Fire Safety Systems in Mitigating Fire Incidents*

Deyi Kong

September 27, 2024

This study investigates the role of fire safety systems, specifically fire alarms and sprinkler systems, in mitigating the effects of fire incidents across Toronto. There are over a thousand fire incidents each year in Toronto, which suffers significant property damage and risk to human life. By analyzing data from the Ontario Fire Marshal (OFM) between 2011 and 2023, we assess how these systems impact evacuation success and the reduction of property loss. Our analysis demonstrates that fire safety systems significantly improve outcomes in fire incidents

1 Introduction

"It was like watching molten lava move through the building," Aronson remembers. "Just a huge blob of fire that flowed and flowed" (Rosen 2019). Fire incidents pose threats to urban safety, causing property damage, injury, and loss of life. As cities like Toronto experience over a thousand fire incidents annually, effective fire safety systems are crucial to minimizing these impacts. Effective fire protection measures have played a crucial role in mitigating the impact of these incidents (Rebekah 2023). Most fatal fires occur at night when people are sleeping, a working smoke alarm will detect smoke and sound to alert you (Fire Chiefs 2024). Sprinkler systems are silent protectors against the threat of fires in buildings and spaces (Origin and Cause 2023). While these systems are widely implemented, questions remain about how these systems specifically influence outcomes such as property loss, fire containment, and successful evacuation.

Toronto Fire Services is the City's only all hazards emergency response organization with an emphasis on quality services, efficiency, effectiveness, and safety (Toronto 2024). This study focuses on analyzing data from Toronto's fire incidents between 2011 and 2023 to evaluate how fire alarms and sprinklers influence key outcomes such as property loss, fire containment, and

*Code and data are available at: https://github.com/eeeee-cmd/Toronto_Fire_System_Analysis.git

evacuation success. Using data provided by the Ontario Fire Marshal (OFM), we examine variables such as the area of fire origin, estimatded property loss, response times, and the presence of fire safety systems. By exploring these relationships, we aim to provide a clearer picture of how these systems contribute to minimizing the damage caused by fire incidents.

The findings of this study have important implications for urban fire safety policies and building regulations. Understanding the real-world effectiveness of fire alarms and sprinkler systems can inform better safety practices, guiding future regulations for the installation and maintenance of such systems in residential and commercial buildings. The remainder of this paper is structured as follows: In Section 2, we provide an overview of the data and methodology used in the analysis in Section 2.1; second, we present the key results and summary in Section 2.2; and finally, we discuss the policy implications of these findings and suggest areas for future research in Section 3.

2 Data

2.1 Raw Data

The data used in this paper is derived from Open Data Toronto and is read into this paper through the opendatatoronto library (Gelfand 2022). All data were processed and analyzed using R (R Core Team 2023), associating with Libraries tidyverse (Wickham et al. 2019), janitor (Firke 2023), knitr (Xie 2024), dplyr (Wickham et al. 2023), and lubridate (Grolemund and Wickham 2011). Graphics were made using ggplot2 (Wickham 2016).

Fire Incidents data used in the paper is provided by the Toronto Fire Service (TFS) and aggregated by the Ontario Fire Marshal (OFM) from Janurary 1, 2011 to December 31, 2023; covering 32000 observations of 43 variables. The dataset tracks the area of origin, building status, business impact, casualties, estimated dollar loss, time stamps for each actions (notified, arrived, controlled), and whether there was a working alarm and sprinkler on site. Incidents with incomplete data may be under investigation or is classified as a no loss outdoor fire.

2.2 Cleaned Data

In the analysis, the data being utilized are within the time range from Jan.1, 2011 to Dec.31, 2023. Due to the high redundancy of the raw data containing variables such as id and generated incident numbers, this paper simply drops all the irrelevant features. The remaining features in the study are area of fire origin, estimated loss, casualties, extent of fire, ignition source, fire alarm system, sprinkler system, smoke alarm system, and status of fire. This paper replaced some of the numeric data points containing missing values "NA" by 0, then the remaining entries that has no determinations were dropped to simplify the analysis procedure.

There are several new feature created for a more effective relation with the time stamps. The new features, year and month, were extracted by the date of each fire incident happens. TFS_duration variable measures the time spent by TFS to control the fire. TFS_Notified_Till_Arrival measures the time spent by TFS to get to the incident once received the alarm. Here is a quick look of the data set:

```
Rows: 13,687
Columns: 12
$ year                                  <dbl> 2018, 2018, 2018, 2018, 2018, 2~
$ month                                 <chr> "Winter", "Winter", "Winter", "~
$ area_of_origin                        <chr> "75 - Trash, rubbish area (outs~
$ estimated_dollar_loss                 <dbl> 0, 2000, 5000, 500, 0, 15000, 0~
$ civilian_casualties                   <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0~
$ extent_of_fire                        <chr> "1 - Confined to object of orig~
$ ignition_source                       <chr> "1 - Confined to object of orig~
$ fire_alarm_system                     <chr> "No System", "No System", "Syst~
$ smoke_alarm_at_fire_origin            <chr> "No System", "No System", "Pres~
$ sprinkler_system                      <chr> "No System", "No System", "Syst~
$ status_of_fire_on_arrival             <chr> "3 - Fire with smoke showing on~
$ fire_alarm_system_impact_on_evacuation <chr> NA, "8 - Not applicable: No fir~
```

Figure Figure 1 shows a set of bar charts of the number of fire incidents happened in each year separate by seasons and filled with fire status. This paper assumed winter from December to February, every season rotates with a cycle of 3. There is an interesting observation such that fire incidents were potentially higher in the Spring than other seasons; and half of the fire incidents were luckily extinguished before TFS takes control or smoke only. In addition, the total fire incidents amount went down significantly in current five years (2019 - 2023) comparing to previous year (2011 - 2018).

The bar graph Figure 2(a) shows the total estimated property loss due to fire incidents for each year from 2011 to 2023. The chart highlights fluctuations in loss over the years, with certain periods showing peaks, possibly due to a few large-scale incidents, followed by a general decline in recent years. This may be indicative of the effectiveness of fire safety systems in reducing the financial damage caused by fires. The bar Figure 2(b) depicts the count of fire alarm systems present at fire incident locations over time. It shows a gradual increase in the installation of fire alarms in buildings throughout the analyzed period, which reflects greater adherence to fire safety regulations and growing awareness of the importance of fire alarms in preventing fire-related damage. In (**Similar?**) to the fire alarm graph, this bar chart illustrates the frequency of sprinkler system presence at fire incident sites over the years. It shows a consistent increase in the use of sprinklers, suggesting that building owners are increasingly adopting these systems as a precautionary measure, further contributing to better fire containment outcomes.

As we can saw previously in Figure 2, the number of fire incident has dropped significantly.

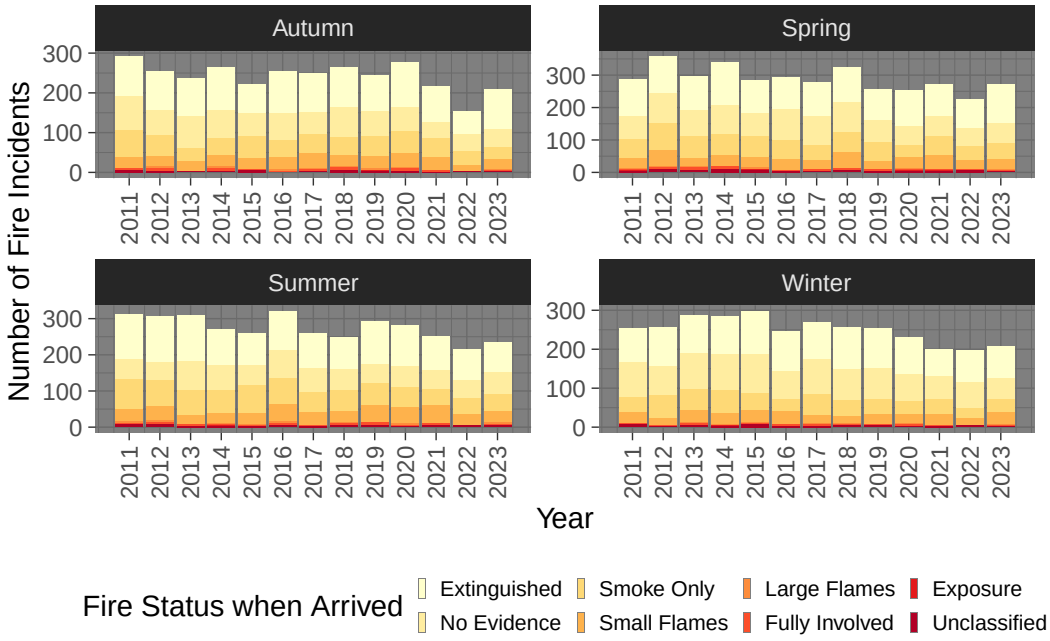


Figure 1: Distribution of incidents in each seasons with respect years by fire status

3 Discussion

3.1 First discussion point

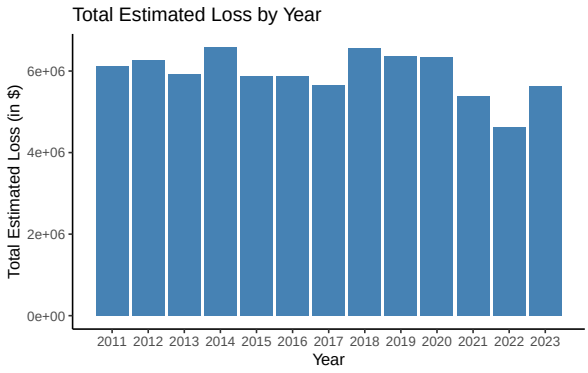
If my paper were 10 pages, then should be be at least 2.5 pages. The discussion is a chance to show off what you know and what you learnt from all this.

3.2 Second discussion point

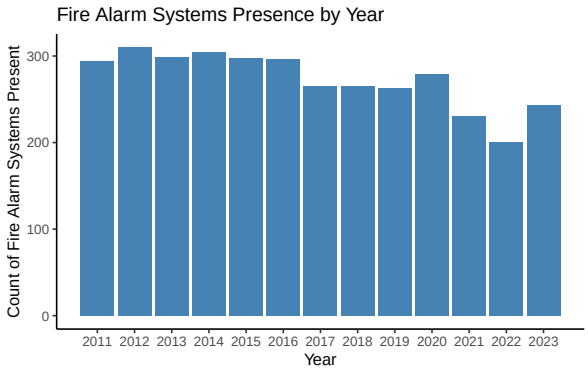
3.3 Third discussion point

3.4 Weaknesses and next steps

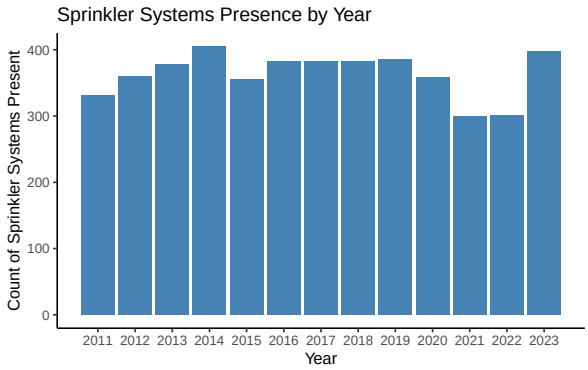
Weaknesses and next steps should also be included.



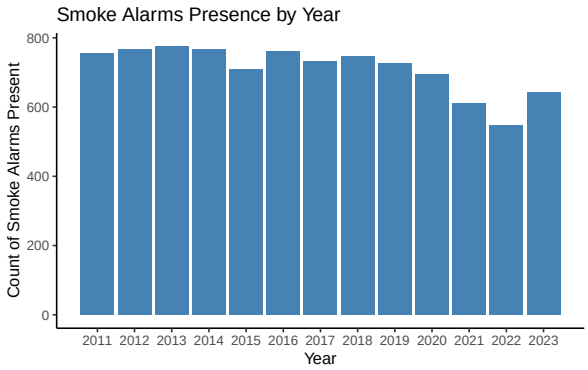
(a) Estimated Dollar Loss by year



(b) Fire Alarm Presence Counts in each year

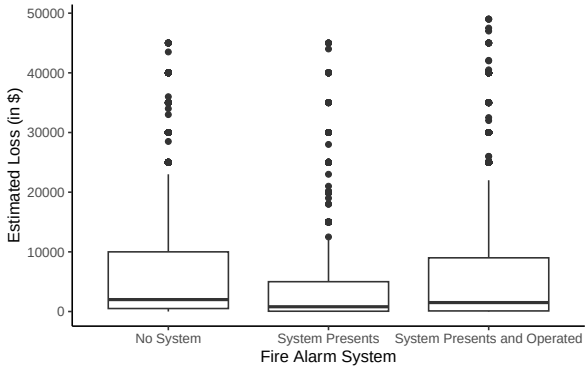


(c) Sprinkler System Presence Counts in each year

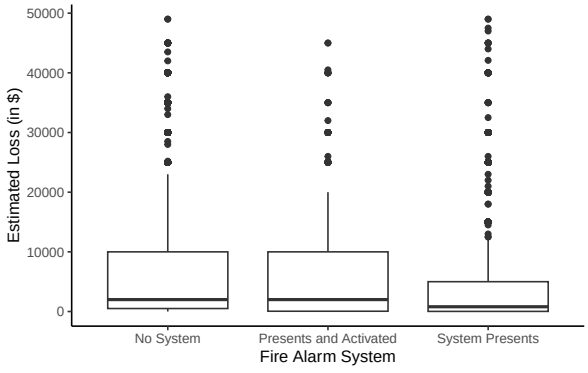


(d) Smoke Alarm Presence Counts in each year

Figure 2: Summaries of estimated loss and Systems in each year



(a)



(b)

Figure 3: Boxplot of Fire Alarm and Sprinkler

Appendix

A Additional data details

References

Fire Chiefs, Ontario Association of. 2024. "Smoke Alarms." https://www.oafc.on.ca/public-safety/smoke-alarms.

Firke, Sam. 2023. *Janitor: Simple Tools for Examining and Cleaning Dirty Data*. https://CRAN.R-project.org/package=janitor.

Gelfand, Sharla. 2022. *Opendatatoronto: Access the City of Toronto Open Data Portal*. https://CRAN.R-project.org/package=opendatatoronto.

Grolemund, Garrett, and Hadley Wickham. 2011. "Dates and Times Made Easy with lubridate." *Journal of Statistical Software* 40 (3): 1–25. https://www.jstatsoft.org/v40/i03/.

Origin, and Cause. 2023. "Fire Services - Understanding How and Why They Fail." https://origin-and-cause.com/articles/fire-sprinkler-systems-understanding-how-and-why-they-fail/.

R Core Team. 2023. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/.

Rebekah. 2023. "Fire Incident Case Studies in the US." Fire Systems, Inc. https://firesystems.net/2023/08/01/fire-incident-case-studies-in-the-us-showcasing-the-importance-of-effective-fire-protection-measures/.

Rosen, Jody. 2019. "The Day the Music Burned." NewYorkTimes. https://www.nytimes.com/2019/06/11/magazine/universal-fire-master-recordings.html.

Toronto, City of. 2024. "Fire Sprinkler Systems." https://www.toronto.ca/city-government/accountability-operations-customer-service/city-administration/staff-directory-divisions-and-customer-service/fire-services/.

Wickham, Hadley. 2016. *Ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York. https://ggplot2.tidyverse.org.

Wickham, Hadley, Mara Averick, Jennifer Bryan, Winston Chang, Lucy D'Agostino McGowan, Romain François, Garrett Grolemund, et al. 2019. "Welcome to the tidyverse." *Journal of Open Source Software* 4 (43): 1686. https://doi.org/10.21105/joss.01686.

Wickham, Hadley, Romain François, Lionel Henry, Kirill Müller, and Davis Vaughan. 2023. *Dplyr: A Grammar of Data Manipulation*. https://CRAN.R-project.org/package=dplyr.

Xie, Yihui. 2024. *Knitr: A General-Purpose Package for Dynamic Report Generation in r*. https://yihui.org/knitr/.