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Emergency Calls in the City of Vaughan (Canada) During the COVID-19 Pandemic: A Spatiotemporal Analysis

Ali Asgary[1], Adriano O. Solis[2], Nawar Khan[1], Janithra Wimaladasa[1], Maryam S. Sabet[3]
[1]Disaster & Emergency Management Area, School of Administrative Studies, York University, Canada, [2]Decision Sciences Area, School of Administrative Studies, York University, Canada, [3]Fleming College – Sutherland Campus, Canada.

Abstract

The COVID-19 pandemic has required governments to introduce various public health measures in order to contain and manage the pandemic's unprecedented impacts in terms of illnesses and deaths. This study analyzes the spatiotemporal distribution of emergency incidents in Vaughan, a medium-sized city in the Canadian province of Ontario, comparing occurrences prior to and during the pandemic. Emergency calls received and responded to by the Vaughan Fire and Rescue Service were examined using spatial density and emerging hotspot analysis based on 11 periods of various public health measures and restrictions set in place from 17 March 2020 to 15 July 2021, as compared with corresponding pre-pandemic periods in the preceding three years (2017-2019). The resulting analyses show significant spatiotemporal changes in emergency incident patterns, particularly during periods of more stringent public health measures such as 'stay at home' orders or lockdowns of nonessential business establishments. Results of the study could provide useful insights for managing emergency service resources and operations during public health emergencies.

Keywords: *Spatiotemporal analysis, COVID-19 pandemic, emergency calls, kernel density, emerging hot spot analysis, City of Vaughan.*

1. Introduction

Since the beginning of the COVID-19 pandemic in Canada in March 2020, regions and cities/municipalities in the Province of Ontario have gone through several stages of public health measures, including closures of public and sports facilities, schools, places of worship, and nonessential businesses. Using standard temporal analysis methods, Solis et al. (2022) observed dramatic downward shifts in frequencies of certain types of emergency calls received by the fire and rescue service of Ontario's City of Vaughan during the first ten months of the COVID-19 pandemic. The drops in emergency incidents have appeared to be consistent with public health measures set in place by government authorities at different stages of the pandemic.

Spatiotemporal methods have been rapidly developing in the field of data analytics, and have been applied in the analysis of emergency incidents for some time. With advances in technology, various new methods have been developed and used (Špatenková and Virrantaus, 2013; Yao and Zhang, 2016; Shafiei Sabet et al., 2019; Yao et al., 2019). Emerging hotspot analysis is among new methods added to GIS-based analyses and its usage in spatiotemporal analysis has been growing (Adepeju et al., 2016; Gudes et al., 2017; Rabiei-Dastjerdi and McArdle, 2020; Hart, 2021). Recent studies have sought to examine spatial patterns, some including emerging hotspot analysis, of COVID-19 cases in various contexts (Andersen et al., 2020; Mollalo et al., 2020; Mylona et al., 2020; de Cos et al., 2021; Purwanto et al., 2021).

Understanding how the pandemic impacts spatial and spatiotemporal distributions of emergency incidents during different pandemic stages may provide useful insights for fire and rescue service decision makers in managing resources as public health measures evolve over time. The current study is aimed at examining the spatiotemporal distribution, using spatial density and emerging hotspot analysis, of emergency calls in Vaughan during different COVID-19 phases and corresponding public health measures. To the best of our knowledge, this is the first study to examine the spatiotemporal patterns of emergency call variations during different phases of the pandemic.

2. City of Vaughan and Dataset

The City of Vaughan is one of nine municipalities in the Regional Municipality of York (also known as York Region) of the Canadian province of Ontario. Vaughan, which has a land area of 273.56 square kilometers, currently has an estimated population of close to 341,000 (City of Vaughan, 2022). It is situated just north of the City of Toronto, which is the provincial capital of Ontario and the largest Candian city in terms of population.

As of January 1, 2019, the Vaughan Fire and Rescue Service (VFRS) operated with ten fire districts and corresponding fire stations 7-1, 7-2, …, 7-9, and 7-10 (Figure 1). VFRS

maintains a Standard Incident Report dataset in which every single emergency call is recorded using a unique incident ID number and with specific attributes including incident type, longitude and latitude coordinates of the incident location, alarm date/time, responding station, dispatch date/time, arrival date/time, etc. (Office of the Fire Marshal of Ontario, 2009). In the three calendar years immediately preceding the pandemic, there were 11,331 emergency incidents in 2017, 11,834 in 2018, and 11,313 in 2019. Compared to the 2017-2019 annual average of just under 11,493 incidents per year, the total number dropped by 12.7% to only 10,037 incidents in 2020.

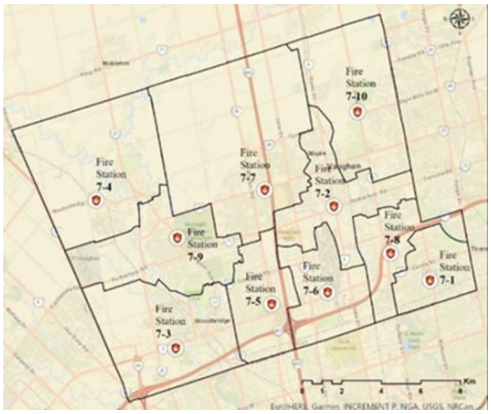


Figure 1. Fire districts and stations, City of Vaughan (as of 01 January 2019)

Table 1 summarizes the first 11 periods of the COVID-19 pandemic for the City of Vaughan. The 11 periods are based largely upon public health measures in effect in the province of Ontario and in York Region.

Table 1. First eleven COVID-19 periods applicable to the City of Vaughan

Period	# of days	Brief description of period
Period 1 (17 March - 18 May 2020)	63	State of Emergency I (lockdown began)
Period 2 (19 May - 18 June 2020)	31	Stage 1 reopening
Period 3 (19 June - 23 July 2020)	35	Stage 2 reopening
Period 4 (24 July - 18 October 2020)	87	Stage 3 reopening
Period 5 (19 October - 13 December 2020)	56	Modified Stage 2 reopening
Period 6 (14 December 2020 - 13 January 2021)	31	Lockdown
Period 7 (14 January - 21 February 2021)	39	State of Emergency II
Period 8 (22 February - 02 April 2021)	40	York Region as a 'red zone'
Period 9 (03 April - 10 June 2021)	69	'Stay-at-home' order; initially 'emergency brake' order
Period 10 (11 June - 29 June 2021)	19	Step 1 of Province of Ontario's Roadmap to Reopen
Period 11 (30 June - 15 July 2021)	16	Step 2 of Province of Ontario's Roadmap to Reopen

3. Findings

3.1. Emergency Incidents Before and During the Pandemic

Table 2 summarizes the total numbers of emergency calls received by VFRS during the 11 periods, in comparison with corresponding periods during the three years (2017-2019) immediately preceding the pandemic. With the exception of Period 9, total numbers of emergency incidents have declined during all 11 COVID-19 periods under study compared to corresponding periods in the pre-pandemic years 2017-2019.

Table 2. Emergency incidents during COVID-19 periods 1-11 vs. corresponding periods in 2017-2019

Period	# of Days	2017	2018	2019	Average 2017-2019	During COVID-19
Period 1 (17 March - 18 May 2020)	63	1,933	2,013	1,821	1,922.3	1,476
Period 2 (19 May - 18 June 2020)	31	989	1,073	974	1,012.0	873
Period 3 (19 June - 23 July 2020)	35	1,094	1,157	1,139	1,130.0	986
Period 4 (24 July - 18 October 2020)	87	2,790	2,829	2,705	2,774.7	2,466
Period 5 (19 October - 13 December 2020)	56	1,699	1,822	1,694	1,738.3	1,570
Period 6 (14 December 2020 - 13 January 2021) *	31	1,223	861	957	1,013.7	854
Period 7 (14 January - 21 February 2021)	39	1,084	1,208	1,363	1,218.3	1,044
Period 8 (22 February - 02 April 2021)	40	1,196	1,153	1,171	1,173.3	1,104
Period 9 (03 April - 10 June 2021)	69	2,122	2,292	2,099	2,171.0	2,236
Period 10 (11 June - 29 June 2021)	19	654	628	589	623.7	549
Period 11 (30 June - 15 July 2021)	16	501	517	515	511.0	484

* Numbers reported for Period 6 in 2017, 2018, and 2019 are for 14 December 2017 - 13 January 2018, 14 December 2018 - 13 January 2019, and 14 December 2019 - 13 January 2020, respectively.

Among all major incident types (e.g., property fires/explosions, medical emergencies, vehicle collisions/extrications, false fire calls), average daily occurrences of vehicle collisions and extrications during COVID-19 periods exhibited the most dramatic percentage changes (decreases) compared to the same period during pre-pandemic years (Figure 2).

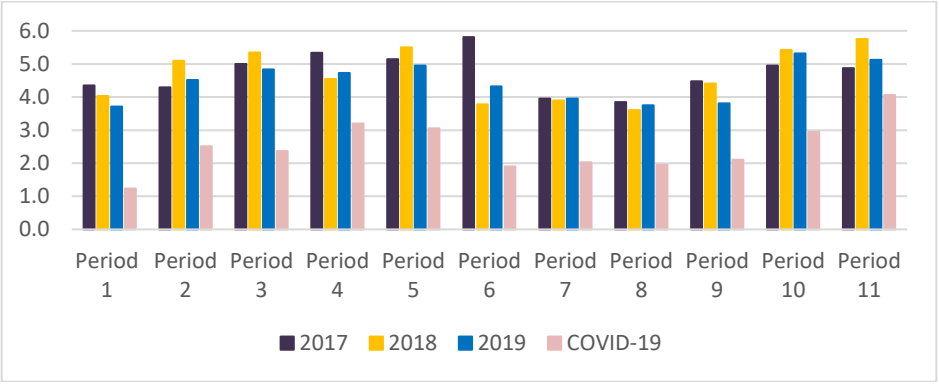


Figure 2. Vehicle collisions/extrications by period: Average per day

3.2. Density Analysis

To analyze the data on emergency incidents, we initially performed kernel density analysis using ArcGIS Pro 2.8 (ESRI, 2021) to examine changes in the spatial distribution of emergency calls (total and by major incident type) before and during various periods/stages of the pandemic. The kernel density tool calculates the density of point features around each 10 m. × 10 m. output raster cell (ESRI, 2021) based on a quartic kernel function (Silverman, 1986, eq. 4.5). Density per 1 sq. km. (1 km. × 1 km.) is evaluated.

In view of the limited space, we provide as an illustration only kernel density maps pertaining to vehicle collisions/extrications, and only for Periods 1 and 2 (Figure 3). These sample maps clearly show less colour/lighter shades in the maps for Periods 1 and 2 of the pandemic relative to the maps for the corresponding periods in the preceding year (2019, left column).

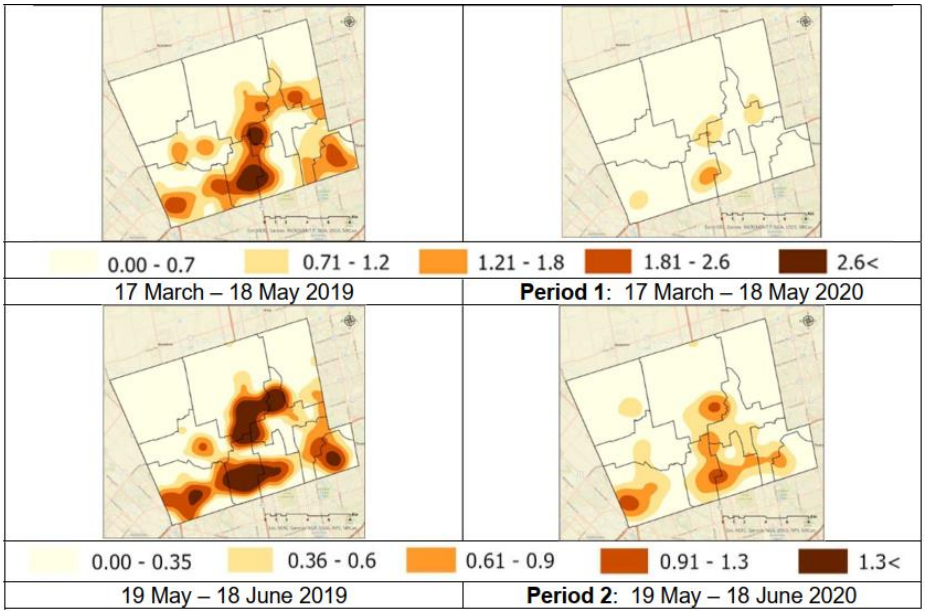


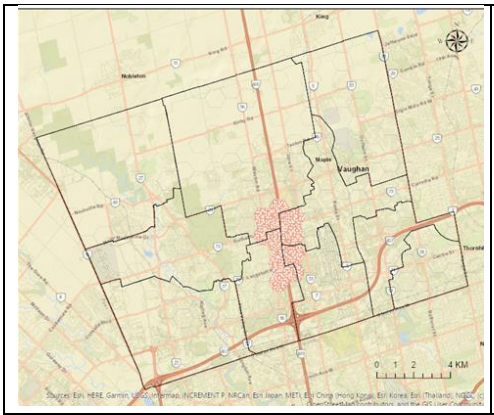
Figure 3. Kernel density maps for vehicle collisions/extrications: Periods 1 and 2

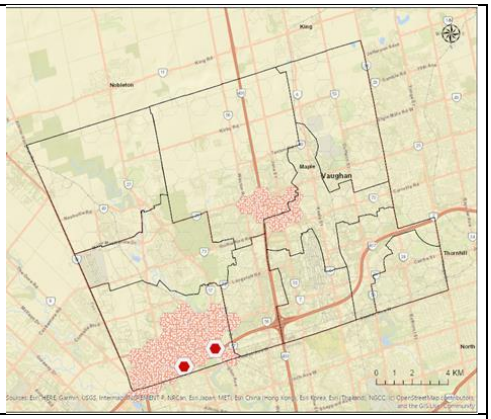
The above observation may be associated with reductions in vehicular traffic resulting from lockdowns, 'work from home', and other public health measures. With vehicle collisions occurring particularly on highways that pass through certain districts, the changes would significantly impact resource use of fire stations in districts that include the major highways.

3.3. Emerging Hotspot Analysis

We applied emerging hotspot analysis (EHA) using ArcGIS Pro 2.8 (ESRI, 2021) to understand spatiotemporal variations of emergency calls. EHA provides a summary of spatial

distribution, identifies significant clusters in the dataset, and explores patterns over time. EHA classifies the data into several patterns including: 1) 'no pattern', 2) 'new pattern', 3) 'oscillating pattern', and 4) 'sporadic pattern' (Gudes et al., 2017). Definitions/indicators of various patterns (new, consecutive, intensifying, persistent, diminishing, sporadic, oscillating, or historical hot/cold spot) are available in the ArcGIS platform (ESRI, 2021). Here we provide as an illustration a sample of EHA outputs pertaining to vehicle collisions/extrications (Figure 4).





17 March 2019 – 16 March 2020 (before pandemic) Time step Interval: 2 weeks Distance Interval: 1 km Neighborhood Distance: 2km	**17 March 2019 – 15 July 2021** (until Period 11 of pandemic) Time step Interval: 2 weeks Distance Interval: 1 km Neighborhood Distance: 2km

Figure 4. Emerging hotspot analysis before and during the pandemic for vehicle collisions/extrications

Prior to the pandemic (17 March 2019 – 16 March 2020), sporadic hotspots were concentrated mainly around the major highway (Ontario Highway 400) which cuts through the city (north-to-south). As restrictions were being lifted in Periods 10-11 and there was more movement of people on the roads, sporadic hotspots, and even a couple of new hotspots, appear to have begun to develop also in District 7-3 (closer to Highway 7).

4. Conclusion

This study has examined the geographic distributions and spatiotemporal patterns of emergency calls in the City of Vaughan during the first 11 periods of the COVID-19 pandemic and compared them with the corresponding pre-pandemic periods in 2017-2019. We believe that this is the first study to apply spatiotemporal methods in evaluating changes in the frequency and mix of emergency incidents that have been responded to by a municipal fire and rescue service over various periods of the pandemic, each period pertaining to specific public health measures/restrictions. We applied kernel density analysis and emerging

hot and cold spot analyses. The results suggest that the COVID-19 pandemic and public health measures introduced to respond to it during different periods had significant impacts on the spatiotemporal distribution of emergency incidents in the city. These may have potential implications for resource planning and allocation across fire districts/stations and provide insights on how to manage fire and rescue service operations as further stages of the pandemic unfold. Conventional data analyses can show changes to some extent, but spatiotemporal analyses enable relating such changes in space over time to further examine locational attributes that determine changing patterns in occurrences of emergency incidents. Emergency service decision-makers (in this case, those of the VFRS) can apply insights gained from the analyses in planning and management of resources – particularly the reallocation of firefighting apparatus and crews to the various fire districts/stations – in line with public health measures/restrictions associated with the latest period of the still ongoing pandemic or of similar new pandemics that may arise in the future.

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