesting that commercial burglary was not as concentrated in the same downtown grid cells in San Francisco and that instead it was diffused across the city during the post-COVID-19 period.



**Fig. 5** Grid cells that have a statistically significant difference in the proportion of commercial burglary following the emergence of COVID-19 SAHO at the  $p < 0.05$  level after adjusting for multiple comparisons. Neighborhoods may have more than one grid cell that experienced a statistically significant change in commercial burglary

Table 1 shows the change in commercial burglary in grid cells with a substantial change in both counts and proportions. The grid cell with the most commercial burglaries from the pre-COVID-19 period had 37 commercial burglaries per 120 days in the pre-period and 16 commercial burglaries per 120 days in the post-COVID-19 period. This translates to a total of 9.2% of all commercial burglaries in the pre- and 5.5% of all commercial burglaries in the post-COVID-19 period, for a decrease of 3.7 percentage points. The grid cell adjacent to the highest crime place experienced a 2.9 percentage point increase in the proportion of commercial burglary from 3.3% (13 commercial burglaries) to 6.2% (18 commercial burglaries).

The grid cells relatively close to pre-existing hot spots also accounted for a larger proportion of commercial burglary. For example, grid cells in Hayes Valley and Pacific Heights accounted for 2.4 and 1.9%, respectively, of all commercial

**Table 1** Change in grid cells with significant differences, San Francisco, from pre- to post-COVID-19 stay-at-home-orders

	Grid cell neighborhood	Pre-COVID		Post-COVID		Change over time			
		Total count: 21,175	Count per 120 days: 404.2	Total count: 1129	Counts per 120 days: 297.8	Proportion of total CB	Change from pre- to post-COVID	Standardized count change	
1	Downtown/Union Square (blue circle)	1950	37.2	62	16.4	9.2	5.5	-3.7	-20.8
2	Downtown/Union Square (red circle)	705	13.5	70	18.5	3.3	6.2	2.9	5
3	Hayes Valley	214	4.1	27	7.1	1	2.4	1.4	3
4	Pacific Heights	123	2.3	21	5.5	0.6	1.9	1.3	3.2
5	Nob Hill	119	2.3	17	4.5	0.6	1.5	1	2.2
6	Duboce Triangle	107	2	28	7.4	0.5	2.5	2	5.4
7	Inner Richmond	62	1.2	15	4	0.3	1.3	1	2.8
8	Excelsior	52	1	15	4	0.3	1.3	1.1	3
9	Cayuga	52	1	13	3.4	0.3	1.2	0.9	2.4
	Total CB	3384	65	268	71	16.1	23.8		

CB, commercial burglary; not all grid cells with statistically significant changes are presented here. Grid cells listed in order of largest proportion of CB to smallest proportion of CB

burglaries in the post-COVID-19 period, or increases of 1.4 and 1.3 percentage points, respectively. The proportional increase in commercial burglary emerged in grid cells distant from the pre-COVID-19 concentration. Specifically, grid cells in Inner Richmond and Excelsior that had less than 0.5% of total commercial burglaries in the pre-COVID-19 period have around 1.3% of total commercial burglaries in the post-COVID-19 period. There is also an increase in counts in these grid cells from 1 to 4 commercial burglaries per 120 days. Along with this absolute increase in counts, the proportional increase in these grid cells can be considered substantial.

## Discussion

An emerging body of research has examined temporal changes in burglary in response to COVID-19 lockdown orders (Abrams, 2021; Ashby, 2020; Carter & Turner, 2021), but changes in spatial patterns of burglary have been understudied. From a routine activity perspective, substantial changes in people's routine activities are likely to disrupt long-term crime clustering patterns, thus causing burglary to spatially shift to other areas. While a small number of studies have investigated the spatial shift in burglary (Campebell et al., 2020; Yang et al., 2021), their findings are limited in understanding the spatial dynamics in burglary due to the failure to disaggregate burglary by its type of location which precludes an understanding of nuanced changes. This study extends the prior work by focusing on a specific burglary type, commercial burglary, and examining the impact of COVID-19 lockdown orders on the spatial distribution of commercial burglary using Andresen's SPPT for San Francisco.

Results from both the quadrat and SPPT analyses indicated a spatial shift in commercial burglary in San Francisco. In the pre-COVID-19 period, commercial burglary clustered in grid cells around the central business district, specifically Union Square. However, these grid cells experienced a substantial decrease in both the density and proportion of commercial burglary. In San Francisco, the grid cell with the most crime in the pre-COVID-19 period experienced the greatest proportional decrease in commercial burglary, an important finding considering crime clustering has been found to be stable over the long term (Curman et al., 2015; Weisburd et al., 2004; Wheeler et al., 2016).

This dispersion in commercial burglary hotspots may be a result of improvements in security and increased police presence, combined with reduced traffic of motivated offenders. As the businesses were forced to close after the stay-at-home orders were put into effect in mid-March in San Francisco, owners of many department stores and shops increased security by boarding up their storefronts (Matier, 2020). This security measure may have reduced offending opportunities by increasing the efforts and the risks associated with committing commercial burglary. Also, the San Francisco Police Department allocated more patrol resources in Union Square to prevent potential crime in the post-COVID-19 period (Matier, 2020). As police officers were able to supervise these areas more frequently, decreases in commercial burglaries were expected.

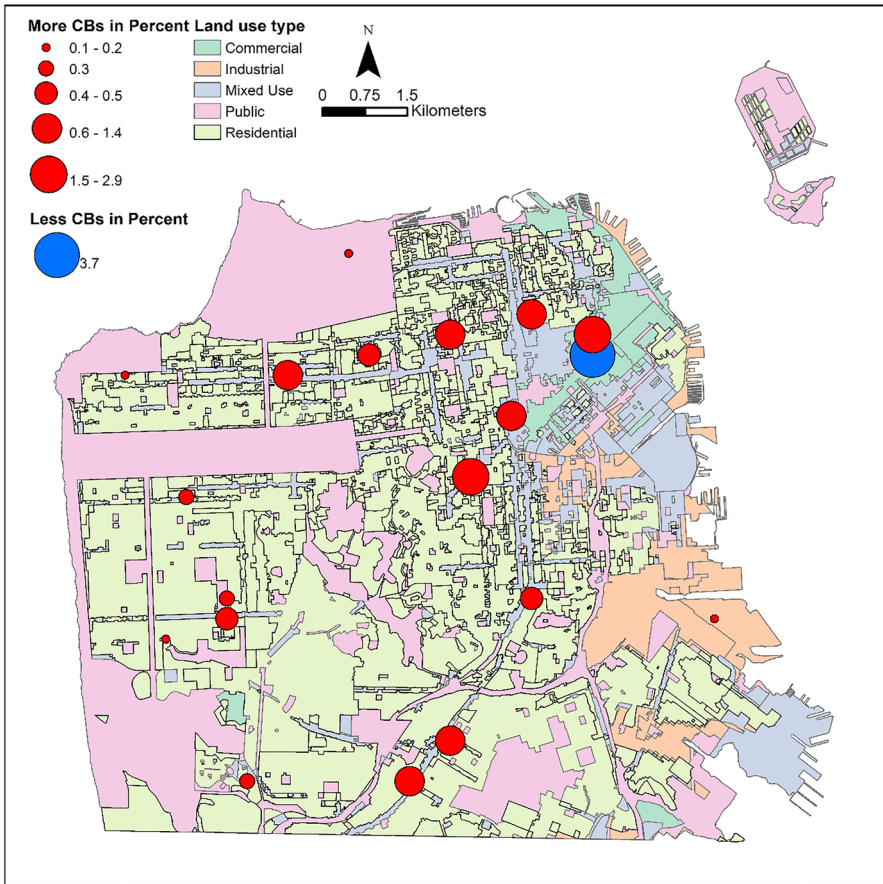


Fig. 6 Land use and SPPT output

Another finding is that commercial burglary spread out across San Francisco, indicating that stay-at-home orders and the like impacted not just crime levels but also long-term crime clusters. Grid cells close to hot spot locations experienced a substantial increase in the proportion of commercial burglary. Even the grid cells that are distant from hot spot areas and were not originally considered high crime places experienced a significant proportional increase in commercial burglary. This spatial shift in the crime distribution may be related to the type of land use in these grid cells. Figure 6 displays the land use with grid cells from the spatial point pattern analysis superimposed. These results show that most grid cells with substantial proportional change are located in mixed residential and commercial areas. Mixed land use areas may have a higher risk of commercial burglary because employees and customers were no longer present to act as capable guardians as businesses were forced to be closed during the lockdown periods (Felson et al., 2020). Also, as there are fewer residential units in mixed land-use areas compared to those in residential



zones, areas with mixed land use lacked the guardianship supplied in residential and business districts and commercial burglary targets became more convenient and available for break-ins (Felson et al., 2020).

Thus, this study finds evidence to suggest substantive shifts in the relative spatial distribution of commercial burglary in San Francisco in response to COVID-19 regulations in a way that a routine activity perspective predicts. Unlike shooting violence in Buffalo, which did not spatially shift even after COVID-19 lockdown orders were put in place (Drake et al., 2022), hot spots of commercial burglary in San Francisco were dispersed to mixed residential and commercial land use areas in the city. The present study suggests that not only do the spatial findings indicate the utility of the routine activity framework in understanding spatial changes in crime post-COVID-19 lockdown orders, but they also emphasize the importance of crime-specific analyses.

In terms of practical policy considerations, the shift in the spatial concentration of commercial burglary in San Francisco implies that it would behoove police departments to regularly monitor spatial patterns and adjust their resources accordingly during the pandemic. Given that one of the most popular interventions to reduce crime to date is hot spots policing (Braga et al., 2019), a hot spots intervention needs to be expanded to areas identified as new hot spots to generate a significant overall reduction in commercial burglary in San Francisco. Likewise, as residential burglary concentrations “cool off,” police departments may be able to shift those resources around to protect commercial burglary concentrations that are “heating up.”

### Limitations and future research

Our work has some limitations worth noting. First, while this is useful to understand the citywide spatial dynamics of crime during the pandemic, this study has the limited ability to uncover causal reasons as to why spatial concentrations have shifted. We have claimed that changes in routine activities of people and police action and land use differences in areas are a possible explanation; however, the current study does not include measures of offender or guardian movement, making any attribution of spatial crime changes post-COVID-19 due to changed routine activities tentative. Additionally, we were unable to incorporate measures for social structural characteristics, and population density, which may be important factors in determining criminal opportunities.

Second, hot spots research has been able to employ more granular address information than the current study (Sherman et al., 1989; Weisburd et al., 2004). For the current study, each crime incident has no specific address for confidentiality because the data is publicly available and is instead geocoded to the nearest street intersection. There could potentially be changes in the assigned quadrant should crimes have been geocoded to specific addresses.

Third, the current study has a specific and narrowed focus on one sub-category of burglary in San Francisco. In another study, shootings were demonstrated to not shift spatially in Buffalo, NY, which raises further questions as to the crimes that experienced dispersion or changes in hot spots during COVID-19 regulations (Drake

et al., 2022). Furthermore, our findings may not be applicable to all cities, as the intensity and duration of lockdown periods varied across the USA, and they may not apply equally across crime types. To address this concern, future research should seek to replicate our approach with various crime types in different jurisdictions throughout the USA.

To date, few studies have monitored the effects of re-opening cities and scaling back social distancing guidelines on crime. It is important to track changes to spatial crime patterns as places re-open to see if crime shifts back to pre-pandemic concentrations, similar to how some work has followed temporal crime patterns during city re-openings (Riddell et al., 2022). It is still unknown when or if crime will return to places that it left during the pandemic, or if the lingering effects of the pandemic on routine activities has shaped unique spatial crime distributions moving forward.

Furthermore, it may be worth investigating if the temporal dynamics of hotspots changed. As Ratcliffe (2004) discusses, hotspots have temporal characteristics as they can heat up or cool off during different times. Should hot spots remain stable during lockdown periods, there is still the potential for heating and cooling times to change, which is of importance to police departments and their resource distribution. There have been many changes to daily routines, and adapting and responding to those changes will be an important challenge faced by practitioners as cities throughout the USA continue to transition through various COVID-19-related restrictions.

## Conclusion

The current study examined the impact of COVID-19 lockdown orders on the spatial distribution of commercial burglary in San Francisco. Findings demonstrated that hot spots of commercial burglary dispersed and spatial crime patterns, while not homogenous, shifted to mixed residential and commercial land use areas instead of clustering in commercial only places. The general findings are consistent with what would be expected if the spatial shift in commercial burglary occurred due to changes in routine activities in San Francisco. We conjecture that specific aspects of spatial variation in commercial burglary are due to the following factors: improved security measures and increased police presence in traditional hot spot locations plus the absence of employees and customers in mixed land-use areas following the emergence of stay-at-home orders. Our work adds to the growing knowledge on the effects of COVID-19 regulations on the spatial dynamics of crime by focusing on its impact on the spatial distribution of commercial burglary in San Francisco, and this study can inform responses to these changes as cities seek to control crime.

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