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Land Use Indexed Mobility Changes’ Impact on Urban Crimes in Metropolitan Cities

Yijing Li1,*, Ivan Y. Sun2, Yan Zhang3 and Yuying Wu1

1 Department of Informatics, King’s College London, the United Kingdom; yijing.li@kcl.ac.uk; ORCID ID 0000-0002-9831-0298
2 Department of Sociology & Criminal Justice, University of Delaware, US
3 School of Regulation and Global Governance (RegNet), Australian National University, Canberra, Australia; ian.zhang@anu.edu.au
* Corresponding author.

Abstract: Social distancing and lockdown measures have been widely deployed in urban areas worldwide to restrict citizens’ movement to help contain the COVID-19 pandemic. This resulted in dramatic changes in people’s daily mobility, as well as the criminality and delinquency in cities. Drawing on crime data in London, Sydney, and New York in 2020, this study attempts the first one-year “look back” on the impact of massive lockdowns on crime trends in the assistance of two classic criminological theories, routine activity, and general strain, as well as cutting-edge machine learning techniques on relating the community-level geodemographics, socio-economic profiles, and mobility changes to changes in crime. The research findings suggest a general crime reduction upon mobility changes during lockdowns among the metropolitan cities, but some city-featured prominent crime types had an eye-catching increase during the period. Holistic mobility change was found to be the most crime-influential factor rather than any fine-scaled residents’ geodemographic characteristics, echoing commonly offline criminal behaviors rather than committing crimes locally; the data-driven evidence could be further utilised for city-wide crime prediction and prevention strategies towards post-pandemic recovery.

Keywords: crime change; lockdown; mobility change; routine activity; land use

1. Introduction

The COVID-19 pandemic has been wreaking havoc on human well-being, economics, crime, government administration, and social interactions within global cities, resulting in irreversible impacts throughout 2020, and will continue to do so into the foreseeable future (Clemens, 2020; Liu et al., 2021; Stickle and Felson, 2020). In response to the pandemic – and to contain the rapid spread of the virus – governments around the world began to impose policies and measures like lockdowns, social distancing, and stay-at-home mechanisms to demobilize people’s activities, especially in metropolitan cities. Understandably, this simultaneously affects the daily routines and the social interactions of millions of people, making 2020 the largest experiment of criminological changes in human history (Liu et al., 2021; Stickle and Felson, 2020). This is evidenced by: the decrease in residential burglary and theft thanks to guardianship strengthened by stay-at-home directives (Ashby, 2020; Campedelli et al., 2020; Halford et al., 2020); the substantial decline in violent crimes against persons immediately following the COVID-19 containment measures (Abrams, 2021; Langton et al., 2021; Payne et al., 2020); the unprecedented...
surge of domestic violence after the deployment of lockdowns (Dai et al., 2021; Mohler et al., 2020; Boserup et al., 2020; Krishnakumar and Verma, 2021; Piquero et al., 2020, 2021; Zhang, 2020); the significant increase of illegal drug abuse during the COVID-19 lockdowns (Balmori de la Miyar et al., 2020; Rashid, 2021; Niles et al., 2021; Zaami et al., 2020); and the increase in reports of cyber victimisation during the lockdowns with the internet as the main source for social interactions of millions of people (Chang et al., 2021; Buil-Gil et al., 2020; Buil-Gil and Zeng, 2021). However, most of the empirical studies in the field mainly focused on one city or one country (e.g., Hodgkinson and Andresen, 2020; Mccarthy et al., 2021; Rashid, 2021); or the only observed crime trends over a short period, ranging from several weeks (see, e.g., Balmori de la Miyar et al., 2020; Felson et al., 2020; Kim and Phillips, 2021), to three months (see, e.g. Mccarthy et al., 2021; Mohler et al., 2020), up to a maximum of six months (see, e.g. Langton et al., 2021; Rivette et al., 2021; Rashid, 2021).

This article tried to draw on the data from three international metropolises, London, New York, and Sydney to explore how the widespread lockdowns have impacted major types of crime in an urban context, and which areas were the main hotspot regions in order to advance our understanding of the unprecedented crime situations imposed by COVID-19 in a comparative way. This study aims to contribute to the field in three different aspects:

1. To deliver more comparative insights and solid evidence to the existing literature, by observing crime patterns in three cities, over a one-year period;
2. To apply classic criminological theories – routine activity and general strain – onto different cities, to identify whether some urban areas have been disproportionately affected by mobility change during lockdowns;
3. To explore how the trends and patterns in urban crimes will develop in the future, assisted by machine learning techniques and spatial predictive models. And, as a result, to provide references for efficient crime prevention and policing strategies.

2. Theories and Methods

The magnitude of the COVID-19 pandemic has manifested in the dramatic changes of social orders and controls (Liu et al., 2021; Stickle and Felson, 2020), during which the period dramatic changes in crime had been evidenced, especially in property crime. With the introduction of COVID-19 containment measures, people have had to stay at home and so strengthened the guardianship over personal property and space, resulting in a significant decrease in residential burglary and theft (Ashby, 2020; Campedelli et al., 2020; Halford et al., 2020). Whereas a substantial level of decline in violent crimes and crimes against persons was found by researchers immediately following COVID-19 containment measures (Abrams, 2021; Langton et al., 2021; Payne et al., 2020), except for domestic violence surges (Dai et al., 2021; Mohler et al., 2020; Boserup et al., 2020; Krishnakumar and Verma, 2021; Piquero et al., 2020, 2021; Zhang, 2020) upon the measures. Besides such conventional crimes, the COVID-19 pandemic has also given rise to other types of crime and delinquencies including, the rise in activity of drug lords in Mexico City despite the stay-at-home order (Balmori de la Miyar et al., 2020); the steep increase of illegal drug trafficking in Dhaka, Bangladesh by 75% (Rashid, 2021), and the significant increase of illegal drug abuse (Niles et al., 2021; Zaami et al., 2020); the skyrocketing number of hate crimes towards different ethnicities or religions (Gover et al., 2020; Xu et al., 2021); as well as the eye-catching increase of cyber victimization reports (e.g., online romance fraud) (Buil-Gil et al., 2020; Buil-Gil and Zeng, 2021) ever since the internet has become a primary source of social interaction during lockdown.

In the hope of containing the outbreak of the contagion, governments around the world have deployed NPI strategies of social distancing and mandatory lockdowns to restrict citizen activities. The changing organisation of individuals’ routine activities is best situated to account for inclinations, patterns, distributions, and trends in criminal activities amid lockdowns; in together with the intensified social isolation, the worsening financial conditions, and the uncertainty and anxiety caused by a lockdown towards aggregated general strain (Agniew, 1992) for committing crimes. Two prominent criminological theories are routine activity theory (RAT) and general strain theory (GST), and so combined to provide useful theoretical supports for understanding crime changes throughout the pandemic.

The RAT theory (Cohen and Felson, 1979) sets up a key foundation to the situation facilitating criminal acts: a motivated offender, suitable target, and capable guardianship, hence focuses on how a social context influences people’s vulnerability to crime (Dugan and Apel, 2005; Xu, 2009), and had been widely tested out on domestic violence research.
in recent decade (Hayes, 2018; Boman and Gallupe, 2020; Mohler et al., 2020; Piquero et al., 2021), which supports the hypothesis that, stay-at-home measures have extended the periods of contact between the vulnerable victims and potential motivated abusers for such type of crime. On the other hand, the rollout of massive containment measures has changed people’s routine activities dramatically, decreasing their time spent at public venues. Instead, people’s time spent in residential areas increased, hence contributing to the plummeting crime rates. GST theory explains that people undergo certain strains or stressors would engage in criminal behaviours (Agnew, 1992, 2002, 2010, 2015), which fits for the potential psychological impacts from extensive lockdowns by COVID-19 pandemic. The pandemic not only significantly boosted the number of unemployed people (Goolsbee and Syverson, 2021; Lemieux et al., 2020), inducing financial stress and substantial inequality, but, violence and property crimes were found concentrated in socio-economically disadvantaged regions (Hipp and Yates, 2011; Hooghe et al., 2011; Hulme et al., 2019; Payne et al., 2020). This also exaggerated the potential range of negative psychological impacts on citizens due to the constrained freedom of movement and changed stress. The lockdown resulting loneliness, anxiety, and depression can all be triggers for a delinquent coping mechanism (Niles et al., 2021), leading to escalating anger and potential violence in the home (Piquero et al., 2021). In line with GST, we can understand how the risk of domestic violence may have been magnified, especially in conjunction with the prevalent abuse of alcohol and drugs during the isolation periods (Piquero et al., 2020).

To reduce the transmission rates and impacts of COVID-19 in target cities in 2020, several non-pharmaceutical intervention (NPI) strategies, most prevalently, the national lockdowns, had been set in place in line with respective national public health policies and guidelines. The COVID-19 lockdown timelines in London, New York, and Sydney are depicted in Fig.1, demonstrating the first lockdown from late March until mid-to-late May 2020, and the second lockdown in November and December 2020.

![Fig. 1 COVID-19 Lockdowns in London and Sydney](https://comparecitycrime.com/london/london_timeline.html; https://comparecitycrime.com/sydney/sydney_timeline.html; https://comparecitycrime.com/newyork/newyork_timeline.html)

Haug et al., (2020) assessed the effectiveness of lockdowns depending on cities’ local context, with an emphasis on the corresponding impacts on local mobility. Halford et al., (2020) theorised that such mobility changes were the primary causes to crime rate changes in UK cities during the pandemic. In view of these insights, this study will take the lockdown milestone events as the temporal benchmarks, utilise city-wide land use functioning data derived from Open Street Map on six land use categories – recreation, grocery, work, transit, residential, and parks – this data is used to calculate monthly average mobility change in space (see detailed animation visualised on the project website http://www.comparecitycome.com) further relating to inner-city crime changes on monthly basis (Equation 1).

\[
Mob_{i,k} = \sum_{j=1}^{6} Mob_{i} \times \left( \frac{Area_{i,j}}{Area_{i}} \right) \quad \ldots \quad (1)
\]
where \( i \) is the index for fine geographical unit (i.e., \( i=1,2,3, \ldots, 4835 \) LSOA in London, \( i=1,2,3, \ldots, 312 \) SA2 in Sydney, \( i=1,2,3, \ldots, 2195 \) TRACT in New York City), \( j \) is the land use category (\( j=1,2,3,4,5,6 \)), and \( k \) is the index for consecutive dates (15th February 2020 – 31st December 2020) or months (February to December 2020).

Against the context of each target city, this study will investigate the correlation between land use-related mobility change and crime change, following the workflow as depicted in Fig.2: (1) time series analyses on monthly crime rate change and mobility change in each city, in the finest geographical scale; (2) spatially exploratory data analysis of inner-city hot spots during lockdowns; and (3) spatial regression analysis considering socio-economic contextual features’ influence, to address the starting question.

![Fig.2 Research design and workflow](image)

Among all three target cities, significant crime rate drops had been witnessed in 2020 compared to 2019 over the national pandemic incurred changes. In acknowledgement of the different crime classifications among the cities, major crime types will be analysed in this study. Alongside the data, the socio-economic status (SES) data for each city was derived from the latest corresponding census sources. This data was clustered by the machine learning KMeans algorithm to provide contextual clusters, and further fit into the spatial regression models for the purpose of predicting crime and providing evidence for crime prevention priority strategies.

### 3. Results

Taking the mobility index of 13th January 2020 as the benchmark for each city, it was obvious that mobility dropped significantly during each lockdown, especially during the early stages of each. This same trend is noticeable regardless of the mobility mode or the city. To get a vivid impression of the mobility change in the context of each city specifically, spatial exploration of at the finest geographical scale could be realised in an interactive way. For example, the monthly mobility change data extracted are in Fig.3 with the relevant hyperlinks.

![Fig.3 Monthly Mobility Change](image)

[https://comparecitycrime.com/london/london_monthly_mobility.html](https://comparecitycrime.com/london/london_monthly_mobility.html)  
[https://comparecitycrime.com/sydney/sydney_monthly_mobility.html](https://comparecitycrime.com/sydney/sydney_monthly_mobility.html)
In Fig. 4, monthly crime changes of the main crime categories – property crime and violent crime, in 2020, can be seen alongside year-on-year crime rates in 2019, to compare the impact of lockdowns on crime changes by main category, where the lockdown periods were highlighted in light yellow rectangular frames.

It is clear that the monthly changes in overall crime rate witnessed a cliff-drop reduction for all target cities during their first lockdowns (i.e., March to May), in comparison with previous year; for a majority part of their second lockdowns (i.e., November to December), the property crime rate shared similar impacts as overall crimes in response to the lockdown due to its bearing the largest proportion: a general decreasing trend in the property crime rate. However, there was an exceptional case in Sydney during the second lockdown with a relatively mild change. Violent crimes across all cities shared similar dramatic drops during the first lockdown when compared to 2019, but unlike property crime rates, they remained steady in the second lockdown. To further investigate the year-on-year variance in crime rate according to crime type across the lockdown months, results in Sydney (Fig.5 and Fig.6), London (Fig.7 and Fig.8), and New York City (Fig.9 and Fig.10) are presented below:
In Sydney, there were significant increases in violent crimes like homicide. The data also shows increased crime rates for several types of offences, including pornography, prostitution, and owning weapons in the March. During the same period, there were obvious year-on-year decreases in gaming offences, kidnapping, liquor offences, and robbery. Similar crime change impacts were reflected in April and May, and even in December, during the second lockdown. Blackmail and extortion became the dominating category to experience increased crime rates, quadrupling by the end of the year. Theft, as the main crime type, didn’t experience much change during the lockdown; there was a slight decrease in the number of theft cases during the lockdown first period. This trend for theft can be seen in parallel with another type of crime: transport regulatory offences. These findings are consistent with the mobility change trends seen upon implementation of NPI measures under the lockdown policy.

London witnessed the most significant crime rate drop during the first lockdown, especially for crime types like theft, burglary, and robbery. These categories saw an average decrease of more than 50% year-on-year, dropping most dramatically in April. There were comparable decreases in Violence Against the Person cases in April (down 30%), and Possession of Weapons dropped in March (by over 30%).

However, some other crimes – such as Domestic Abuse and Anti-Social Behaviour – saw large increases during the lockdown period when compared to 2019. For example, Drug Offences increased by over 50% in May compared to 2019 and continued increasing into the second lockdown in November.
New York City had exhibited abnormal pattern to the other two cities, in seeing significant crime increases in burglary, grand larceny of motor vehicle, and Murders throughout the lockdown months; but experienced cliff drops of Grand Larceny, Rape, Robbery and Felony assaults in the first lockdown (April and May). It indicated a stronger impact on local crime from the first lockdown, but severer crime recoveries in the second lockdown, making property crimes prominent for the city.

The spatial distribution of crime change hot spots in New York City was consistent with the other cities in that, the downtown of Manhattan saw the most crime decreases or fewer changes in the city, whilst the outskirt Staten Island and the Queens districts which had long been bearing higher crime rates in the city, saw most of the “parceled” crime increases during lockdowns.
The visualisation of results identified hot spots in these cities where the crime rate had dropped significantly. These areas with the greatest reduction in crime centred around transportation hubs and city centre areas, which is consistent with the hypothesis that mobility-related crime decreases during periods of national lockdown. It also demonstrates increasing crime rates in parks and other outdoor leisure spaces, in line with the RAT hypothesis that a lack of surveillance, or guardianship, results in increased delinquency. Alongside the overarching trends, the results depict an emerging increase of certain crimes, i.e. cybercrime, and a rocketing increase in drug-dealing over the lockdown periods. These crimes were found to occur in rural areas and parks in the city outskirts, possibly related to tension as defined in the GST model.

Upon applying the K-Means clustering technique on selected demographical, social, and economic status (SES) variables at the finest geographical scale, it was found in both target cities an optimal six (or five in New York City) clusters as depicted in Fig. 11. The clustering features were included in a spatially weighted regression model on crime change and mobility change, for prediction purposes.
To reflect the neighbouring regions’ influences on crime change against lockdowns, i.e., regional SES profiling, and impacts from mobility changes, the spatial lag model (SLM) and spatial error model (SEM) had been utilised to identify the most influential factors in Table 1. In London, mobility change and neighbouring regions’ crime change had exhibited significant positive influences on crime change; in exception with the insignificant relation between crime change and local SES features. However, Sydney’s crime change had been identified as only affected by its neighbouring areas’ crime changes, rather than the mobility change throughout lockdowns. New York City had been found to be influenced significantly by not only the neighbouring crime rates over the lockdowns, but also in the SEM model to have positive associations with mobility change and negative relation with contextual profiling during the 2nd lockdown.

Table 1 Spatial Regressions among London, Sydney and New York City

<table>
<thead>
<tr>
<th></th>
<th>London</th>
<th>Sydney</th>
<th>New York City</th>
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<tbody>
<tr>
<td></td>
<td>SLM</td>
<td>SEM</td>
<td>SLM</td>
</tr>
<tr>
<td><strong>R-squared</strong></td>
<td>0.553</td>
<td>0.068</td>
<td>0.198</td>
</tr>
<tr>
<td><strong>1st Lockdown</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobility Change</td>
<td>0.304***</td>
<td>0.342***</td>
<td>0.011</td>
</tr>
<tr>
<td>SES Cluster</td>
<td>0.178</td>
<td>0.129</td>
<td>-1.351</td>
</tr>
<tr>
<td>Neighbours’ Crime</td>
<td>0.127***</td>
<td>0.130***</td>
<td>0.087***</td>
</tr>
<tr>
<td>Change</td>
<td></td>
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<tr>
<td><strong>2nd Lockdown</strong></td>
<td></td>
<td></td>
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<tr>
<td>Mobility Change</td>
<td>0.375***</td>
<td>0.397***</td>
<td>0.273</td>
</tr>
<tr>
<td>SES Cluster</td>
<td>0.149</td>
<td>0.118</td>
<td>0.399</td>
</tr>
<tr>
<td>Neighbours’ Crime</td>
<td>0.125***</td>
<td>0.127***</td>
<td>0.082***</td>
</tr>
<tr>
<td>Change</td>
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***p<0.01, **p<0.05, *p<0.1

4. Conclusions

The study had compared lockdown impacts in 2020 in London, New York City, and Sydney, to relate the mobility changes with crime changes on a monthly basis in order to capture the city profiled features of crime changes in both type and spatio-temporal patterns. It had been recognised as a natural experiment of two prominent criminological theories: RAT and GST, in the conclusions that: (1) the impacts of the Covid-19 pandemic on the cliff-drops of most crimes greatly rest on RAT, as people’s mobility is constrained by lockdowns; while the emerging rise of particular crimes, such as domestic violence and drug abuse, which could be a result of people’s coping mechanisms to escape from the mental and emotional pressure caused by lockdowns are thus supported by GST; (2) identified hot spot regions experiencing most eye-catching cliff crime drops during lockdowns were mostly in transit hubs, city centres, etc., where the human mobility decreased significantly from the series NPI measures during lockdown; (3) those abnormal increases of city-characterised types of crime (e.g., blackmail in Sydney, drug offences in London, vehicile larceny in New York) may due to being lack of surveillance (e.g., national parks, public venues, etc.), with some seeing crimes bouncing back right upon the lifting of NPI measures considering tension resenting or strain expression. (4) It highlighted the driving effect from mobility change to crime change during lockdown periods in London and New York, but not the case in Sydney.
The work is expected to not only generate some comparative data-driven evidence for city policymakers, on crime prevention strategies and efficient policing, but also build up a replicable workflow/model based on the identified similarities among target cities, and to expand further to a broader range of cities. In future studies, wider variables would be considered, such as the variable measuring people’s actual strain levels or the changes of citizens’ routine activities to fit for more optimal model configurations.

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References