An Analysis of Firearm-Related Shooting Occurrences in Toronto*

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Gun violence remains a significant public safety concern in Toronto that necessitates appropriate enforcement strategies to minimize. This paper analyzes police shooting occurrences in the city from 2014 to 2023, where data shows that incidents peaked during summer months and late hours of the day, and the number of shooting occurrences experienced constant decline following the introduction of stricter gun control measures. Findings also highlight the influence of seasonal factors and potential nighttime effects that may inform the necessary approaches to minimize firearm-related shootings. Understanding these dynamics is essential for not only reducing shootings but also crime as a whole most especially in urban environments.

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*Code and data are available at: https://github.com/jfhasj/opendata-toronto-analysis

1 Introduction

The increasing prevalence of gun violence in densely-populated and urban settings has raised significant concerns among policymakers, law enforcement, and communities alike. Ontario experienced the largest increase in shooting occurrences from 2021 to 2022 (Perreault 2024), and analyzing patterns and trends in shootings in this regard could become vital in understanding the broader ramifications of firearm-related incidents and crime in general. This being said, this paper aims to provide a comprehensive analysis of firearm-related shooting occurrences in Toronto from 2014 to 2023 using data from the Toronto Police Service available as a dataset on Open Data Toronto (Toronto 2024). By examining this data, we seek to identify any potential arising trends that may assist law enforcement in developing appropriate strategies to mitigate the number of shootings in years to come.

Despite the existing literature on gun violence, there remains a lack of localized studies that specifically address the temporal aspect of shootings in Canada, more specifically Toronto since most studies have largely focused on national trends or on cities in the US where shootings often occur. This paper aims to bridge this gap by investigating the possible presence of similar trends within Toronto and how these could be explained within the Canadian context. This paper also aims to provide details on and answer the question, "Are patterns in shooting occurrences noticeable over time? If so, in what ways? This paper aims to answer this question in relation to the number of shooting occurrences in Toronto with respect to seasonal variations and time-of-day effects.

Results show that the number of shooting incidents generally increased from 2014 to 2019, followed by a decrease from 2020 to 2023. This trend correlates with implemented nationwide laws aimed at reducing gun violence, including the ban on assault-style weapons after the 2020 Nova Scotia mass shooting. Furthermore, results indicate that summer and winter months exhibit the highest and lowest rates of shooting occurrences respectively. Additionally, we observed a trend based on the time of day, where shootings are more likely to occur during nighttime hours and less likely to occur during the day.

Understanding these patterns is crucial for developing targeted interventions to reduce gun violence in Toronto. This study has numerous implications, the most significant of which is its potential to provide valuable insights for creating safer environments. This paper is structured as follows: Section 2 delves into an overview of the data used and some results and findings on this data, and Section 3 presents discussions surrounding our results, along with limitations and recommendations for future research.

2 Data

2.1 Overview

The dataset used in this analysis, entitled "Shootings & Firearm Discharges", was taken from Open Data Toronto and downloaded using the `opendatatoronto` library (Gelfand 2022). It records every reported occurrence of shootings or firearm discharges (excluding suicides and police involvements). All the data analysis was done through R (R Core Team 2024), along with external R packages, namely `tidyverse` (Wickham et al. 2019), `knitr` (Xie 2024), `png` (Urbanek 2022), `here` (Müller 2020), `ggplot2` (Wickham 2016), `grid` (R Core Team 2024), and `dplyr` (Wickham et al. 2023).

The dataset used in the Open Data Toronto catalogue is published by the Toronto Police Service via the Toronto Police Service Public Safety Data Portal (CPLC, n.d.). The data is refreshed quarterly and is accurate as of July 23, 2024. The raw data set contains information on the date and time — with varying granularities — of each reported shooting and the number of injuries and deaths, if any, among others.

The process of collecting data on shooting occurrences is as follows: when a shooting is reported, it is either done through 911 calls (which are recorded), or it is reported to a police officer who takes note of important details (date, location, names, and the like). These details are then inputted into the Toronto Police Service's database. After some data transformations (such as splitting dates and times, classifying the time of day, and so on), data is then published as a dataset on their portal as well as Open Data Toronto.

This being said, it is worth noting that only one other dataset in the Open Data Toronto catalogue contains data about shootings; however, it contains data only from 2014-2019, is less granular with its data on shooting times and dates, and has not been updated since 2022. Thus, it was not used in this analysis. The variables used in this analysis include the following: `OCC_DATE`, `OCC_YEAR`, `OCC_MONTH`, `OCC_TIME_RANGE`, and `DIVISION`. A sample of the cleaned data is provided in Table 1. Note that these column names from the original dataset were consequently renamed for easier reference.

Table 1: Sample of Cleaned Shooting Dataset

date	year	month	time_of_day	division
2014-01-01	2014	January	Afternoon	D14
2014-01-01	2014	January	Night	D33
2014-01-02	2014	January	Evening	D12
2014-01-08	2014	January	Afternoon	D41
2014-01-10	2014	January	Afternoon	D42

Additional summary statistics are displayed in Table 2 below. We see that there were a total of 3,779 shooting occurrences from 2014-2023, giving a mean of about 378 shootings per year, equivalent to more than 1 occurrence per day. However, as we have seen from Table 1, shootings do not actually happen every day (for example, the next shooting after January 2, 2014 occurs on January 8, 2014). In addition, consider the standard deviation of 90.7 shootings; this tells us that there is considerable variation in the number of shootings each year, as seen in Figure 1.

Table 2: Summary Statistics for Shooting Occurrences in Toronto from 2014-2023

Statistic	Value
Total Shootings	3779.00
Mean Shootings per Year	377.90
Mean Shootings per Month	31.49
Mean Shootings per Day	1.04
Standard Deviation of Yearly Shootings	90.70

2.2 Results and Findings

The succeeding graphs in this section display various relationships between shooting occurrences and the variables in Table 1. Figure 1 shows the number of shootings by year.

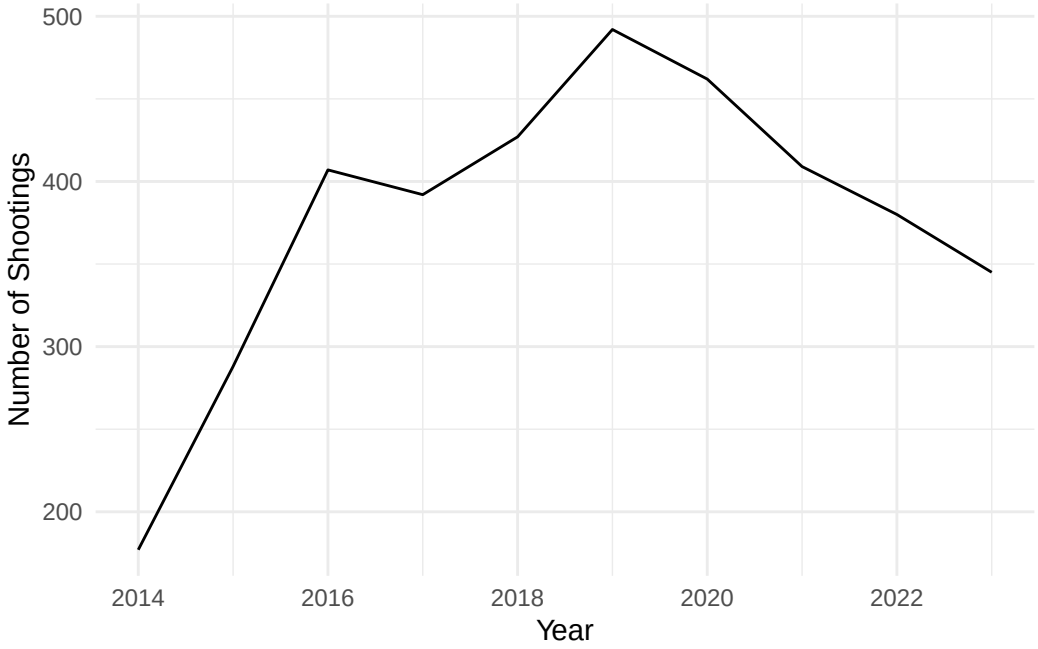

Figure 1: Total Number of Shooting Occurrences from 2014-2023

We can see that shootings increased in every year from 2014-2016, decreased in 2017, increased again in every year from 2017-2019, followed by decreases in every year from 2020-2023.

It is worth investigating how the number of shooting occurrences change throughout the seasons. Figure 2 shows that among the seasons, summer has generally more shootings than any other; winter has the least.

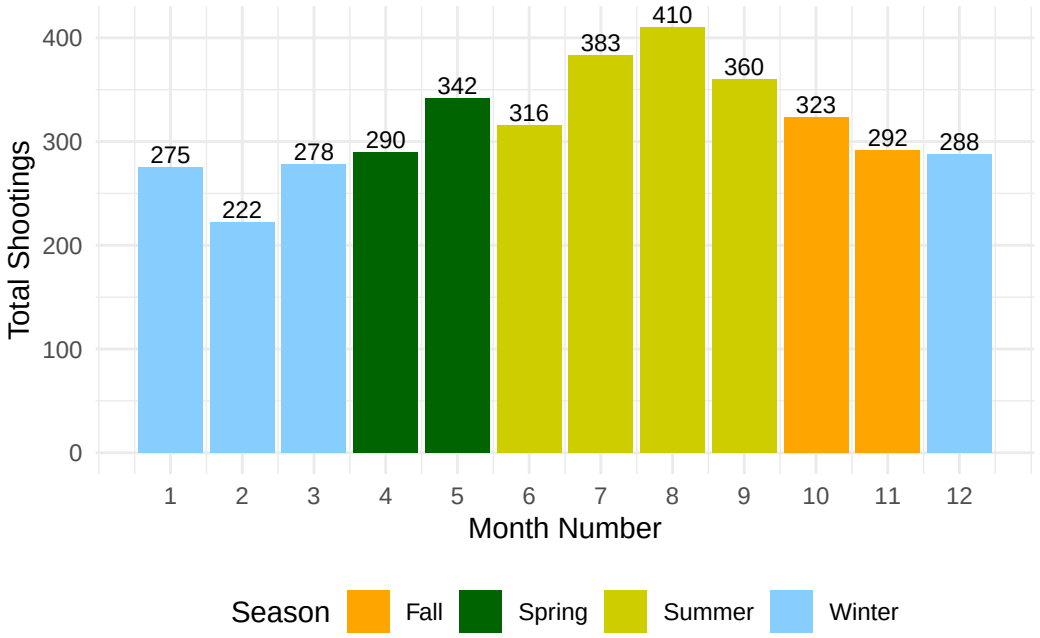

Figure 2: Total Number of Shootings by Month

Moreover, we see that at the peak of summer (around July and August) is when the highest monthly total number of shootings occur while the peak of winter (around February) is when the least number of shootings occur.

We investigate this more in Figure 3 where we show the average number of shootings per month by season.

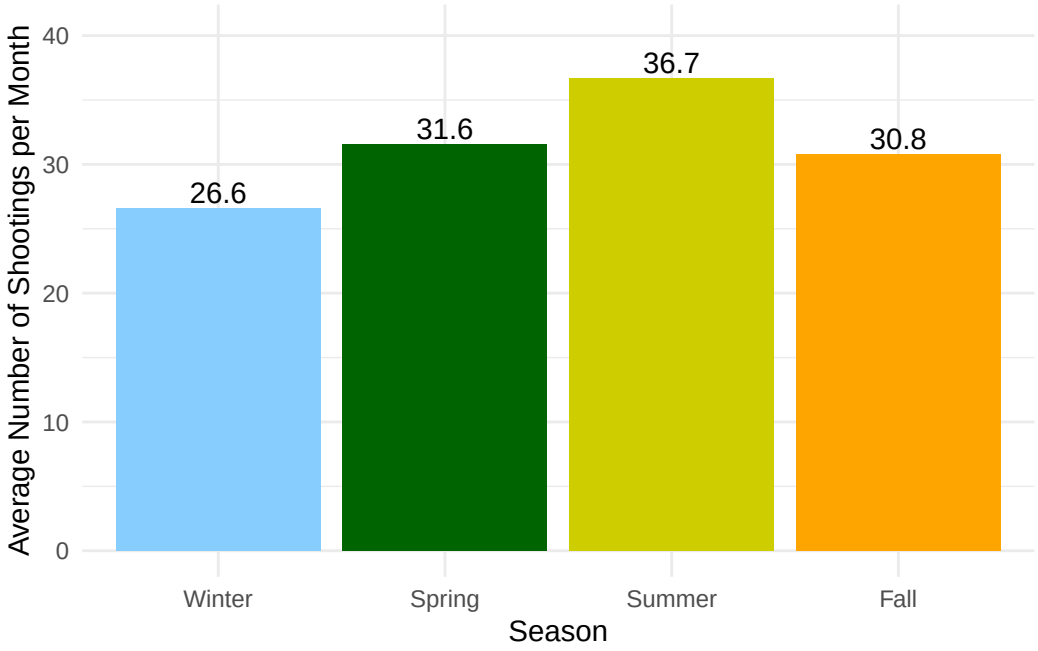

Figure 3: Average Number of Shootings per Month by Season

We see that from 2014-2023, the number of shootings are highest over the summer months (with 36.7 occurrences per month on average) and at its lowest over the winter months (with 26.6 occurrences per month on average).

Figure 4 shows the average number of yearly shootings by the time of day, with about 27 shootings per year occurring in the morning, and about 148 shootings per year occurring in the evening.

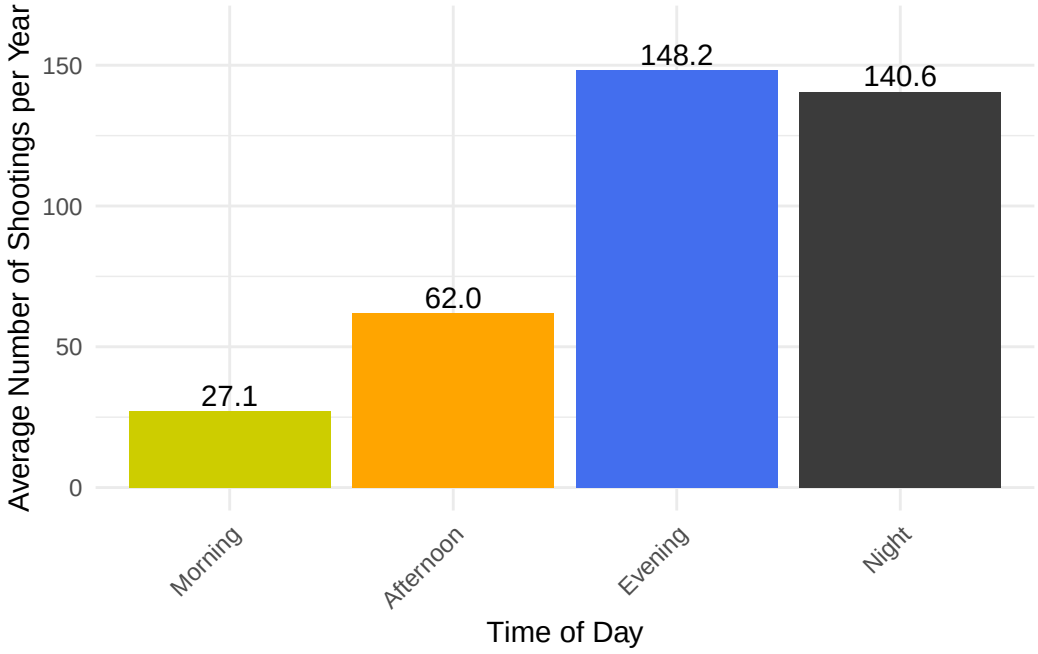

Figure 4: Average Yearly Number of Shootings by Time-of-Day

As such, shootings are about 5.2 to 5.5 more likely to occur in the evening (6pm to 11:59pm) or at night (12am to 5:59am) compared to morning hours (6am to 11:59am).

Figure 5 shows divisions in Toronto where firearm discharges and shooting occurrences might be more prevalent.

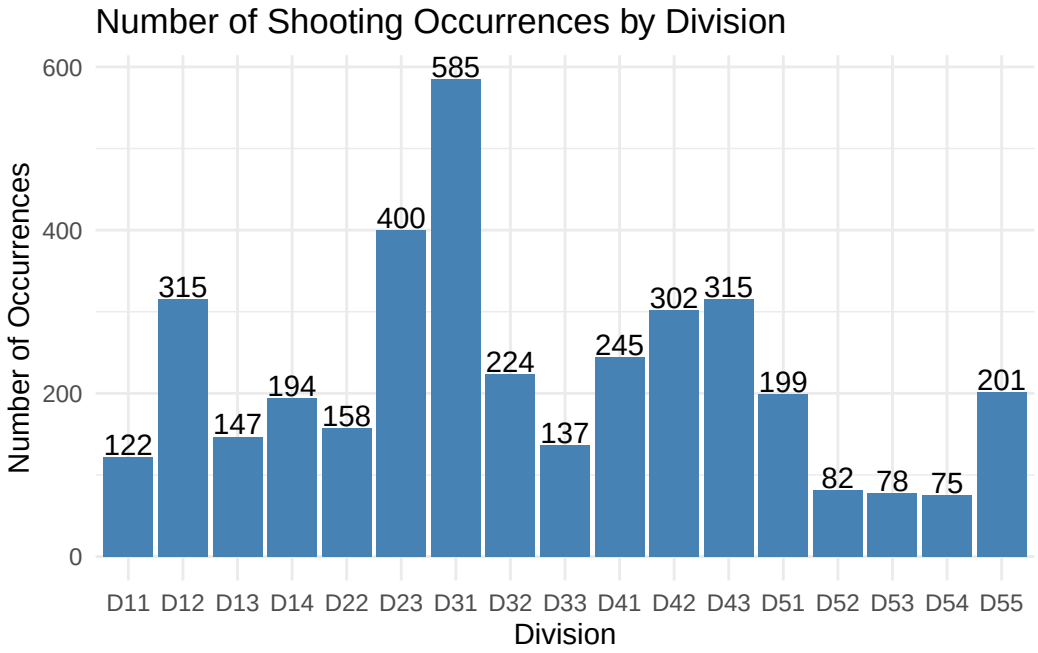

Figure 5: Number of Shootings by Division

Here, we see that D23 and D31 have 400 and 585 shooting occurrences respectively from 2014-2023, which are significantly higher than other divisions such as D53 and D54, which have 78 and 75 shooting occurrences respectively along the same timespan.

We discuss each of the above graphs further in Section 3 next.

3 Discussion

In Figure 1, we see a general increase in the number of shootings from 2014-2019 before successive decreases from 2020-2023. One reason for the decreasing trend from 2020-2023 could partially be attributed to the effects of the pandemic. National lockdowns forced people to stay inside their homes, minimizing face-to-face interaction and thus limiting opportunities for shootings.

However, it could be argued that a larger contributor to the sudden shift in the number of shootings between the aforementioned time periods is the Canadian government's implementation of a ban on assault-style weapons as a result of the Nova Scotia mass shooting in 2020,

the worst in Canadian history (Cecco 2020). This ban covers the buying, selling, importing, and owning of such weapons. Although handguns are most often used in shooting-related crimes such as homicides (Perreault 2024), the ban on assault-style weapons still contributed to the decrease in the number of shootings. The Canadian government has implemented parts of Bill C-21, an initiative to strengthen gun control measures. One measure which has already been put in place is the aforementioned ban on assault-style weapons; another is the "National Handgun Freeze" which imposes "restrictions on the sale, purchase, transfer, or import of handguns by individuals (with limited exceptions)" according to (Canada 2022). With this, we expect the number of shooting occurrences in 2024 to further decrease from previous years.

From Figure 2 and Figure 3 above, we see that summer and winter months see the highest and lowest (number and) rate of shootings. This is consistent with what (Geoffroy and Amad 2016) find in their study "Seasonal Influence on Mass Shootings." In the years covered by their study (2013-2015), the researchers found that there was "a clear increase in the number of mass shootings as well as the numbers killed and injured during the summer", which is consistent with our findings in Toronto. They also state that shootings are highest "in May and finishes around September – October" which we also see in Figure 2. Additional data also support this idea as found by (Moreau 2022) where he showed the existence of a seasonal regularity of crime in Canada. He states that in 2021, crime levels are lowest during fall and winter and highest during summer. He also postulates that this phenomenon is due to higher and lower tendencies for socialization during summer and winter months respectively.

From Figure 4, we see that shootings occur most in the late hours of the day (at night and in the evening). This trend was also examined by (Klerman et al. 2024); in analyzing some US cities, data showed that most shootings occurred at night and that such a nighttime effect exists. They also observed seasonality in crimes which was previously seen in Figure 2 and Figure 3 as well.

All this being said, there is substantial evidence of relationships between the number of shooting occurrences and the year where we saw a general increase and decrease from 2014-2019 and 2020-2023 respectively as shown in Figure 1. Moreover, there also exists seasonal trends in shooting occurrences from Figure 2 and Figure 3, where we saw that most shootings occur in the summer, and the least occur in the winter. Finally, the time of day also has an effect on the number of shootings, with a nighttime effect being prominent as shown in the study by (Klerman et al. 2024) and Figure 4.

4 Appendix

4.1 The Different Divisions

The divisions referenced in Figure 5 cover different neighbourhoods in Toronto and is also shown in Figure 6 below. The whole list of divisions and their neighbourhoods can be found here. For example, University of Toronto St. George belongs to D52 (Service 2024a).

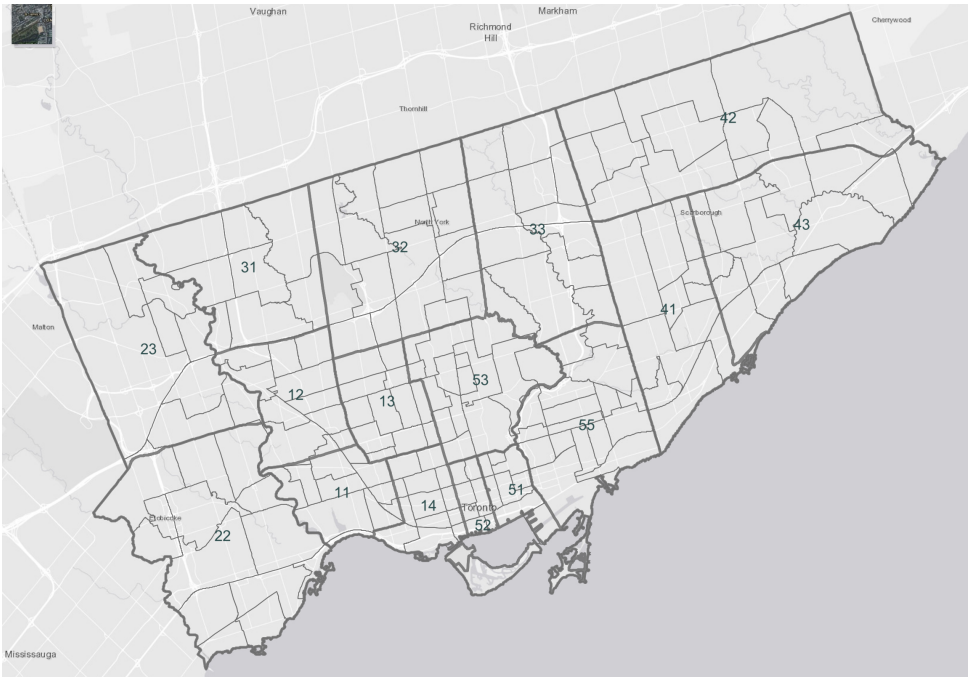

Figure 6: A Map of Toronto's Different Divisions

4.2 Data Cleaning, Limitations, and Future Research

This dataset provided by the Toronto Police Service has incomplete location data before 2014, so we focus on 2014-2023. 2024 data is excluded, as it is currently incomplete. Columns not pertinent to this analysis were also removed, namely `X_id`, `EVENT_UNIQUE_ID`, `HOOD_158`, `NEIGHBOURHOOD_158`, `HOOD_140`, `NEIGHBOURHOOD_140`, and `geometry`. Moreover, the creation of the cleaned dataset also involved removing any entries with `NA`s in any of the columns in Table 1. This ensured that no missing data was present, and unambiguous analysis was able to be performed.

The dataset used in this analysis does not take into account firearm-related shootings caused by police involvements and suicides. It also includes instances of accidental firearm discharges, which may not injure anyone. Although all these are not technically crimes, their exclusion (or

inclusion, in the case of accidental firearm discharge data) might affect how the use of firearms in Toronto and Canada is perceived and is something worth taking note of. It is also important to note that although D54 is present in the dataset, it is not seen in Figure 6. This is because D54 and D55 recently amalgamated (Service 2022), and neighbourhoods subsumed under D54 have now been subsumed under D55 instead. Moreover, neighbourhoods may overlap between more than one division. Aside from this, there may be some inconsistencies with the dataset with regards to the location data of shooting occurrences. This is because of privacy concerns with those involved in shootings; as such, "the location of crime occurrences have been deliberately offset to the nearest road intersection node" (Service 2024b). Consequently, however, the quantities shown in Figure 5 may either be understated or overstated, which results in inaccuracies.

With this, an area of future research worth studying further is the correlation between the number of shooting occurrences and the socio-economic status of those committing the crime or the area in which the shootings occurred. In addition, the population densities of each division could be obtained, and another analysis could be performed to investigate a potential correlation between population density, among other factors, and the number of shootings (and crime in general). This would provide a better idea on the "distribution" of shootings in different neighbourhoods of Toronto, as well as see which factors have larger effects or stronger correlation with crime statistics, allowing law enforcement to focus strategic efforts in more affected areas.

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