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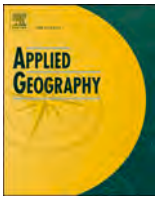

Crime deterrent effect of police stations☆

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ABSTRACT

This paper discusses the empirical strategy used to test which approximation to journey-to-crime theory is more appropriate for modelling the crime deterrent effect of police stations. Using crime spatial analysis, this paper tests whether monotonic criminal distance decay from police stations or a buffer zone in the vicinity of police stations is the most appropriate way to model criminal behavior. The aim of the paper is to detect fixed patterns of spatial distribution of crime in relation to the location of police stations, independent of other variables. A new high-frequency daily dataset of the years 2016, 2017, 2018 and 2019 with reported property crimes (robbery, theft, car robbery and theft) and personal crime (homicide) in the City of Buenos Aires, is used to model the paper's findings. The authors found empirical evidence of a non-random spatial concentration for all crimes. It was also found that the commission of crimes increases exponentially as the distance from the nearest police station increases, until reaching an interval of 500–600 m, at which point, it begins to descend once again. Evidence seems to show that police stations have a deterrent effect on crime.

1. Introduction

Modelling criminal location choice is fundamental for researchers and practitioners. Understandably, then, one of the most developed areas of research in recent years (other than offender/victims-based characteristics) to explain the spatial distribution of crime, is precisely, the geography of offenders. The majority of studies attempt to model journey-to-crime based on the hypothesis that either a) there is monotonic criminal distance decay from offenders' homes, similar to that of the majority of human mobility (for example, the study by Gimpel et al., 2008; on voting patterns), or b) there is a buffer zone near offenders' homes with significantly reduced criminality (O'Leary, 2011). Both hypotheses have implications for theories explaining criminal behavior (Rengert, Piquero, & Jones, 1999). However, studies attempting to prove the existence of a buffer zone, have had mixed empirical findings. For example, the recent literature review by Bernasco and van Dijke (2020) identifies 108 studies on the relationship between the frequency of crime and offenders' homes, of which, only 33 provide solid evidence for the existence of a buffer zone, while the remaining 75 have contrary evidence.

While studies of journey-to-crime use offenders' homes as the point of reference in seeking to understand the distance covered by an offender in order to commit a crime, the study of the distance-decay function can also be useful to look at other spatial patterns of criminal activity, for example, by using a deterrent location as the point of departure – such as police stations. This would determine whether a buffer zone exists around police stations (such as that around offenders' homes), or whether there is a monotonic increase in distance regarding police stations. By definition, the logic of criminal causality is similar (although inverted in relation to offenders' homes): if a rational choice or routine activities theory is adopted, a potential offender will choose the furthest point from a police station to commit a crime, without entering the radius of operations of the next closest police station (Groff, 2007). Following this logic, the majority of property crimes, at least

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those committed in the street, should occur equidistant from neighboring or nearby police stations in a determined area. These same theories can explain the buffer zone hypothesis as offenders could choose to commit crimes away from police stations as offending near them substantially increases the possibility of apprehension. Thus, just as policing has a deterrent effect on crime within a determined space, so too should police stations have a permanent effect on the decision-making process of offenders. In short, the question regarding the presence of a spatial pattern related to a distance decay/rise or buffer zone, remains the same.

This paper discusses the spatial analysis of criminal distance decay for specific crimes (crimes against persons, such as homicides, and crimes against property, such as robbery and theft), using police stations as reference points (that is, the effect of the spatial location of police stations and not the deterrent effect of patrolling). The key research question is whether there is monotonic criminal distance decay from police stations or a buffer zone of reduced criminality around the police station. This distance decay could potentially be linked to the area which criminals assume is patrolled by a certain police station. In order to do this, the locations of police stations in Buenos Aires (Argentina) from 2016 to 2019 were used. Property crimes were selected (car theft, car robbery, robbery, and theft) as it is assumed that they are crimes involving a certain rational calculation by the offender in order to avoid arrest. The opportunity-of-crime literature argues that the situational context is fundamental for theft and burglary (Clarke, 2012) and thus the location of police stations may provide opportunities for property crimes due to an increase or decrease in police presence. Proximity to a police station "represents a parameter for the expected value of getting caught and changes the expected benefits of crime" (Blesse & Diegmann, 2018, p. 2). A violent crime, unassociated to property crimes, was included (homicide) in order to control for whether the decay or buffer zone occurs only with crimes where there may be a greater possibility of rational calculation.

Causal inference calculations for deterrence are difficult as crime distribution may be affected by police station patrolling. In this sense, police stations have districts in which response times to citizen calls, possibilities for apprehending offenders, identifying and locating witnesses, gathering physical evidence and providing lifesaving first aid are determined (Cordner & Scarborough, 2010; Simpson & Hancock, 2009).

The overall aim of this article is to detect fixed patterns of spatial distribution of these crimes in relation to the location of police stations, independent of other variables (such as patrolling, socio-demographic factors, etc.); that is, that these crimes are repeated in such a way that their mean can only be explained by their distance from the police station (and not, for example, by local income inequalities or differences – Stucky et al., 2016). Our results indicate the existence of a buffer zone, not of low criminality, but rather of a greater incidence of crime midway between neighboring police stations. The commission of homicides, car theft and robbery is maximized in the buffer zone between the nearest two police stations, while 21% of thefts occur within a 400–600 m radius of the nearest police station, and car robbery is concentrated 800–900 m from the closet station (although frequencies in the buffer zones are similar).

The significance of our findings is that they develop a framework and establish some baselines for further analyses in cities outside the English speaking world. Furthermore, the practical significance is these findings can help police forces and international funding agencies in implementing intelligence-led policing and CCTV location strategies. Finally, the academic significance of this study is that it opens up for an evidence-based discussion on where and how locate police stations and why.

2. Literature review

This paper is positioned between two bodies of literature: criminal distance decay/buffer zones and police deterrence (which includes CCTV and police resource allocation). While offenders choose targets, rather than distance (O'Leary, 2011: 162), this decision is conditional on the existence or proximity of capable guardians. The distance decay/-buffer hypothesis enjoys much empirical support (Bernasco et al., 2013; Gill et al., 2019; Hammond & Youngs, 2011; Levine & Lee, 2013; Santtila et al., 2007; Rossmo, 2000; Vilalta, 2010). The hypothesis that the frequency of crime decreases monotonically as the offender is further from their place of residence is generally explained by the principle of least effort. This means that distance may be one of the decisive criteria in offenders' decision-making processes (Bernasco & Block, 2009).

On the other hand, some studies on criminal distance decay argue that offenders try not to commit crimes close to their homes, for fear of being recognized. In the first studies on the issue in 1969, Turner found an area of reduced criminality close to juvenile offenders' homes. The buffer zone hypothesis proposes that there is no distance decay pattern from an offender's home, but rather, an area around their homes in which they avoid committing crimes (with monotonic distance decay beginning after this buffer zone). Indeed, in a series of qualitative interviews, Wright and Decker (1994) registered offenders' concerns of being recognized close to their homes, which would explain the buffer zone. Nevertheless, other studies (O'Leary, 2011; Rengert et al., 1999) have attempted to explain the buffer zone as an increase in criminal opportunities as offenders are further from their homes (the cost of greater effort is compensated by better targets).

Regardless, the distance decay function tends to be the starting point for most approaches to modelling crime locations (Levine, 2009; O'Leary, 2009), as well for developing "geographical profiling systems in order to prioritize areas according to their likelihood of containing an offender's home or base" (Hammond, 2011: 92), although different functions describe patterns of spatial distribution of crime - offending decay as distance from home increases (Canter and Hammond, 2006).

The majority of distance-to-crime studies have focused on the function of distance between crime location and offenders' homes (Townsley & Sidebottom, 2010, p. 901), although Wiles and Costello (2000) show that crime trips can originate from different spatial nodes, such as the workplace, a partner's home, shopping areas, etc. It is here that this paper is located: the police station as an awareness space that establishes a spatial pattern of crime (Brantingham and Brantingham, 1981), consistent with the offender's routine activity theory (Cohen & Felson, 1979).

This lends support to the idea that the presence of criminal activity in certain areas depends on a "unique combination of certain factors that make these places opportune or inopportune locations for crime" (Kennedy et al., 2010, p. 341; Mazerolle et al., 2004). A police station is part of this environmental context that contributes to defining an area as opportune, as, if it exerts a deterrent effect, then crime hot spots should be located outside of its operative radius. In fact, the location itself of police stations should be related to the existence of specific hot spots (the furthest possible or equidistant from police stations and as close as possible to suitable targets). This does not refer to "environmental backcloths" (Brantingham & Brantingham, 1995), but rather to a direct predictor of risk, as police stations increase the risk terrain (Caplan et al., 2010; Kennedy et al., 2010) of committing a crime nearby, or substantially alter opportunity structures by increasing the costs involved in the commission of a crime (Groff & La Vigne, 2001). Police stations define what is referred to in cognitive mapping as "risky places" (Zurawski, 2007) for committing crime due to the high possibility of apprehension by police.

Recent studies on police deployment have generally focused on: a) the increase in police presence as a result of terrorist threats (Di Tella & Schargrodsky, 2004), which have been shown to have a crime deterrent effect; b) an increase in patrolling under "normal" conditions (Blanes I Vidal and Mastrobuoni, 2018), which appears to have no effect on crime levels; and c) contrasting irregular patrolling and simple police presence (Weisburd, 2016), with a minimal difference in deterrence effect found between these options. This paper does not attempt to analyze increases

in police presence, but rather, the location of police stations, similar to Di Tella and Schardgrodsky's study of the increase in police deployment relative to a fixed place (Jewish institutions). Police in this case functioned virtually as "sentinels" (Nagin, 2013) with no capacity to move (as their area of actions was restricted to the institutions). Such police allocation replicated small police stations, with notable distance decay. The authors found that car robberies fell by 75% within 1 block of the institutions, with the effect fading notably within a 2 to 3 block radius thereafter.

To a certain degree, the location of police stations has a similar impact as that of CCTV. While a camara is not the same as a police station with the movement of officers and patrols, both have a fixed spatial deterrent effect. For example, Mazerolle et al. (2002, p. 59) "found that surveillance cameras create somewhat of an initial deterrent effect in the month, perhaps two months, following implementation", however this is followed by an adjustment period in which the effect is lost (2002:59). Similarly, Gill and Spriggs, who studied target areas in a 360° circular buffer zone around cameras, found that "crime levels in the target area had fallen below their pre-peak levels, though on the general reducing trend of pre-peak values, whereas in the buffer area and the division as a whole crime levels remained high" (2005: 28). In this study, it was once again confirmed that "crime rose in both the buffer and target areas in the 12 months following the intervention and then fell back to the pre-intervention values" (2005: 31). Many studies have measured the deterrent effect of cameras, such as Farrington et al. (2007) who investigated the direct impact of cameras and that of Squires (2000) who focused on the regional level, such as in "downtown" areas of cities.

Finally, this paper is also related to those investigating the optimal location of police stations. Almost all research on this issue has attempted to develop an optimal model for the allocation of police resources, based on econometric models of police deterrence and crime. The main rationale behind this is that crime can be prevented by the rational distribution of police services in space, according to the number of criminal incidents (Mukhopadhyay et al., 2016). Criminal action and public response go hand in hand in positioning police stations. A well-located police station should have a deterrent effect as well as better response times to police calls. These locations also determine the district/precincts that police stations will be responsible for patrolling, both by car and on foot. This has resulted in police organizations dominated by a management style "oriented by incidents" (Guedes et al., 2014, p. 288). For example, the work of Benson et al. (1998) and more recently that of Galiani et al. (2018), developed a model of optimal allocation for cities based on the concentration of crime in certain areas.

This paper contributes to the literature on distance decay - police deterrence by focusing on an understudied aspect: the existence of criminal distance decay/buffer zones in the distribution of crime as a result of police stations. Results show that the location of police stations appears to contribute to the development of hot spots on the (administrative) borders of the radius of action of police stations, while the finding related to buffer zones allows for a comparison between the fixed effect of police stations and that of CCTV, and facilitates the gathering of necessary evidence on police intervention and resource allocation for the development of public policy (Berk, 2011). The study of criminal distance decay – deterrent effect is crucial for any strategy regarding the allocation of police stations as their installation will cause a fixed redistribution of crime that should be calculated in relation to other already established police stations.

2.1. City of Buenos Aires Police (CBAP) organization[1]

The City of Buenos Aires Police -*Policía de la Ciudad*- (CBAP) is the Buenos Aires local police force and depends both hierarchically and functionally on the Justice and Security Ministry of the City. It combines members of the former Federal Police force deployed in the city with the local Metropolitan Police force. These two organizations were fused in 2015.

The CBAP is organized into police stations (precincts) which, in addition to crime prevention, interact with the neighborhood population, listen to their needs and proposals (simplifying bureaucracy and administrative processes), and provide reliable information for decision making. The main responsibilities of police departments are to maintain peace and order in the city; to protect citizen's physical integrity, rights, and properties; and to prevent crime.

Since 2018 police stations have been organized into two hierarchical groups: communal stations and neighborhood stations. There are currently 15 communal police stations and 28 neighborhood police stations, for a total of 43. The geographical location of each communal and neighborhood police station was determined by the administrative division of the city into 15 communes and their neighborhoods.

Each commune has its own police station, charged with understanding crime in its territory and seeking solutions through its own means and through interaction with outside authorities and organisms.

Each communal police station has two main areas: security and prevention (responsible for planning of prevention operations, executing the prevention, complying with deployment, implementing territorial patrols and responding to neighborhood needs), and investigation (responsible for crime reports and monitoring of all legal proceedings). Nine of the communal police departments have holding cells for suspects and detainees.

The 15 communal police station departments for security and planning are further divided into four directories: north (communal police stations 12, 13, 14 and 15), east (communal police stations 1,2,3 and 5), south (communal police stations 4,8 and 9) and west (communal police stations 6,7,10 and 11). These 15 departments supervise and oversee the services in each station. The investigation department has two directories (north-south) responsible for investigating crime, felonies/violations/minor crimes, and misdemeanors in the City of Buenos Aires. Each directory has its own resources and structures, which are independent of the communes.

Neighborhood police stations, which oversee minor procedures, also receive complaints and questions from the neighboring population, and coordinate police force agents before they are deployed in the territory.

The City of Buenos Aires had a total of approximately 25,200 police, of which 18,100 were on the street and 7100 in dependencies. Of the 18,100, 72% (13,200) were deployed according to crime analysis tactics. The remaining 26% (5000) were assigned specific duties, such as transferring prisoners, providing private security services, special police force duties (DOU), etc.

3. Data and methods

The data used in this study correspond to Buenos Aires city for 2020. They were taken from public sources published on the open government site, "Buenos Aires Data". The information portal depends on the Executive branch of Buenos Aires City, and draws on information provided by the Ministry of Justice and Security. The same information is available for consultation in the "Crime map"[2] of the city. Crimes analyzed

[1] This section was based on the Institutional Manual of the Human Capital Deputy-Secretary of the Ministry of Justice and Security of the City of Buenos Aires and the City of Buenos Aires Police webpage.

[2] The data is public, collated by the police and based on crime reports. Available at the following link: https://mapa.seguridadciudad.gob.ar/.

included robbery, theft, car robbery and theft, and homicides. These crimes account for approximately 60% of the total reported crimes, as some were not available and others were impossible to geo-reference (such as fraud or crimes against public administration, etc.).

We began with a mapping and spatial analysis of crimes. Crimes (points) registered from 2016 to 2019 were first geo-referenced onto the urban layout of the Autonomous City of Buenos Aires (BA), using the X–Y coordinate associated with the police report. The city of BA was then sectioned into 500 m diameter hexagons (approximately 2.2 km^2 surface area) in order to aggregate the crimes. This was decided due to the limited spatial variance in the occurrence of crime from 2016 to 2019 at the commune and neighborhood level (see Fig. 1).

In the second stage, in which the spatial analysis was conducted, data was processed using the Geographic Information System. The methodology followed various steps. Police stations (units of police vigilance) -points- in BA were incorporated with the already geo-referenced crimes, giving rise to the construction of 100 m coverage areas (polygons) up to 1 km (Fig. 2) (Fig. 3).

Finally, in order to statistically support the deterrent effect of the location of police stations for each type of crime, and whether the effect is different according to the crime, a chi-squared (x^2) test was conducted. This is used to contrast hypotheses based on the distribution of frequencies. In this case, the distribution of crime incidents across 100 m radii from the nearest police station, was analyzed. The decision to use 100 m radii was based on three factors: 1) it corresponds to the size of a "standard" block in Buenos Aires; 2) the availability of georeferenced locations of crimes (x.y coordinates); and 3) the scale of the area of study. Given that crime in Buenos Aires was analyzed, and police stations are responsible for covering specific neighborhoods, the (common) crimes under examination occurred on a neighborhood scale and within walking distances. For example, studies on mobility and insecurity have concluded that crime is a serious problem in walkable residential areas with insufficent street lighting (Pain et al., 2006) (see Fig. 4).

The following section shows the results of the geographic patterns of each crime in relation to the location of police stations (Table 1).

4. Results

4.1. Spatial descriptive statistics

Table 2 shows the set of spatial descriptive statistics which provided an initial understanding of the spatial patterns of crime incident distribution and police stations in Buenos Aires from 2016 to 2019. Notable differences can be seen in the geographic patterns of each crime and their relation to the location of police stations.

In the first instance, the average density per square kilometer refers to the number of crime incidents per square kilometer in the city. Obviously, this is a function of the number of crimes and the area of the zone under study. This is not a measure of geographic concentration, but rather of geographic intensity – the greater the average density, the greater the intensity or criminal activity in the area under study. In this case, the greatest geographic intensity corresponded to robbery, with 280.4 incidents per square kilometer. On the other end of the spectrum, homicide showed a geographic intensity of a thousandth per square kilometer – that is, from a strictly geographical perspective, homicide has a far lower probability of occurrence than robbery.

The standard distance, a comparative measure of dispersion between different types of crime incidents, indicates that 75% of crime incidents occur in an area double the size of the standard distance. In this case, around 75% of homicides are committed within an area of 10.8 km (i.e. 5389*2), while 75% of robberies are committed within a 10.1-km area. Homicides are the least frequent crimes and the most geographically dispersed, however, it is worth noting that differences between the various crimes are not that significant.

The average distance between the closest neighboring incidents shows that robbery and theft occur closest geographically. The former has an average occurrence distance of 5.7 m between each and the latter has a distance of 6.2 m - that is, both have a high intensity and geographical concentration in the city. Conversely, on average, there is the greatest distance between incidents of homicide, with an average of 218 m. This highlights the difficulty in preventing such a crime with a police deployment strategy, given the limitations on resources to patrol an extensive geographic area.

The Nearest Neighbor Index (NNI) is an inferential tool of geographic concentration of crime. It is obtained by dividing the Mean Nearest Neighbor by the Expected Nearest Neighbor. For all crimes, the indices are less than 1.0, indicating that their incidence is geographically concentrated.[3] All indices are statistically significant and indicate a non-random spatial concentration for all crimes, with robbery showing the greatest concentration and homicide the least, although only marginally above auto robbery and theft.

Regarding police stations, Buenos Aires had a total of 54 stations during the period under study, which, as indicated in the NNI, do not show a geographic pattern of concentration or dispersion. The average distance between two station was 1.091 km, and thus the mapping in the previous section, as well as the analysis below, was undertaken with a radius of not more than a lineal kilometer and in 100 m intervals. This allowed for the distance decay analysis tests of the following section.

These descriptive statistics show that all crimes have non-random spatial patterns of geographic concentration in Buenos Aires, while police stations show a random pattern. This suggests that while the location of police stations is not spatially dependent, the incidence of crime is. The stations under study were established following a 2018 reform, when the Minister of Security and Justice instructed the Police Chief to accommodate police districts and stations into the communal system. This was subsequently done through Resolution759,[4] which reordered districts to match the administrative boundaries of the city's communes and neighborhoods. Thus, we can confirm that the commission of crimes had a geographic logic. In the following section we analyze the spatial relationship between the location of police stations and crime incidence. We prove the buffer zone hypothesis, which proposes that there are areas of reduced criminal activity due to the fear of being recognized by acquaintances (Bernasco & Van Dijke, 2020, buffer home area) or, as we have argued, for fear of detention by the police.

4.2. Distance decay analysis and the buffer zone hypothesis

In the following section, we analyze whether distance to police stations is related to crime incidence. Specifically, we seek to prove the hypothesis that proximity to the station reduces crime incidence and argue that the main reason for this is the increased perception of risk of detention by potential offenders. This means that areas close to the station have less criminal risk, that is, they are safer areas for citizens. Our findings seem to support this hypothesis for the different types of crimes analyzed in this study.

In order to test the "safe buffer zone" hypothesis, we divided the space around the stations into 10 concentric intervals of 100 m and an 11th interval of just over a kilometer. We analyzed the distribution of crime incidents within the 1-km interval around each station, as our prior analysis had demonstrated that the average distance between two police stations was exactly 1.035 km. It would be expected that within this buffer, the deterrent effect of one police station would be the same as that of the closest neighboring station. Based on this, we estimated the number of crime incidents in each buffer zone and tested whether or not the distribution was statistically random.

Tables 3 and 4 below show the distribution and the percentage

[3] A random geographic distribution would result when the mean observed distance from the closest incident and the mean expected distance from the closest incident are equal, that is, when the index was equal to 1.0.

[4] https://boletinoficial.buenosaires.gob.ar/normativaba/norma/419263.

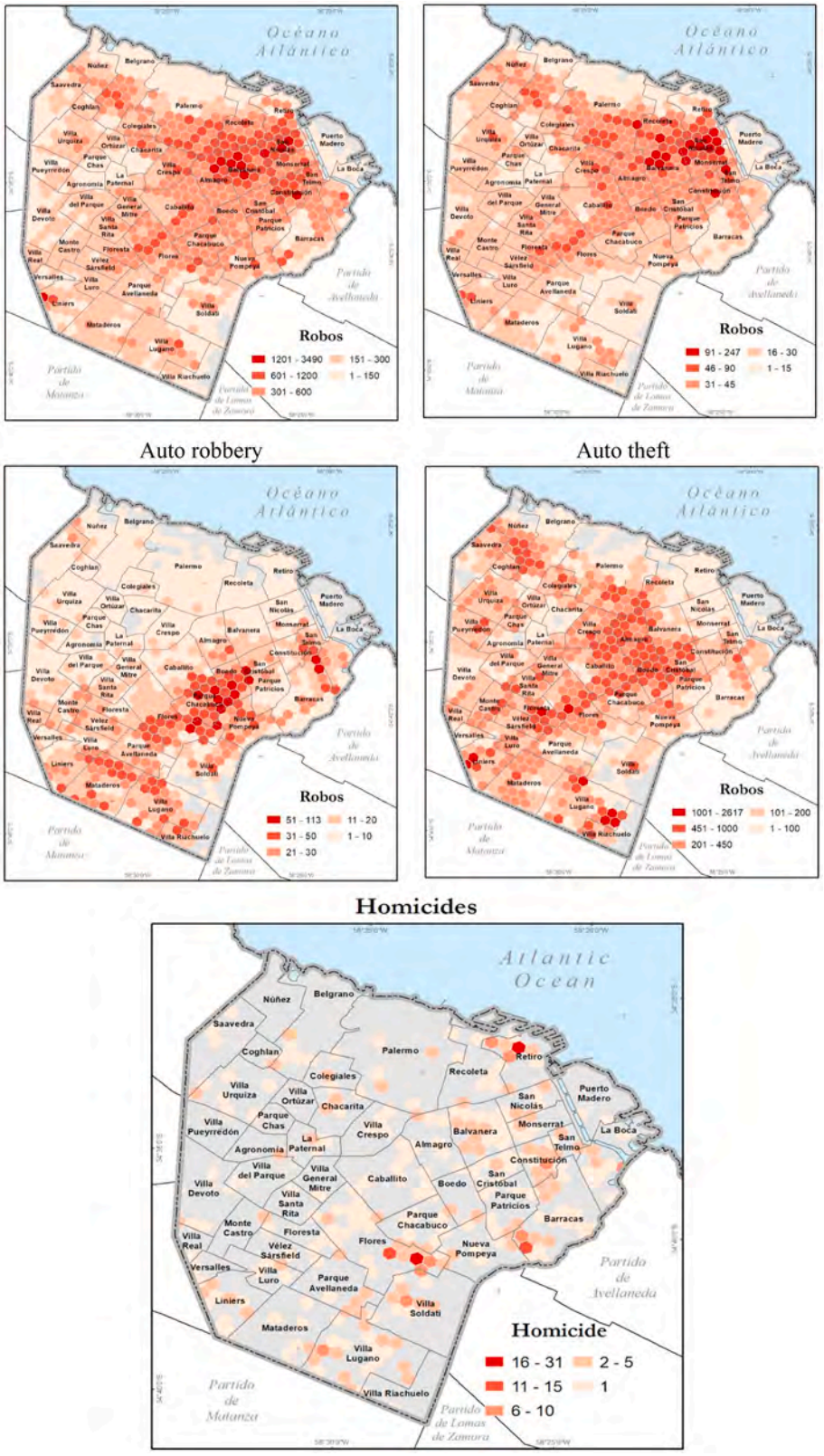

Fig. 1. | Buenos Aires: Crime distribution by type 2016–2019 (aggregated).

cumulative distribution, respectively, of crime incidents by type of crime, in the buffer zone of the closet police station. Our hypothesis predicts that if the presence of a police station had a deterrent effect on crime activity due to its location, creating low criminal risk buffer zones, then a lower crime frequency could be expected within radii closer to police stations. Indeed, data show a pattern of lower frequency of crime around police stations, which increases progressively as the distance from the station increases, but only until a certain point. For example, the proportion of homicides close to police stations is low, and gradually increases as the distance increases, until a buffer point of 600 m, at

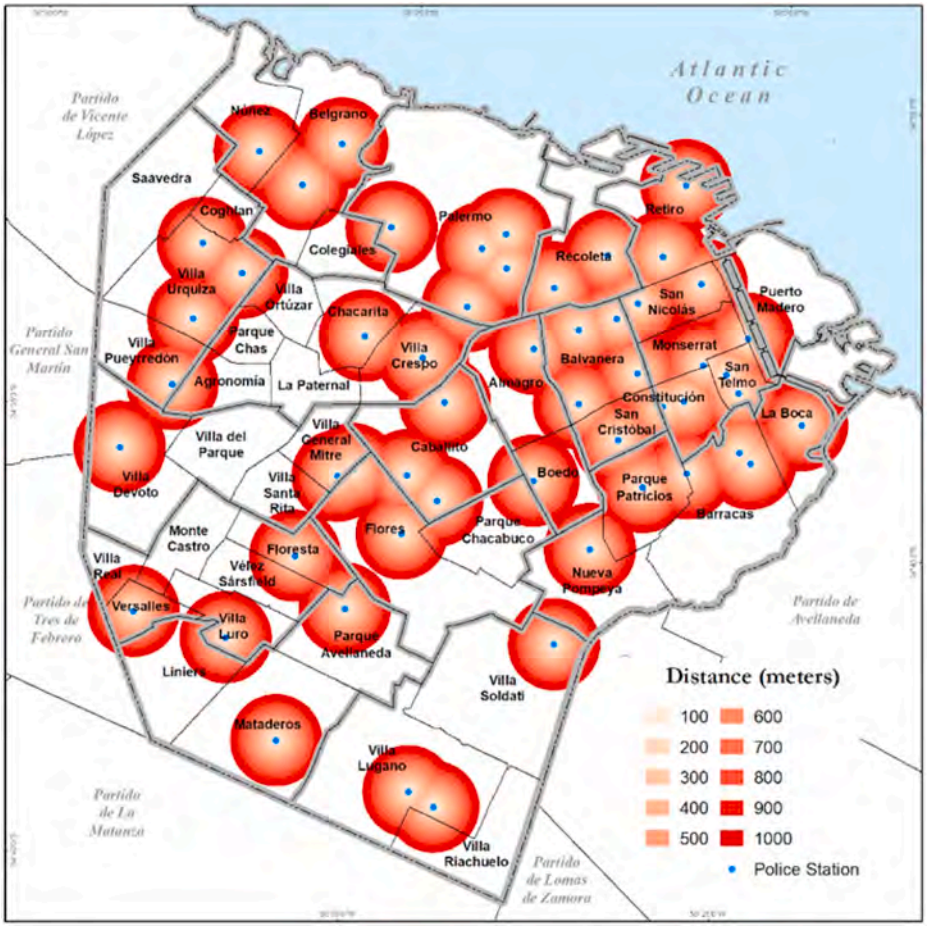

Fig. 2. | Buenos Aires: location of police stations and outline of coverage areas.

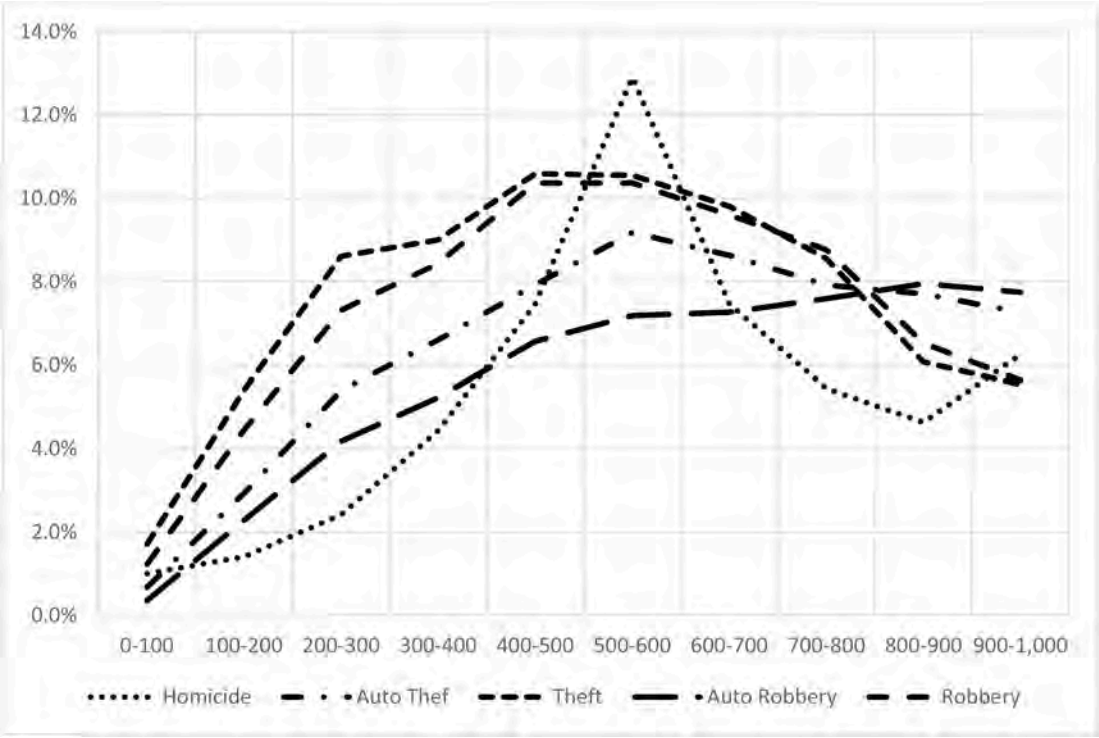

Fig. 3. Distribution of crime incidents per buffer zone distance to nearest police station (distance in meters).

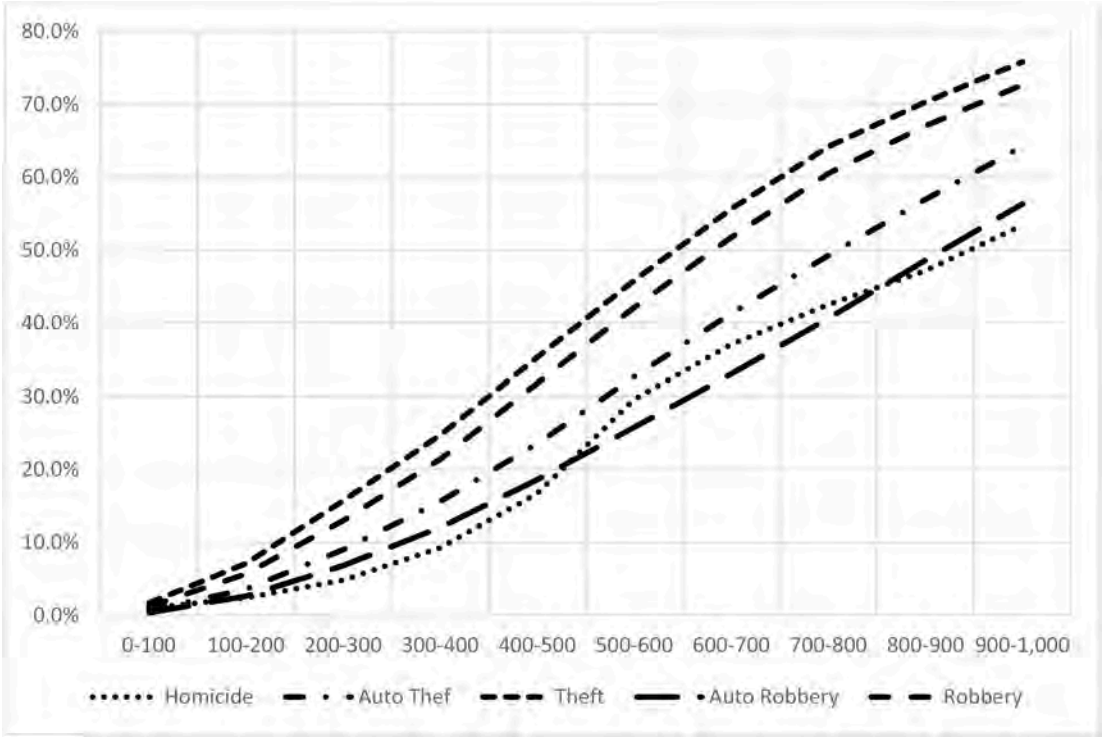

Fig. 4. Cumulative distribution of crime incidents per buffer zone distance to nearest police station (distance in meters).

Table 1
| Buenos Aires: evolution of crime by type, 2016–2019.

Type of crime	2014[a]	2015[a]	2016	2017	2018	2019	Total[b]
	Absolute						
Robbery	75,299	65,819	70,963	66,601	69,279	62,649	269,492
Theft	48,851	43,933	46,070	42,050	40,941	49,163	178,224
Auto robbery	3669	2926	3452	3477	2705	1423	11,057
Auto theft	7441	6462	6125	5952	5719	4649	22,445
Homicides	185**	155**	145	134	124	93	496
Percentaje							
Robbery	–	–	26.3%	24.7%	25.7%	23.2%	100.0%
Theft	–	–	25.8%	23.6%	23.0%	27.6%	100.0%
Auto robbery	–	–	31.2%	31.4%	24.5%	12.9%	100.0%
Auto theft	–	–	27.3%	26.5%	25.5%	20.7%	100.0%
Homicides	–	–	29.2%	27.0%	25.0%	18.8%	100.0%

[a] As we used geocoded data for our statistical test, data for the years 2014–2015 is of no use for calculations (as it is aggregated at a city level, with no possibility of imputation to any specific address). Nevertheless, we built the time series between 2014 and 2019 to provide a framework for the reader. We used the data from the Buenos Aires Autonomous City Ministry of Justice and Security 2020 report on crimes to cover the 2014–2015 period and the map data for the 2016–2019 period. We only have geocoded data for the years 2016–2019 while the data for 2014 and 2015 is aggregated at a city level. We use the report to complete the time series for data for consistency purposes, as is the same authority in charge of the primary data of the map. We are using the "point of fact" information (hecho) not the number of victims (there could be more than one victim for each "point of fact"), as the primary geocoded dataset records this kind of information. This technicality is especially important for homicides and mainly in the years 2014 and 2015 (**), where data was collected from a different source.

[b] Total colum only contemplates 2016/2019 data which was used in the calculations.

Table 2
Spatial descriptive statistics.

	Homicides	Auto theft	Theft	Auto robbery	Robbery	Police stations
Average density (km2)	0.001	2.1	197.1	0.523	280.4	0.00009
Min. Distance	0.0	0.0	0.0	0.0	0.0	326.7
Max. distance	17,151	18,425	20,866	18,801	19,491	15,049
Standard distance	5389.3	5243.9	5121.3	5115.4	5071.3	5130.7
Mean nearest neighbor	217.8	31.7	6.2	46.9	5.7	1091
Exp. nearest neighbor	380.8	58.8	17.1	83.1	17.7	1007
Nearest neighbor Index (NNI)	0.572***	0.539***	0.361***	0.564***	0.295***	1.083
Total incidents	496	22,445	178,224	11,057	269,492	54

***$p < 0.01$, **$p < 0.05$.
Note: Distance in meters.

Table 3
Distribution of crime incidents per buffer zone distance to nearest police station.

Radius	Homicides	Auto theft	Theft	Auto robbery	Robbery
0–100	1.0%	0.7%	1.7%	0.4%	1.2%
100–200	1.4%	2.9%	5.4%	2.3%	4.5%
200–300	2.4%	5.4%	8.6%	4.2%	7.3%
300–400	4.4%	6.6%	9.0%	5.2%	8.4%
400–500	7.5%	7.9%	**10.6%**	6.6%	10.36%
500–600	**12.9%**	**9.2%**	10.5%	7.2%	**10.37%**
600–700	7.5%	8.6%	9.8%	7.3%	9.6%
700–800	5.4%	7.9%	8.6%	7.6%	8.8%
800–900	4.6%	7.7%	6.1%	**7.9%**	6.5%
900-1000	6.3%	7.3%	5.5%	7.7%	5.6%
Above 1000	46.6%	35.8%	24.2%	43.7%	27.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
N =	496	22445	178,224	11,057	269,492
Chi-square[a] =	103.1	2288.0	17,007.9	1193.4	28,082.1

***p < 0.01, **p < 0.05.
Note: Distance in meters. Modal values in Bold.
a: The results of the tests are for the distribution of crime incidents under the 1000 m threshold.

Table 4
Cumulative distribution of crime incidents per buffer zone distance to nearest police station.

Radius	Homicides	Auto theft	Theft	Auto robbery	Robbery
0–100	1.0%	0.7%	1.7%	0.4%	1.2%
100–200	2.4%	3.6%	7.1%	2.6%	5.7%
200–300	4.8%	9.0%	15.7%	6.8%	13.0%
300–400	9.3%	15.6%	24.7%	12.1%	21.4%
400–500	16.7%	23.5%	35.3%	18.6%	31.8%
500–600	29.6%	32.7%	45.9%	25.8%	42.2%
600–700	37.1%	41.3%	**55.7%**	33.1%	**51.8%**
700–800	42.5%	49.3%	64.2%	40.7%	60.5%
800–900	47.2%	**57.0%**	70.3%	48.6%	67.0%
900-1000	**53.4%**	64.2%	75.8%	**56.3%**	72.7%
Above 1000	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Distances in meters. Median value in Bold.

which point the frequency begins to gradually decrease once again. This was also true of the other crimes. The results of the chi-squared test applied to the distribution of crime incidence registered under the 1000 m limit, show that these incidence frequencies are significantly different to those that would be expected from a uniform distribution – that is, statistically significant differences were found between the number of incidents in each distance interval to the nearest police station.

These data suggest that the presence of police stations impact the commission of crimes. Considering that stations have an average distance of 1.035 km between them, it is noteworthy that the buffers with the highest crime incidence can be found in the midpoint between neighboring police stations. That is, it appears that the commission of homicides, auto theft and robbery are highest in the buffer zone midway between neighboring police stations. A similar effect could be seen with theft, with 21% of incidents occurring within a radius of 400–600 m from the nearest police station. Similarly, the majority of auto robberies occur between 800 and 900 m from the nearest police station – although the frequencies within the surrounding buffer zones are almost the same.

From another point of view, the cumulative distribution below (Table 4) shows that while half of thefts and robberies took place within a radius of not more than 700 m from the nearest police station, 50% of homicides and auto robberies were committed in a radius of less than 900 m. This appears to indicate that the deterrent effect of police stations on homicide and auto robbery is greater than their effect on theft, robbery, and auto theft.

Graphs 3 and 4 below show more clearly the relationship between distance from the nearest police station and crime frequency. Graph 3 presents the crime incidence data per distance interval, whereas Graph 4 presents the cumulative frequencies. It is interesting to observe how the commission of crimes increases exponentially as the distance from the nearest police station increases, but, as has been mentioned, this occurs until the 500–600 m interval, at which point it begins to decrease. This initially exponential behavior or accelerated increase in homicides until the buffer zone of maximum incidence, contrasts with the other crimes, which show an initial logarithmic increase, that is, increasing to a lesser degree until reaching its greatest incidence tangent or buffer zone, following which, the frequency begins to decrease. It is possible that the low volume of homicides in comparison with other crimes could explain this difference.

From this analysis, it can be inferred that shorter distances from police stations reduce the incidence of crime, thus creating spaces of less risk. This effect is observed until a certain point or buffer of influence of each station and varies by the type of crime. Nevertheless, the observed effect appears to remain: the closer to a police station, the lower the crime frequency.

5. Discussion

It has been argued that crime trips can begin from different spatial nodes (Wiles & Costello, 2000) and that police stations are particular deterrence points around which inevitable spatial patterns of crime are formed (Brantingham and Brantingham, 1981). In effect, results of our case study in Buenos Aires, Argentina, show a pattern of few crime incidents around police stations, increasing in frequency until a certain point when they begin to decrease once again. Contrary to that proposed by the criminal distance decay pattern (Bernasco et al., 2013; Gill et al., 2019; Hammond & Youngs, 2011; Levine & Lee, 2013; Santtila et al., 2007), an increase in crime incidents after the initial buffer of low crime incidence was observed (O'Leary, 2011; Rengert et al., 1999; Rossmo, 2000). Specifically, in this study we found that crime incidence increases progressively by 100-m intervals around each police station, until reaching its peak at the 500-600-m interval, following which, it begins to gradually decrease once again. The 500-600-m breaking point in the distribution of incidents is exactly halfway between the average of 1.035 m between neighboring police stations in Buenos Aires. That is, we found that distance to stations appears to determine the geographical distribution of incidents as predicted by the offenders' decision-making process (Bernasco & Block, 2009). This distribution is not random for any crime and provides initial and tentative proof of a rational decision in the commission of a crime as a function of the distance from stations.

In this sense, our findings seem to indicate that police stations have a deterrent effect on the crimes under analysis. According to RAT, or opportunity theories, this could be explained by a decreased perceived risk of sanctions at greater distances. Our results suggest that offenders maximize the commission of homicides, auto theft and robbery in the buffer zone midway between police stations. This is also true for the other crimes. This paper thus expands the literature on journey to crime, by analyzing an understudied spatial node of activity: the police station. The findings show a zone of limited criminality and a pattern of increasing crime until the buffer of maximum crime concentration midway between the locations of police stations.

Deterrence by police stations relates to the increase in probability of apprehension, which, according to Nagin, is a "more effective deterrent" (2013: 199). Part of the literature focuses on measuring this deterrence using official statistics of detention percentages, resolved cases or offenders' own perspectives of risk (Apel, 2013; Anwar & Loughran, 2011; Wright, 2004), neglecting the sentinel role of the permanent effect of police stations on criminal opportunity structures on a micro-location level – meters – (Cornish & Clarke, 2008). The findings of this work contribute to this analysis in two ways: a) the spatial concentration of certain criminal behavior can be explained by the location of police stations, and b) at the same time, this location could be related to the presence of hotpots. Further research should analyze the distance

between hotspots and police stations to verify whether the location of police stations is related to that of hot spots. This is an important research question for this type of spatial crime analysis.

These data contribute novel information to a variety of discussions. First, if police stations are related to the formation of hot spots, their location should be included as an important factor when establishing patrolling for hot spots (Berk, 2011), together with other considerations of a spatial (businesses, poorly guarded corners, abandoned buildings, lighting, deserted streets), sociodemographic (economic and educational level), or social disorder nature (public drinking, prostitution, street gangs, etc.). The study of the relationship between the hotspots and police station locations could be extremely valuable, both theoretically as well as for crime prevention policy.

Considerations of the distance between police stations would also be useful for optimal police resource allocation (Fegley and Growette Bostaph, 2018), as, for example, if certain crimes, such as property crimes, are committed in the administrative limit of the radius of action of police stations and the distance to this limit is great, the response time to a police call is likely to increase. Literature on police districting has advanced significantly by including new variables for analysis, such as the recent incorporation of the analysis of neural networks for computing incidents and predictive models (Corcoran et al., 2003). This will further the understanding of the opportunity structure of crime (unless the limit is somehow included in some form of patrolling). Any management style "oriented by incidents" should take into consideration that the location of police stations has fixed effects on incidents: a growth curve from 100 to 500–600 m (Guedes et al., 2014).

Finally, discussions on the location of CCTV should also be planned in relation to the deterrence in meters of police stations. Intuitively, the increase in property crime in relation to the fixed point of police stations could perhaps be offset by an adequate design of CCTV installation (King et al., 2008). It would thus be useful to study the effect of the location of public security cameras together with the location of police stations, as it could be expected that their effects would be similar, given that CCTVs are "extensions" of the surveillance capacity of the police.

Future research should also focus on the distance decay/deterrence of other crimes – committed in the street – as well as on modeling variation in the spatial concentration of property crimes, introducing controls to understand other factors that contribute to the deterrent effect of police stations.

6. Conclusion

Several literatures in the last years has been studying how to modelling criminal location choice explaining the spatial distribution of crime thorough the geography of offenders. Also, crime deterrence of police has been long studied, especially patrolling impact on criminal activity. This paper innovates by testing the deterrent effect of police stations in Buenos Aires, understanding that the spatial patterns of criminal activity, can be linked to police activity in general and to the deterrent effect of police stations in particular. Two set of hypotheses are tested regarding crime spatial analysis of the police station effect. On one hand the paper tests whether monotonic criminal distance decay from police stations exits, as distance could potentially be linked to the area which criminals assume is patrolled by a certain police station. On the other, a buffer zone in the vicinity of police stations is the second way to model criminal behavior, as a greater incidence of crime midway between neighboring police stations seems to be an appropriate idea to model criminal location of choice. Causal inference calculations for deterrence are difficult as crime distribution may be affected by police station patrolling and other issues. As a consequence, the aim of the paper is to detect fixed patterns of spatial distribution of crime in relation to the location of police stations, independent of other variables.

Through a new high-frequency daily dataset of reported property crimes and personal crime in the City of Buenos Aires covering a four year period (2016, 2017, 2018 and 2019) the authors found that empirical evidence seems to point out a non-random spatial concentration for all crimes. The main paper findings can be summarized in the idea that the commission of crimes increases exponentially as the distance from the nearest police station increases, until reaching an interval of 500–600 m, at which point, it begins to descend once again. Our results points to the existence of a buffer zone, not of low criminality, but rather of a greater incidence of crime midway between neighboring police stations. The commission of homicides, car theft and robbery is maximized in the buffer zone between the nearest two police stations, while 21% of thefts occur within a 400–600 m radius of the nearest police station, and car robbery is concentrated 800–900 m from the closet station (although frequencies in the buffer zones are similar). Consequently, evidence seems to support the corollary that police stations have a deterrent effect on crime. Buenos Aires registra una población de poco más de 15 millones de habitantes (incluyendo su zona metropolitana), cuenta con una traza urbana de diseño ortogonal y para realizar las labores de combate y contención a la criminalidad, se distribuyen estaciones de policía a lo largo y ancho de la ciudad y la labor se complementa con labores de patrullaje y monitoreo.

There are of course a number of limitations in our research. One is that our analyses did not control for structural covariates and were limited to a short timeframe. Another is that even though los elementos de estructura urbana y problemas de criminalidad en Buenos Aires pueden encontrarse en otras ciudades grandes de la región latinoamericana, still one limitation is the generability of our findings to other urban contexts. One thing is for places to share the same urban characteristics and crime incidences or rates, and another to have the same pattern of correlations across geospatial units of analysis (Vilalta, 2013). The study of criminal distance decay/buffer zones (in relation to police stations) is very important from a public policy point of view, as it can facilitate the design of specific crime prevention and deterrence strategies. If police station allocation influences on the distribution of crime per se, the design of police districts, planning of patrolling activities and routines (both on foot and car/motorcycle), CCTV deployment and even environmental design issues (such as lighting, bus stations, etc.) should take it into account. A holistic approach to citizen security policy would net the effect of the current allocation of police station and those to come, starting with crime prevention through environmental design strategies, such as incorporating high affluent points as bus stations, shops and ATMS within the buffer zone. Consequently, if police stations are related to the formation of hot spots, their location should be included as an important factor when establishing patrolling for hot spots (Berk, 2011) as well as districting characteristics. Any management style "oriented by incidents" should take into consideration that the location of police stations has fixed effects on incidents: a growth curve from 100 to 500–600 m (Guedes et al., 2014). Finally, the allocation of CCTV should also be planned in relation to the deterrence in meters of police stations, taking into account that the increase in property crime is in relation to the fixed point of police stations.

Appendix

Table A1
Count distribution of crime incidents per buffer zone distance to nearest police station

Radius	Homicides	Auto theft	Theft	Auto robbery	robbery
0–100	5	153	3056	40	3323
100–200	7	659	9639	253	12,004
200–300	12	1211	15,335	462	19,705
300–400	22	1481	16,037	578	22,725
400–500	37	1778	18,868	726	27,922
500–600	64	2059	18,797	794	27,935
600–700	37	1937	17,476	803	25,866
700–800	27	1777	15,239	839	23,611
800–900	23	1729	10,823	879	17,572
900-1000	31	1629	9869	856	15,195
Above 1000	231	8032	43,085	4827	73,634
Total	496	22,445	178,224	11,057	269,492

Note: Distance in meters.***Do Offenders avoid offending near Police Stations?***.

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