

Shaking urban crime: Earthquakes, stress and crime in neighbourhoods

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ABSTRACT

Criminology maintains that disasters modify routines and social control in disaster areas, impacting the incidence of crime. However, the spatial concentration of crime in affected areas has been little explored. This study analyses the impact of the earthquakes that occurred on the 7 and 19 September 2017, with magnitudes of 8.2 and 7.1 respectively, on crime patterns in Mexico City. Using geo-spatial techniques (LISA and SPPT), crime data in 1807 neighbourhoods were examined, with particular attention to the 196 areas affected by the collapse of buildings. Results reveal the appearance of new crime hotspots that significantly modified the spatial patterns of sexual abuse, robbery in public transport, and domestic violence, although with no significant effect on rape and death from self-harm. These patterns vary on a spatial level: there is a concentration of interpersonal crimes in the northern neighbourhoods, while domestic violence was concentrated in the south. The study uses General Strain Theory (GST) as a theoretical framework for interpreting the various responses to post-disaster stress based on pre-existing local conditions. By using the location of collapsed buildings as an indirect measure of stress, the study demonstrates the usefulness of GST for understanding crime following earthquakes on a neighbourhood level, and highlights the role of disasters as catalysts for latent criminogenic dynamics. These findings have important implications for the design of targeted public policies and strategies for reducing the risk of victimisation following disasters in urban contexts.

1. Introduction

Disasters cause significant human and economic losses, while simultaneously intensifying social vulnerabilities. On one hand, victims are forced to adopt survival strategies, while on the other, the chaos created by these events can lead to the appearance of anti-social or criminal behaviours. The post-disaster environment can modify individual opportunity costs, incentivising the commission of crimes [1,2]. In addition, deterioration of economic conditions [3,4] or the lack of adequate institutional or police response [5,6] can contribute to an increase in crime. It has also been observed that disasters and other extreme weather events can trigger crimes driven by intense emotions ([7]; Wright & Stewart, 2025). Alternatively, contexts of disasters can also stimulate prosocial or altruistic behaviours [8] and encourage collective action to address the challenges of the post-disaster environment [9]. In fact, disasters can reduce crime by strengthening altruism and social capital [10,11].

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In general, empirical evidence is ambiguous on the relationship between exposure to disasters and crime. Some studies have identified a positive correlation [12,13], while others have noted a negative relationship [4,6,14]. These studies tend to be context specific and have mostly documented experiences in developed countries [3,10,15,16], where institutional structures can partially cushion the effect of these events and interventions tend to be quicker and more comprehensive.

Within the criminological field, a new research line has emerged that focuses on the risk of criminal victimisation following disasters [16,17]. This agenda has explored variations in crime incidence following hurricanes [18,19], flooding [1,20], and earthquakes [11,21–23], among others. In some countries, such as Indonesia and Haiti, the absence of reliable criminal registries in high seismicity areas has complicated the analysis [24,25]. In addition, studies that apply spatial methods to examine the relationship between crime and earthquakes are scarce ([12]; Silverio-Murillo et al., 2025). Despite these limitations, research conducted in Chile, Nepal, and Mexico has identified variations in crime patterns following earthquakes [11,22,23,26].

Such research tends to reference therapeutic community, routine activity, and social disorganisation theory to explain the observed changes. Researchers of the sociology of disasters, based on the hypothesis of therapeutic community, have long argued that disasters tend to reduce criminal activity both during and after the event. Criminologists using the social disorganisation theory maintain that disasters can decrease social control and collective efficacy, increasing crime probability and incidence, while studies based on routine activity theory suggest that disasters can both increase and decrease crime, depending on how criminal opportunities are restructured and the presence of capable guardians. Thus, incorporating other theoretical perspectives and using spatial techniques on a neighbourhood level could reveal previously unidentified crime dynamics, helping to clarify the mixed results that have so far been documented.

Mexico City was chosen as a case study as (1) it is a city with some of the highest seismic activity in Latin America and has a georeferenced criminal registry system that has been used in previous studies on crime and disasters, enabling a high-resolution spatial analysis [11,22,23]. In addition, (2) the September 2017 earthquakes resulted in a concentrated pattern of damage, with 53 collapsed buildings in 196 neighbourhoods, offering a unique opportunity to examine the relationship between the territorial distribution of physical damage and the appearance of crime hotspots [27]. Finally, (3) the city has marked socio-economic and socio-spatial inequalities between the north and south, which determine the way in which different communities respond to stress resulting from disasters, as has been documented in studies on vulnerability, social disorganisation, and territorial inequality [28,29].

This study analyses the spatial concentration of crimes at the neighbourhood level, before and after the earthquakes that occurred in Mexico City in September 2017. These events, measuring magnitudes of 8.2 and 7.1, affected ten states in the country, and had estimated losses of US\$4.875 billion (CONAPRED, 2019). Mexico City was particularly affected: 53 buildings collapsed, resulting in 228 deaths and economic losses in 196 neighbourhoods (CONAPRED, 2019). This research poses the question of whether the increase or decrease in crime is spatially concentrated in the city's neighbourhoods.

Using local spatial association indicators and spatial point pattern tests (LISA and SPPT), significant changes in crime patterns were detected in neighbourhoods affected by the earthquakes. An increase was observed in sexual crimes (sexual abuse and rape), robbery in public transport (metrobus), death from self-harm, and domestic violence. Exploratory Spatial Data Analysis shows a spatial heterogeneity not identified by previous studies: new hotspots in northern neighbourhoods concentrated sexual crimes and robbery in public transport, while hotspots in the south showed increases in deaths from self-harm and domestic violence. A comparison between the 196 affected neighbourhoods and the 1611 unaffected neighbourhoods shows that the spatial modification is greater and significant for sexual abuse, domestic violence, and robbery in the metrobus in affected neighbourhoods, but not significant for rape and death from self-harm, according to the SPPT test (95% confidence level). However, no crime coldspots were found in the affected neighbourhoods nor in adjacent ones, and thus no evidence was found to support theories on prosocial or altruistic behaviours.

General Strain Theory (GST) offers an interpretative framework for making sense of these findings. The intense experience of the earthquake, exposure to collapsed buildings and the recovery of bodies, together with slow reconstruction, constitute visible sources of stress. In the north, this stress can be interpreted as being associated with patterns of aggression towards others, while in the south, people seemed to turn this violence against themselves or towards their nuclear family. In this way, the earthquakes may have catalysed pre-existing local conditions, creating new crime hotspots according to the characteristics of each area: residential areas with public transportation in the north and indigenous communities in the south.

Within this context, this study has three main contributions: It (1) introduces General Strain Theory as a relatively innovative theoretical framework for the criminology of disasters, capable of explaining the mixed effects observed; (2) uses the location of collapsed buildings as an indirect proxy for stress, providing empirical evidence for GST on a neighbourhood level, where studies are scarce; and (3) clarifies the role of disasters as catalysers of pre-existing local conditions. These can orientate targeted public policies to reduce the risk of victimisation in areas vulnerable to disasters.

Despite these findings, further research is needed. Although crimes such as battery (injuries caused by blows and knives) and substance abuse (drugs and alcohol) increased in the city, no new hotspots were created in the neighbourhoods affected by the 2017 earthquakes. These results suggest that not all crimes respond in the same way to the stress generated by disasters, which poses further questions for future research. Furthermore, our empirical evidence and our study are observational. As such, we used GST as an interpretative framework to understand the spatial concentration of certain crimes after the earthquakes, without claiming a direct causal relationship. Future studies should incorporate neighbourhood level proxies for strain, support networks, displacement, and service disruption to test these mechanisms more precisely.

2. Literature

Sociological literature on disasters has dealt extensively with the relationship between crime and catastrophes. In general,

therapeutic community, social disorganisation, and routine activity are the three main theories employed to explain criminal behaviour following a catastrophe.

One of the most traditional theories in the field is probably that of the therapeutic community, formulated by Fritz [30] and developed by Barton [31,32]. This approach argues that disasters induce situational characteristics that encourage social cohesion, solidarity, altruism, and prosocial action [33]. The public experience of collective suffering promotes empathy and cooperation between previously disconnected groups, contributing to community restoration and a decrease in criminal activity.

However, various studies have questioned the equalising nature of disasters (without considering other variables). For example, Kaniasty and Norris [34] found that race and education level moderated altruistic behaviour after Hurricane Hugo: African Americans and those with lower education levels reported less community support. In a comparative analysis of tornados, floods, earthquakes, and hurricanes, Bolin and Bolton [35] concluded that minorities and economically disadvantaged groups face greater obstacles in accessing shelter and assistance. This appears to indicate that social inequalities supersede the altruism and solidarity created by a disaster [28]. Enarson et al. [36] added that gender, intersected with race and class, aggravates the vulnerability of women. In summary, post-disaster community cohesion is stratified by variables such as race, gender, education, religion, and age.

In the study of disasters and crime, one of the most studied crimes is looting, that is, generalised opportunistic robbery [37], although, to some degree, it is difficult to differentiate this crime from accidental loss or the legitimate appropriate of resources [33]. In fact, Barsky et al. [38], found that survivors of Hurricane Katrina distinguished between illegitimate looting and legitimate appropriation [39,40]. Nevertheless, beyond looting, research into violent and property crime appears to support the therapeutic theory by demonstrating that these tend to remain constant or decrease following disasters [41–43]. For example, Leitner et al. [44] found that the majority of parishes in Louisiana did not experience an increase in crime after Hurricane Katrina; and Zahran et al. [45] found a modest decrease in crimes in Florida, although they also identified an increase in domestic violence, which suggests that the therapeutic effect does not extend to domestic environments. Finally, Barsky [46] warns that the decrease in crime reports could be due to the prioritisation of rescue efforts by law enforcement agencies, affecting the gathering of crime data during the period immediately following a disaster.

In contrast to the therapeutic hypothesis, social disorganisation theory considers disasters to be factors that exacerbate the rupture of community order. Berkowitz (1993), Curtis et al. [47], Davila et al. (2005), Siegel et al. [48], and Siman (1984) argue that disasters can weaken social cohesion and collective efficacy, complicating the control of antisocial behaviour. The concept was introduced by Thomas and Znaniecki (1918), who noticed that social institutions lose influence when they are unable to adapt to structural changes. Park et al. [49] linked this disorganisation to urbanisation and racial heterogeneity, while Shaw and McKay [50] demonstrated empirically that juvenile delinquency is related to institutional weakness in neighbourhoods characterised by poverty, ethnic diversity, and housing insecurity. Sampson and Graves [51] subsequently broadened this theoretical framework, proposing that factors such as family disruption, residential mobility, and urbanisation affect collective efficacy, understood as a community's capacity to maintain social control through formal and informal networks. Empirical research has confirmed that these indicators are solid predictors of crime [52].

Disasters can intensify these factors. Weber and Peek [53] show that temporary or permanent displacement affects housing stability. Adams and Adams [54], Norris et al. [55], and the National Survey on Drug Use and Health [56] demonstrate that post-disaster stress increases the consumption of substances and weakens support networks. The loss of social connections is an important factor of vulnerability [57]. For example, Curtis et al. [47] found a significant increase in child abuse after Hurricane Hugo and the Loma Prieta earthquake, attributing this to the breakdown of family networks. However, Siegel et al. [48], in their study of the Northridge earthquake, found no evidence of an increase in crime, which suggests that effects can vary according to context.

Research into Hurricane Katrina also offered mixed results. On one hand, Harper and Frailing [39] and Frailing and Harper [58] attributed the rise in robberies in New Orleans to previously identified socioeconomic conditions and social inequalities, while Leitner et al. [44] found no significant increases. On the other hand, Varano et al. [59] explored crime displacement towards Houston, Phoenix, and San Antonio, cities that received high numbers of evacuated people. Their study identified tensions in public services and loss of social networks, finding modest evidence of an increase in crime in Houston and Phoenix.

Routine activity theory, proposed by Cohen and Felson [60] and Felson and Cohen [61], is the third approach that could be employed to study crimes related to disasters. The theory argues that changes in crime rates are connected to the transformation of the socio-structural organisation of daily activities. According to this theory, crime occurs when three elements converge in time and space: (1) suitable targets; (2) absence of capable guardians; and (3) presence of motivated offenders. A lack of any one of these elements can prevent crime. Applied to the context of disasters, this theory suggests that catastrophic events can alter social routines in such a manner as to increase the likelihood of the convergence of these elements [62]. Cromwell et al. [63] showed how the different phases of Hurricane Andrew altered routines and facilitated the emergence of conditions conducive to crime in Dade County, Florida. Curtis and Mills [64] found that crime was geographically distributed in the neighbourhood of Holy Cross, New Orleans, according to the degree of occupation and reconstruction, and was most frequent in areas with less community activity after Hurricane Katrina. LeBeau [65] also applied this theory to Hurricane Hugo, and found a significant increase in calls to police, robberies, and reports of the presence of armed individuals in the neighbourhood. However, an increase in informal guardianship was also observed, suggesting that disasters can activate community mechanisms of social control.

2.1. General Strain Theory

Although not commonly used to explain post-disaster crime, General Strain Theory could constitute a significant and complementary contribution to explaining certain findings in the literature. General Strain Theory (GST), formulated by Merton [66], posits

that crime emerges when there is a discrepancy between culturally-valued objectives, such as economic success, and legitimate means of obtaining these. Such tension leads to deviant behaviours as a form of adaptation. Agnew [67,68] broadened this General Strain Theory perspective, incorporating tensions derived from the loss of positive relationships and exposure to adverse circumstances. The most criminogenic tensions are those perceived to be unjust and intense, which, combined with low social control, create pressure to offend. These tensions are grouped into three types: failure to reach goals, loss of positive stimuli, and exposure to negative stimuli, all of which generate emotions such as anger and frustration [69].

Within disaster contexts, these tensions are intensified: the loss of housing and employment inhibits the attainment of basic goals; separation from support networks implies a loss of positive stimuli; and adverse conditions in shelters constitute negative stimuli. These may derive in deviant adaptations, such as robbery and substance consumption [70] as well as a rebellion against social norms. For example, as has already been mentioned, Curtis, Miller and Berry [47] documented an increase in child abuse after Hurricane Hugo and the earthquake in Loma Prieta, linked to the loss of support networks, while Frailing and Harper [58] indicated that socioeconomic inequalities prior to Hurricane Katrina exacerbated the impact of the disaster on crime. These findings make more sense from a GST perspective. In addition, recent meta-analyses confirm that GST is one of the most robust predictors of deviant behaviour within contexts of stress [71]. For example, in contrast to the therapeutic community hypothesis [30,32] that emphasises post-disaster social cohesion, GST explains the increase in crime within the private sphere, such as domestic violence [45]. In comparison with the social disorganisation theory [50,51] that focuses on structural factors, GST includes a micro dimension that analyses the way in which tensions affect individuals. It also stands apart from routine activity theory [60], by explaining the emotional motivation behind crime, including non-opportunistic crimes, such as fraud and domestic violence [65]. In summary, General Strain Theory offers a comprehensive perspective by considering both structural and emotional factors, explaining a wider range of crimes, and taking into account individual differences in resilience and coping strategies, making it an interesting analytical tool for understanding the relationship between disasters and crime (Table 1).

To further understand the role of GST in post-disaster contexts, it is important to consider social, economic, and psychological factors that interact to induce criminal behaviours following earthquakes. Breaks in routine, loss of community support, and temporary institutional disorganisation may increase social tension in areas with already existing vulnerable structural conditions [28]. This is aggravated by economic effects, such as loss of employment, decrease in income, and uncertainty around reconstruction, all of which are factors that the literature has linked to an increase in stress and dysfunctional behavioural responses [55,70]. At the same time, prolonged exposure to negative stimuli (collapsed buildings, delays in reconstruction, or loss of family members) can intensify emotions such as frustration, fear, or anger, which the GST identifies as triggers of criminal adaptations, particularly when combined with weak support networks and informal control mechanisms ([69]; Curtis et al., 200). These dynamics contribute to explaining the unequal distribution of criminal reactions in the city and the concentration of certain crimes in areas with particular social and psychological characteristics.

3. Latin America

Highly susceptible to disasters and marked by structural inequalities, Latin America offers a complex scenario within which to analyse the criminological effects of disasters. Hurricanes, earthquakes, and floods interact with accelerated urbanisation, institutional fragility, and poverty, with various impacts on criminality [72]. The literature focuses on countries with high seismicity (Mexico and Chile), while post-flooding records predominate in other cases. The majority of these studies report an increase in certain crimes, based on official data and indicators of social cohesion. The usual frameworks used are routine activity, social disorganisation, and criminal governance theories, applying models such as fixed effects and difference-in-difference.

Following the 2017 earthquake in Mexico, opportunistic crimes and reconstruction fraud were documented, especially in urban areas with recorded corruption [73], similar to findings after the earthquake of 1985 [74]. Silverio-Murillo et al. [22] found that earthquakes increase the number of assaults (14%) and vandalism (12%), in addition to kidnappings (4%) [75], sexual abuse (11%) and rape (12%), with a 2% drop in femicides (Silverio-Murillo et al., 2024c).

Findings in Chile, however, show certain contrasts: high levels of social cohesion were initially evident after the 2010 earthquake and tsunami, followed by robberies in coastal areas [76]. Calo Blanco et al. [77] confirmed that social cohesion increased after large earthquakes but was erased over time, while García Hombrados [11] found lasting decreases in property crimes in affected municipalities.

In Peru, the looting that followed the Pisco earthquake (2007) was concentrated in areas where aid was slow to reach [78,79]. Ecuador experienced looting and conflicts after the 2016 earthquake linked to the loss of social networks and the perception of institutional State inefficiency (Estado [29,80]. In Venezuela, López and Romero [81] reported looting and violence in shelters following the 1999 Vargas floods. In Bolivia, following the floods in 2014, robberies and conflict over resources were reported, attributed to weak social control [82]. In Central America, the 1998 Hurricane Mitch was linked to domestic violence and alcohol consumption due to stress and the loss of social networks [83,84].

Haiti experienced looting, violence, and sexual assault in camps after the 2010 earthquake given the rupturing of social networks and institutional weakness [74,83], while in Brazil and Argentina, flooding in urban areas was associated with robberies and looting: in Rio and São Paulo due to the lack of infrastructure and socioeconomic inequality [85], and in La Plata to the prolonged lack of State services [86].

Table 1
Comparative.

	TC	SD	RAT	GST
Main idea	Disasters generate solidarity and social cohesion, reducing crime.	Disasters disorganise institutions and social networks, increasing vulnerability.	Disasters alter routines, creating crime opportunities.	Crime emerges from the tension arising from the loss of goals and resources following a disaster.
Prediction on crime	Decrease or remain stable after a disaster.	Increase due to the loss of social control and support networks.	Can increase if targets, offenders and the lack of guardianship converge; can decrease if informal guardianship increases.	Increase in property crime, domestic violence, and drug consumption.
Explanatory mechanism	Empathy, public cooperation, and emerging norms of mutual support.	Disruption of social networks, residential mobility, poverty, lack of collective efficacy.	Changes in daily activities that facilitate criminal opportunities.	Negative emotions (anger, frustration) in response to stress, maladaptive coping strategies.
Key variables	Social cohesion, altruism, support networks.	Socioeconomic status, racial heterogeneity, residential mobility, urbanisation.	Suitable targets, motivated criminals, absence of guardians.	Loss of goals, positive stimuli, and exposure to negative stimuli.
Empirical evidence	General support: decrease in violent and property crimes, increase in domestic violence [45].	Mixed: some studies show an increase in child abuse and robbery; others fail to confirm an overall increase [47].	Mixed: some studies have shown an increase in robbery and calls to police; others indicate greater guardianship and the reduction of crime [65].	Consistent: increase in domestic violence, child abuse and opportunistic crimes after disasters [47,58].
Advantage over others	Explains social cohesion, but not crimes in the private sphere.	Explains community structure, but not individual motivation.	Explains opportunities but neither emotions nor non-opportunistic crimes.	More complete: integrates the individual level, emotions, variety of crimes, and resilience.

4. Data

We mapped the 53 buildings most affected by the earthquakes of September 2017 using their geographical coordinates (red points on Figure Map 1). The geographical location of the buildings is based on reports from the city's newspapers during September 2017, compiled by Wikipedia [87,87–89]. We manually verified the information with reports by the City government [90]. The Mexico City Government's reports only include buildings affected by the earthquake of 19 September and recognised by administrative procedures established by the Reconstruction Commission [90]. The greatest human and material losses in Mexico City were concentrated around the buildings, and their slow reconstruction was a constant reminder of the damage and anguish experienced by neighbours and visitors [91].

We used crimes registered in judicial files by the Mexico City government from 12 months before the earthquakes to 12 months after (1 September 2016 to 30 September 2018) (GCDMX, 2025). Based on the literature ([12,22,23,75]; Silverio-Murillo et al., 2025), we selected sexual crimes (sexual abuse and rape), property crime (business robbery), substance abuse (simple drug dealing and death from alcohol ingestion), and domestic violence. We also included crimes not previously considered in the literature on earthquakes and crime but that could be related to Stress Theory: non-violent robbery in public transport, specifically in the metrobus, injuries resulting from battery and stabbings, and death from self-harm (Table 2).

Figure Map 1 presents three groups of neighbourhoods affected by the earthquakes, in blue. The central part corresponds to the historical centre of the city; the neighbourhoods in the north, surrounding that of Lindavista II, are residential areas; and the neighbourhoods in the south are places inhabited by indigenous people in Mexico City (around the Santa María Nativitas neighbourhood). In neighbourhoods in the south, around a third (32.60%) of households do not have access to health services, and are overcrowded (30.21%), while between a quarter and a fifth of adults do not have basic education (23.18%). These figures are higher than the city average (26.88% without health services, 20.66% overcrowding, and 17.54% without basic education). Percentages of homes without running water (3.62%) and with dirt floors (3.92%), are also higher than the city average (2.04% and 0.79%, respectively). In contrast, neighbourhoods in the north have fewer overcrowded households (8.49%) or households without access to health services (21.68%), and fewer adults without basic education (9.37%). In addition, among the northern neighbourhoods, only 0.04% of homes do not have running water, and 0.13% have dirt floors [92].

Data was managed with QGIS. In addition, we mapped crimes in Mexico City neighbourhoods using their geographical coordinates. We then counted the crimes in the 1807 neighbourhoods of the city one year before the September 2017 earthquakes and one year after to create two data sets. The unit of analysis was therefore the neighbourhoods of Mexico City. Finally, we identified the 35 neighbourhoods that contained the 53 damaged buildings and included their 161 adjacent neighbourhoods with a queen type matrix for a total of 196 affected neighbourhoods.

5. Methodology

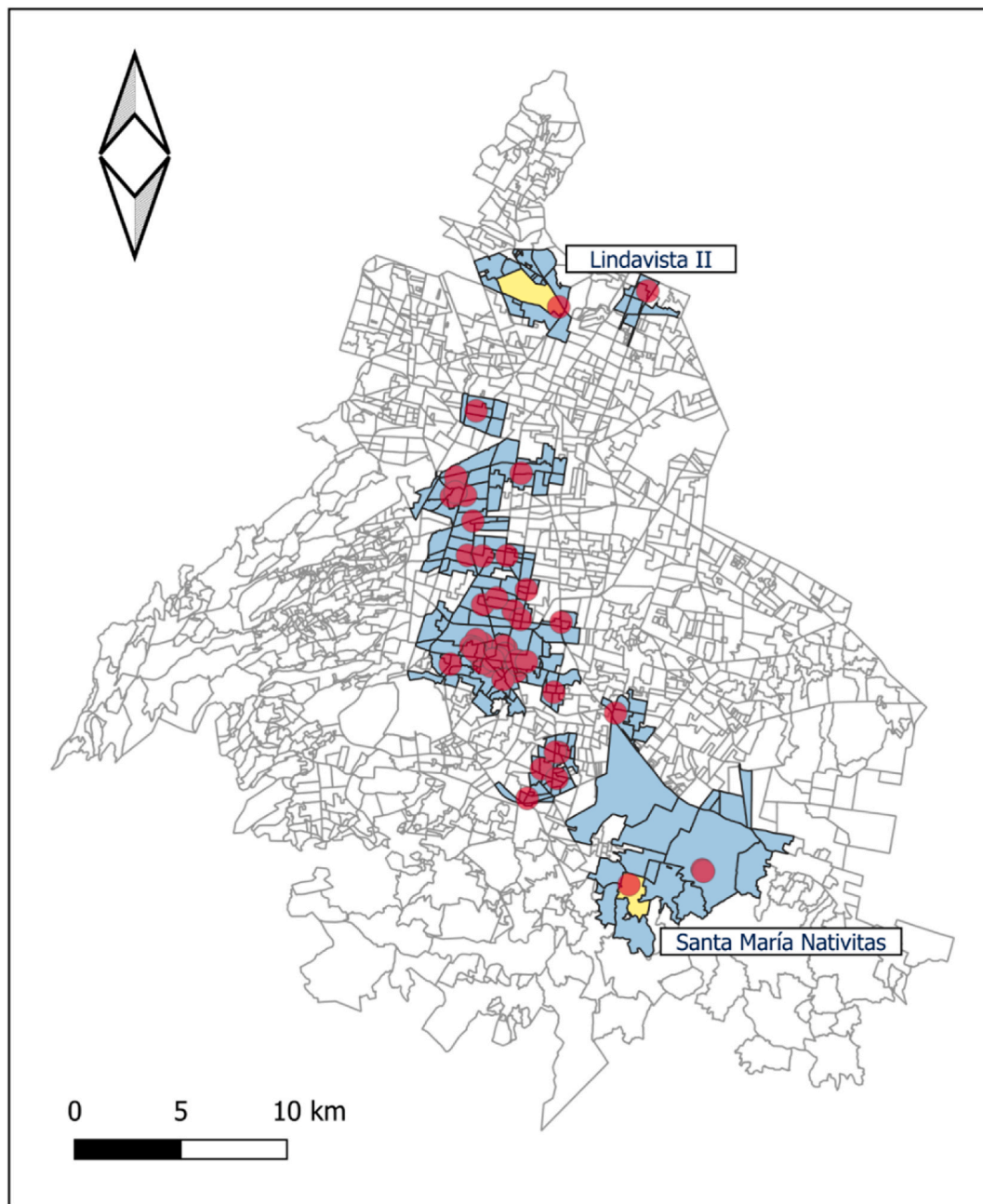
We implemented two spatial analysis techniques using the crime data sets from 12 months before (September 2016 – August 2017) and 12 months after (October 2017 – September 2018) the earthquakes (September 2017) to identify significant changes in the crime pattern of Mexico City. We used local indicators of spatial autocorrelation (LISA) as an exploratory spatial data analysis ([93]; Wei 2022) and relied on Spatial Point Pattern Test (SPPT) as the confirmatory step (Andresen, 2016; Wheeler, 2021; Steenbeek et al., 2020).

We used local indicators of spatial autocorrelation (LISA) to find the emergence of new crime clusters in the 1807 neighbourhoods of the city and to identify hotspots that corresponded to the 196 neighbourhoods affected by the earthquakes and their neighbours. Originally proposed by Anselin [94], the Local Indicator Spatial Association (LISA) identifies areas with high or low spatial concentrations of crime. The technique identifies polygons with high and low values of the variable of interest, that border other areas with similar values. We used a queen type matrix to operationalise spatial proximity. Significance level was set at 0.01, with 999 permutations, and a Bonferroni bound and false discovery rate of 0.000005534. The results facilitated the mapping of results to identify crime hotspots in the city. In particular, we sought to identify new hotspots in the neighbourhoods affected by the earthquakes. In addition, the test provides a Moran's I statistic that summarises the degree of spatial autocorrelation of the variable of interest. GeoDa software was used.

Table 2

Number of registered crimes in Mexico City. The earthquakes occurred on 7 and 19 September 2017, with magnitudes of 8.2 and 7.1, respectively.

Crime	12 months before	12 months after	Increase
Robbery in transport (metrobus)	298	954	220.13%
Simple drug dealing	1283	3557	177.24%
Rape	407	1072	163.39%
Sexual abuse	1677	2359	40.67%
Death from self-harm	335	384	14.63%
Domestic violence	18,184	19,933	9.62%
Business robbery	14,950	15,558	4.07%
Injuries from battery	2796	2812	0.57%
Injuries from stabbings	1100	1103	0.27%
Death due to alcohol consumption	26	26	0%



Map 1. Fifty-three buildings damaged in the 2017 earthquakes (red points). The 35 affected neighbourhoods and their 161 adjacent neighbourhoods are identified in blue.

Following the exploratory spatial analysis, we used SPPT as a confirmatory step to compare the significant changes in spatial patterns in the 196 affected neighbourhoods with the 1611 neighbourhoods outside of the disaster areas (before and after the earthquakes for both data sets). Spatial Comparison is a recent research line that incorporates innovative methods to study the link between observed spatial patterns and the processes that generate them ([95]; Hattis et al., 2024). Thus, SPPT analyses the statistical similarity or difference between two patterns to improve inferences from the spatial patterns involved (Andresen, 2016; Wheeler, 2021; Steenbeck et al., 2020). SPPT has been used in studies of crime and Covid-19 to analyse the spatial distribution of shooting violence in Buffalo, NY (Drake et al., 2022), the pattern of fires in businesses and extortion in Mexico City [96], the spatial distribution of property crimes, such as theft and burglary in Chicago [97], and commercial burglary in San Francisco (Yim and Riddell, 2022), among others.

SPPT calculates the difference between two sets of spatial point patterns in the same unit of analysis. The technique uses the

geographical coordinates of each crime and assigns it to the neighbourhood in which it occurred. It then takes a random sample from both datasets to resample them in the neighbourhoods with replacement and estimate the percentage difference. The comparison uses a Chi-square test with Yates continuity correction to test whether the difference in proportion of points in each neighbourhood is non-random, surpassing an established level of confidence. For our study, we used the R package SPPT (Steenbeek et al., 2020), applying a bootstrap resampling procedure for both point datasets. Neighbourhoods in the city were used as the unit of analysis, and we established the sample number at 200 with a 95% confidence level for the Chi-square test, as per statistical convention.

The SPPT showed a number of neighbourhoods with significant increases or decreases before and after the earthquakes and identified them for mapping. It also estimated a local index of similarity. The index of similarity is calculated based on the proportion of areas without significant changes. For example, a score of 90 points indicates that around 90% of neighbourhoods are statistically similar, before and after the earthquakes. In the interpretation of the results in our study, a lower index of similarity in neighbourhoods with collapsed buildings (196 neighbourhoods) shows that neighbourhoods in these areas experienced more significant changes after the earthquakes than those outside the affected areas (1611 neighbourhoods). Thus, when comparing affected and unaffected neighbourhoods, a score closer to 1 indicates fewer spatial pattern changes.

6. Results

The earthquakes likely modified the spatial patterns of sexual abuse, public transport robbery (metrobus), and domestic violence in neighbourhoods in the north and south of Mexico City, but possibly did not affect business robbery, street fights (injuries), and substance abuse (alcohol and drugs). The impact of the earthquakes was not significant for rape and death from self-harm.

6.1. Exploratory spatial data analysis

Results showed that neighbourhoods that concentrated the damage from the 2017 earthquakes registered new hotspots for sexual abuse, rape, public transport robbery (metrobus), death from self-harm, and domestic violence (Table 3). However, there are substantial differences in the new crime clusters. Increases in sexual crimes and transport robbery (metrobus) were concentrated in neighbourhoods in the north, adjacent to the neighbourhood of Lindavista II (Figure Map 2). In contrast, death from self-harm and domestic violence were spatially concentrated in neighbourhoods in the south, around Santa María Nativitas (Figure Map 4).

Analysis of neighbourhoods in the north reveals the emergence of hotspots of sexual abuse, rape, and non-violent robbery in the metrobus that had not previously existed (Figure Map 2). The results of the LISA show that neighbourhoods around Lindavista II formed new clusters for sexual crimes and public transport robbery (metrobus). This neighbourhood registered the greatest damage resulting from the earthquakes in the north of the city. A 7-storey building with 13 apartments and one commercial property collapsed, killing 9 people. The city government cordoned off six blocks around the building and formal reconstruction began in 2018. However, in February 2021, an official report of the Commission for Reconstruction noted that the project had only advanced 28% (Ortega, 2017; GCDMX, 2021).

Results of the exploratory spatial analysis regarding the neighbourhoods in the south were mixed. Various domestic violence hotspots exist in the city (Figure Map 4). In fact, the LISA test detected a domestic violence hotspot in the neighbourhoods in the south around Santa María Nativitas that had also been identified before the earthquakes. Regarding deaths resulting from self-harm, this phenomenon formed a hotspot that had not previously existed in the neighbourhoods south of Santa María Nativitas (Figure Map 4, top right). Finally, results of the LISA test for injuries resulting from battery and stabbings, substance abuse (drugs and alcohol), and business robbery showed that hotspots in the city remained in the same areas before and after the earthquakes of 2017. No reports of the emergence of coldspots were registered in the affected neighbourhoods.

6.2. Significant changes in neighbourhoods in the north

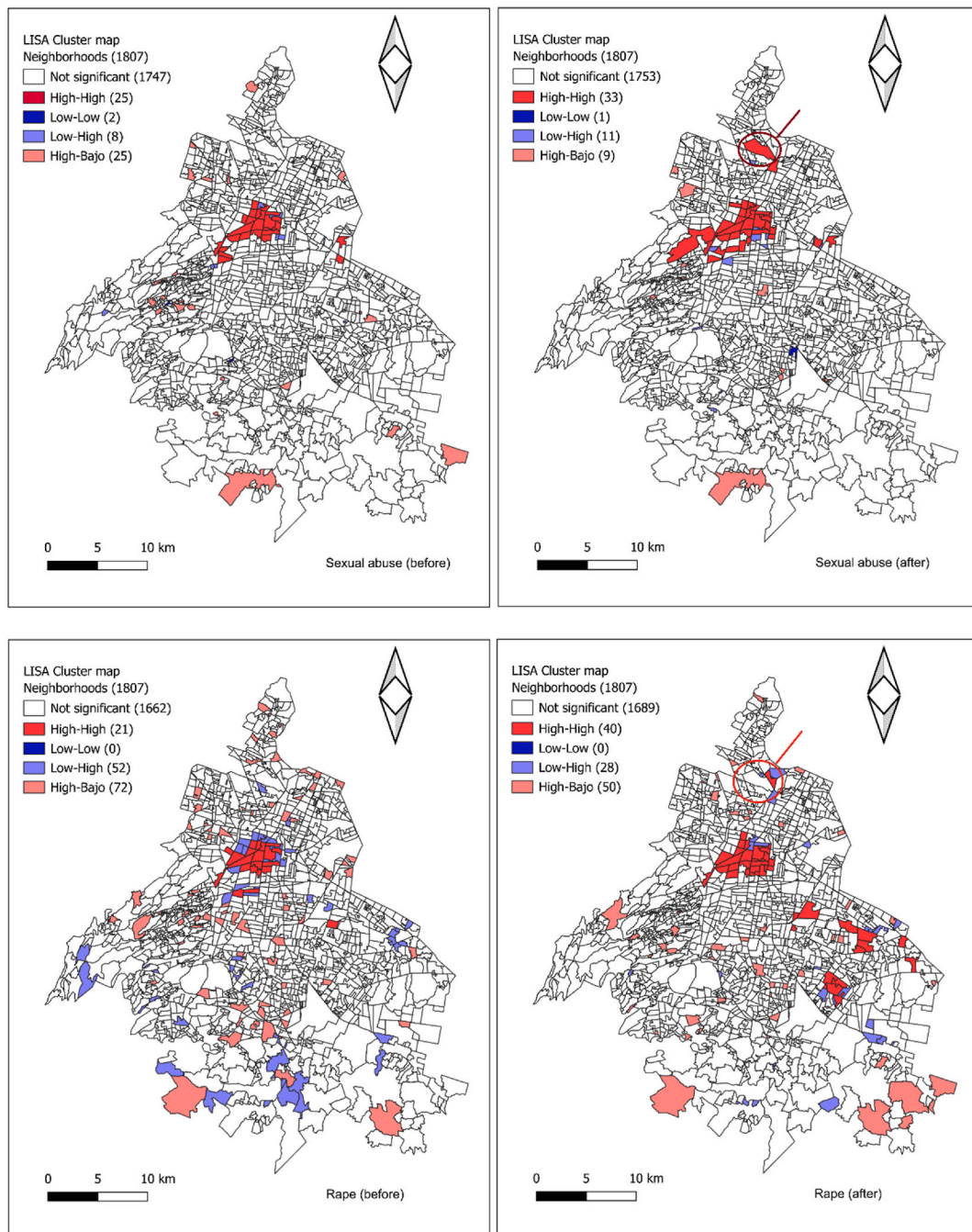
When analysing the 196 affected and 1611 unaffected neighbourhoods, the SPPT test shows that the earthquakes likely had a greater impact on the affected areas (Table 4). The index of similarity shows a greater and significant modification in the spatial pattern of sexual abuse (0.9455) as well as robbery in the metrobus (0.9111) in affected neighbourhoods in comparison with unaffected neighbourhoods (0.9594 for sexual abuse and 0.9428 for robbery). The lower the index score, the greater the change in spatial patterns after the earthquakes at a 95% confidence level. Thus, in the affected areas, the percentage of neighbourhoods with increases

Table 3

Crimes that form new hotspots in neighbourhoods affected by the 2017 earthquakes.

Crime	Hotspots (LISA)		area	Moran's I***	
	before	after		before	after
Sexual abuse	no	yes***	north	0.2140	0.2170
Rape	no	yes***	north	0.0840	0.1580
Robbery in metrobus	no	yes**	north	0.3610	0.3430
Death by self-harm	no	yes***	south	0.0260	0.0350
Domestic violence	yes	yes***	south	0.2150	0.2200

Note: **p < 0.05; ***p < 0.001.

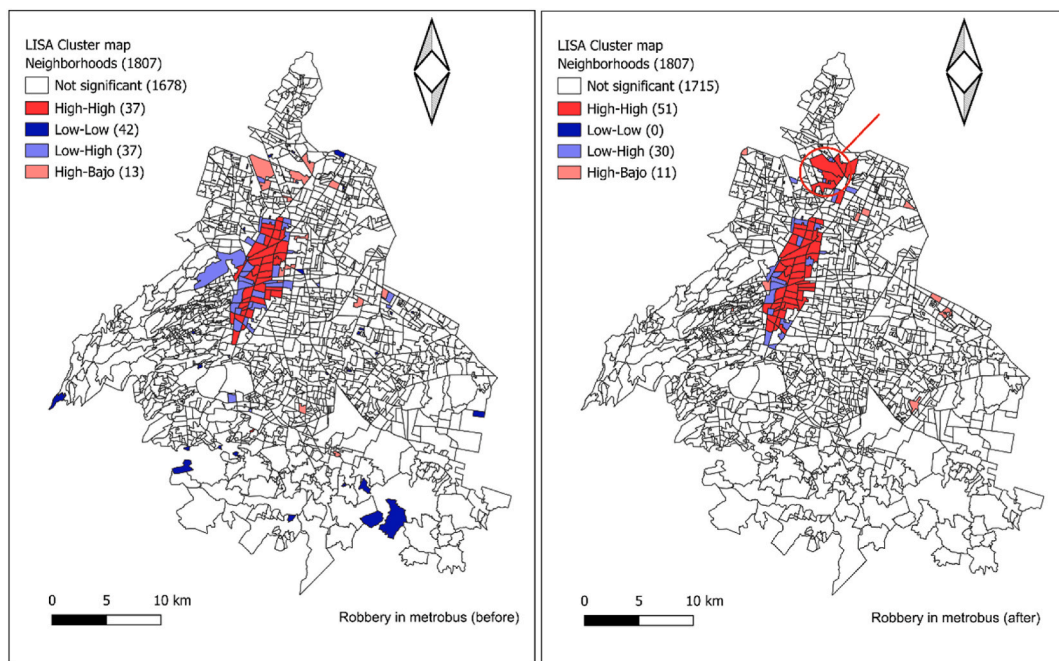


Map 2. Sexual abuse, rape, and robbery (metrobus) before and after the 2017 earthquakes. Lindavista II neighbourhood is in the red circle.

was greater for sexual abuse (3.06% vs 1.68%) and robbery in the metrobus (2.04% vs 0.31%) than in unaffected neighbourhoods. In the case of rape, no differences in spatial patterns were identified between affected and unaffected areas. Finally, increases in sexual abuse and robbery in the metrobus were concentrated in the neighbourhoods of the north and center of the city (Figure Map 3), confirming the exploratory analysis detected by the LISA maps.

6.3. Significant changes in neighbourhoods in the south

In the south of the city, spatial patterns of domestic violence showed greater changes in the affected areas than in neighbourhoods



Map 2. (continued).

Table 4
Results of the SPPT test for affected and unaffected neighbourhoods.

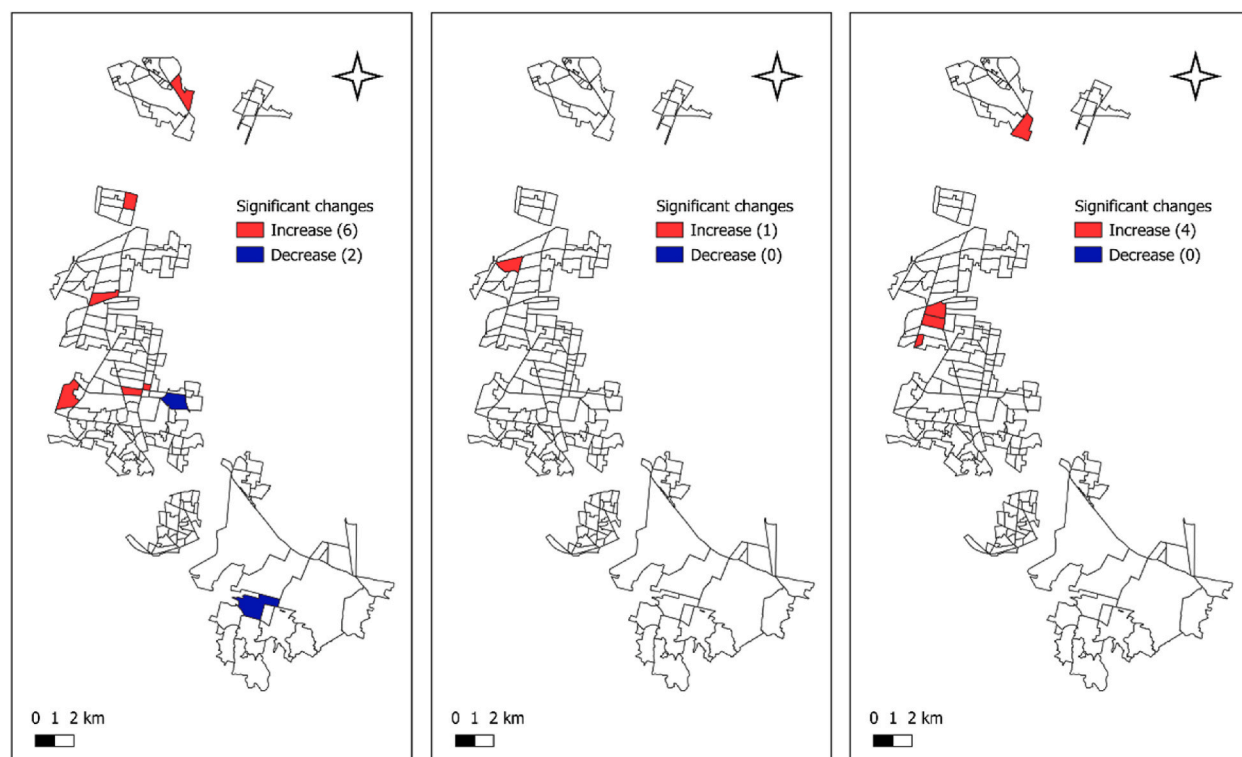
Crime	Neighbourhoods (1807)	Significant changes (percentage of neighbourhoods)		Index of similarity**
		Decrease	Increase	
Sexual abuse	Affected zone (196)	2 (1.02%)	6 (3.06%)	0.94558
	Unaffected zone (1611)	10 (0.62%)	27 (1.68%)	0.95947
Rape	Affected zone (196)	0 (0%)	1 (0.51%)	0.98856
	Unaffected zone (1611)	0 (0%)	11 (0.68%)	0.98067
Robbery in metrobus	Affected zone (196)	0 (0%)	4 (2.04%)	0.91111
	Unaffected zone (1611)	1 (0.06%)	5 (0.31%)	0.94286
Domestic violence	Affected zone (196)	9 (4.59%)	9 (4.59%)	0.90625
	Unaffected zone (1611)	66 (4.10%)	61 (3.79%)	0.91482
Death by self-harm	Affected zone (196)	0 (0%)	0 (0%)	1.00000
	Unaffected zone (1611)	1 (0.06%)	0 (0%)	0.99764

Note: **p < 0.05.

outside of these (Table 4). The SPPT test demonstrated that 9 neighbourhoods registered significant increases (4.59%) in the affected areas in comparison with the 61 neighbourhoods with increases outside of the area (Figure Appendix 1). It is interesting that the test also detected 9 neighbourhoods affected by the earthquakes with significant decreases (4.59%) and that 66 neighbourhoods outside of the affected area also experienced decreases (4.10%). Nevertheless, regarding both increases as well as decreases, the change in spatial pattern was greater in areas affected by the earthquakes, according to the index of similarity (0.9062 v 0.9148). Consequently, as in the case of the neighbourhoods in the north, the earthquakes likely had a greater impact on neighbourhoods closer to collapsed buildings than on neighbourhoods that were further away. Furthermore, the proportion of neighbourhoods with increases and decreases is similar in both types of neighbourhoods, suggesting that the earthquakes may have revealed a more complex criminal dynamic in the south than in neighbourhoods in the north, where there were more significant increases than decreases. Finally, although a new hotspot for death from self-harm was identified, its index of similarity remained virtually unchanged, meaning the SPPT test did not register a variation in any of the 196 neighbourhoods affected by the earthquakes, and variation was minimal in the 1611 unaffected neighbourhoods, with only one registering a significant decrease (0.06%) (Table 4).

7. Discussion

It is likely that the earthquakes significantly modified the spatial patterns of sexual crimes (sexual abuse), robbery in public transport (metrobus), and domestic violence in neighbourhoods in the north and south of Mexico City, but do not appear to have significantly impacted rape or death from self-harm.

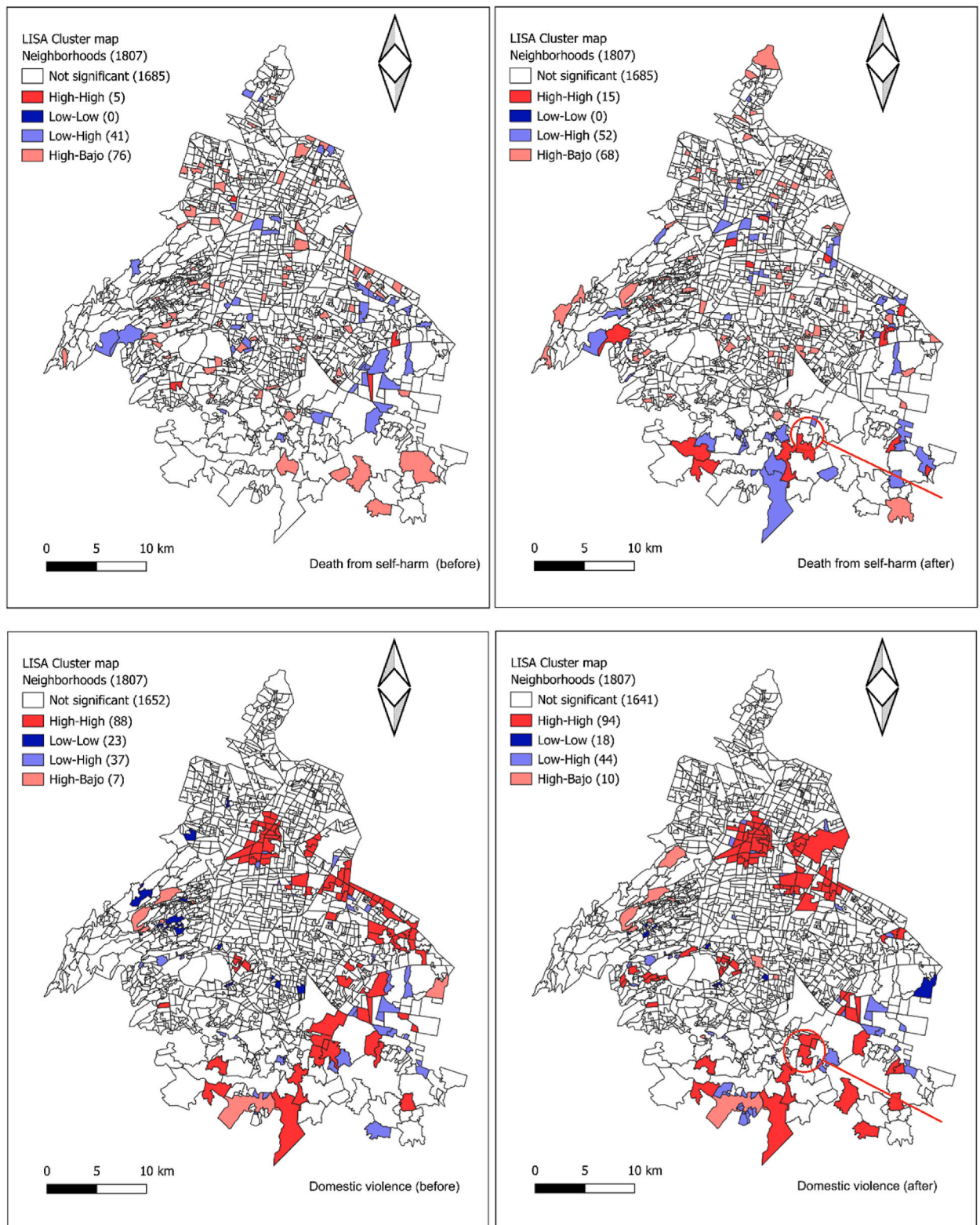


Map 3. Significant variations in crime incidence. Sexual abuse (left), rape (centre), and robbery in public transport: metrobus (right). Confidence level of 95%.

Spatial patterns changed in both the 196 affected neighbourhoods and the 1611 unaffected ones. However, the change in spatial pattern in neighbourhoods of affected areas was greater and significant for sexual abuse, robbery, and domestic violence, according to the index of similarity (95% confidence level). As such, the percentage of neighbourhoods that registered a rise in crime increased more in disaster affected areas than in neighbourhoods further away. According to Tobler's first law of geography, increases in crime incidence and new crime clusters may be interpreted as being spatially associated with collapsed buildings and other damage resulting from the 2017 earthquakes due to their geographical proximity and experiences of neighbours and passers-by in the affected neighbourhoods.

These findings partly coincide with the literature that supports the social disorganisation and routine activity theories but also differ in key aspects. For example, studies such as those of Curtis et al. [47] and Frailing and Harper (20,101) note an increase in crimes such as child abuse and robbery following disasters, which align with the idea that the collapse of social networks and structural poverty intensify criminality. However, in our study, no new hotspots emerged for crimes such as battery and business robbery. That is, not all crimes respond in the same way to community disorganisation. On the other hand, the therapeutic community theory, that argues that disasters promote social cohesion and reduce crime [30,32], was not completely confirmed. Although some crimes did not increase, such as business robbery and battery, others, such as domestic violence and sexual abuse did increase, especially in affected areas. This suggests that the therapeutic effect may be limited to certain types of crimes or specific contexts (precisely as was noted by Ref. [45]). Furthermore, studies such as those of Siegel et al. [48] and Leitner et al. [44] have shown that a decrease in crime after disasters could be influenced by the lack of reporting or the prioritisation of rescue efforts, which may explain why some crimes do not have new hotspots in our study, despite having increased in absolute numbers.

Similarly, it is important to mention that the increase in robberies on the metrobus appears to confirm the routine activity theory, as public transport continued to operate in affected areas, but the formal guardianship related to this service may have been weakened or the number of potential targets may have increased. Routine activity theory predicts that disasters can alter routines and create crime opportunities, as shown by LeBeau [65] and Curtis and Mills [64] in the context of hurricanes. They observed that crime was concentrated in areas with low community activity and slow reconstruction. However, in the case of earthquakes, the literature has found decreases in crime around affected areas. Robbery of religious art decreased in Nepal following the 2015 earthquake [26], attributed to the presence of search and rescue teams in collapsed buildings. In the earthquakes in Canterbury, New Zealand (2010-2011), one study found a decrease in assault, burglary, and arson, "cooling" previously existing hotspots in areas that had been cordoned to prevent access to collapsed buildings (Breetzke, 2018). Given this, it is difficult to identify any theoretical reason that would explain a larger number of potential crime targets moving to areas affected by earthquakes, thereby creating new hotspots. Nevertheless, measures of transit exposure could enhance the policy relevance of our findings regarding robbery on the metrobus, as



Map 4. Death from self-harm, and domestic violence before and after the 2017 earthquakes. Santa María Nativitas neighbourhood is in the red circle.

the lack of data on passenger flow is a limitation of our study that could be addressed in future research.

An alternative explanation for both cases is provided by General Strain Theory. Differences in crimes in the north and south of the city may be interpreted in light of preexisting conditions in the neighbourhoods. Neighbourhoods in the north are mostly residential with public transport that connects them and where responses to stress are directed towards other people, while in the neighbourhoods of the south, there is a strong presence of indigenous people with pre- and post-Hispanic customs, and responses to stress are directed towards themselves or their family circles.

Among neighbourhoods in the south of the city, 30.21% of households are overcrowded, 32.60% do not have access to health services, and between a quarter and a fifth of adults lack basic education (23.18%). Some of these households also have dirt floors (3.9%) with no running water (3.62%). These figures, reflecting educational disadvantages and lack of services, are higher than the city average, and thus exposure to local damage, in the form of proximity to collapsed buildings, may possibly increase exposure to stress and heighten psychosocial pressure [47,70]. In contrast, neighbourhoods in the north have less overcrowding (8.49%), fewer households that lack access to health services (21.68%), and fewer adults without basic education (9.37) than the city average. Furthermore, less than 1% have dirt floors or no running water. Although these indicators may suggest a lower stress level in the north in comparison with the south, exposure to neighbourhood stress due to collapsed buildings in the area and slow reconstruction has been documented in the north, at least in the press, with various neighbours referring to feelings of impotency, anger, and sadness when passing the collapsed buildings [91].

This type of territorial differentiation has also been documented in studies such as García-Hombrados [11] in Chile, where the effects of an earthquake varied according to the type of community and prior levels of cohesion. GST allows for the interpretation of these variations as emotional responses to different structural and cultural tensions in the affected areas, such as the weakening of emotional support networks in southern neighbourhoods, and the failure to manage the anger and frustration in northern neighbourhoods when exposed to intense and adverse circumstances caused by the earthquakes. However, there is no direct data regarding tension, networks, displacement, or interruption of services before and after the earthquakes. As such, no strong causality is proposed, and it is suggested that future studies consider neighbourhood level proxies for strain, support networks, displacement, and service interruption to more precisely test these mechanisms.

Within this context, the incorporation of General Strain Theory is an important theoretical contribution as it explains the different effects in the north and south of the city. In comparison to structural or situational theories, GST introduces an emotional and micro-social dimension that contributes to understanding why certain crimes, such as domestic violence or sexual abuse, increase in contexts of prolonged stress. This approach aligns with the findings of Agnew [70] and Brezina [69], who highlighted that tensions perceived as unfair and without resolution can trigger deviant behaviour. In some cases, the earthquakes appear to have increased stress in areas where crime had already been registered, and thus GST does not explain the incidence of crime (that may have various social, economic, or opportunity origins, etc.) nor its increase in time (that may vary for a variety of circumstances). Rather, GST is a useful interpretative framework for understanding the spatial concentration of certain crimes around collapsed buildings and their spatial heterogeneity in the city. Given that spatial pattern changes are greater and significant in affected neighbourhoods, there may be a link between the spatial dynamics of exposure to stress and the observed pattern of the emergence and overlap of new hotspots for sexual abuse, robbery on the metrobus, and domestic violence, which spatially correspond to collapsed buildings and deaths in affected neighbourhoods.

Furthermore, the results coincide with recent studies conducted in Latin America, such as that of [22,23], who found an increase in sexual and property crimes following the 2017 earthquake in Mexico. However, our neighbourhood level spatial analysis offers an additional level of understanding by showing that these increases are not homogenous, but rather, concentrated in specific areas. This territorial approach has also been suggested by Pérez and Torres [29] in Ecuador, who noted that post-disaster social disorganisation manifests differently according to the degree of impact and the capacity of institutional response. Evidence presented in this study furthers this understanding by linking physical damage (collapsed buildings) to the spatial co-occurrence of crime hotspots. Nevertheless, we propose using GST as an interpretative framework rather than directly as a causal mechanism as our evidence uses collapsed building as an indirect measure of the phenomenon. Future research could use better spatial indicators of the stress generated by the impact of disasters.

8. Conclusion

After an earthquake, interpersonal crimes, and domestic violence are concentrated near affected neighbourhoods. We found significant changes in the spatial patterns of sexual abuse, public transport robbery (metrobus), and domestic violence. However, the emergence of new hotspots may be related to the pre-disaster criminological environment, as the type of crime that was concentrated depended on whether the neighbourhoods were located in the north or south of the city. Thus, our spatial analysis provides an additional level of understanding of the increase in crime following disasters, by showing that these increases are not homogenous, but rather, are concentrated in specific areas, linking physical damage (collapsed buildings) to the appearance of crime hotspots.

GST, used as an interpretative lens, helps to account for the spatial heterogeneity of the city's neighbourhoods. The stress created by the earthquakes was concentrated in places where buildings had collapsed and the most severe human and material damage was registered. Residents in these neighbourhoods were exposed to negative stimuli that created tensions and that may be interpreted as contributing to the spatial concentration of certain crimes where few support networks existed or where it was difficult to manage the intensity of the emotional response. Finally, the delayed reconstruction by the local government exposed these people to negative stimuli for months and even years, sustaining conditions under which certain crimes became spatially concentrated. As such, interventions to reduce the risk of criminal victimisation should consider neighbourhoods as a whole, providing tools to cope with stress

and accelerating the pace of reconstruction in the city.

Finally, this research introduced GST as an innovative and useful framework to understand the criminology of disasters by explaining the spatial concentration of sexual crimes, property crimes, domestic violence, and self-harm. It also presented empirical evidence of GST on the neighbourhood level, where studies are scarce, and as such, contributes to the study of the theory on a micro level. Furthermore, we clarify the role of disasters as sources of stress, capable of catalysing existing criminological conditions in areas with the greatest risk of victimisation. Public policy aimed at reducing risk should consider exposure to negative stimuli as a possible source of criminal incidence following a disaster. These findings can be of particular use within an international context, where climate change is accelerating the prevalence and intensity of disasters, such as hurricanes and floods.

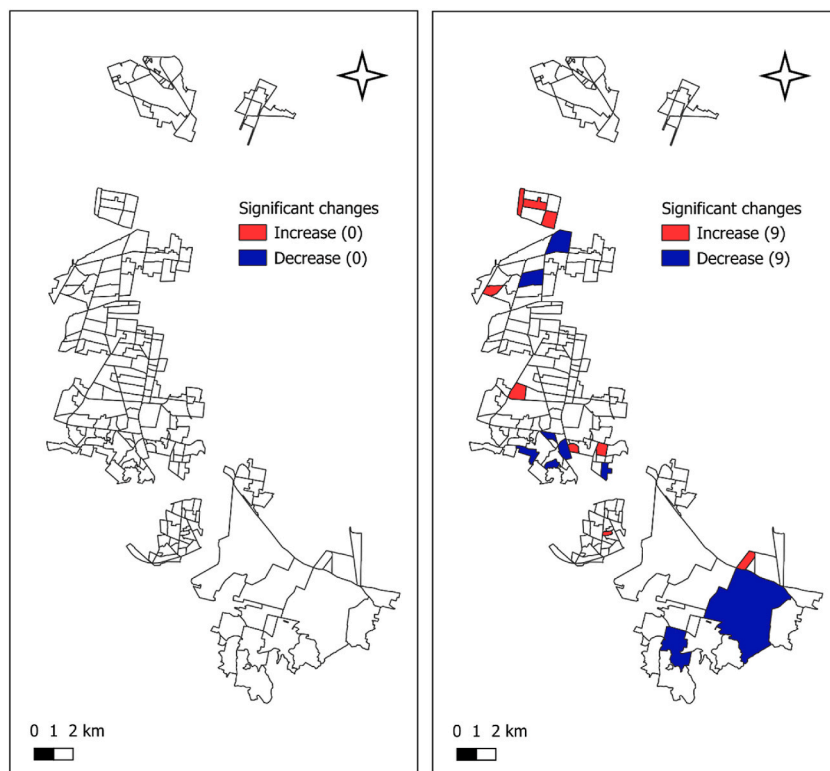
CRedit authorship contribution statement

Enrique García-Tejeda: Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Gustavo Fondevila Pérez:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendices.



Appendix 1. Significant increases (red) and decreases (blue) in deaths from self-harm (left) and domestic violence (right) in the 196 neighbourhoods affected by the earthquakes. Confidence level 95%.

Data availability

Data will be made available on request.

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