Fire Safety Systems in Mitigating Fire Incidents*

Deyi Kong

September 26, 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. By analyzing data from the Ontario Fire Marshal (OFM) dataset, we assess how these systems impact evacuation success, fire containment, and the reduction 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 are a persistent threat to urban safety, causing significant damage to property, loss of life, and injury. Effective fire protection measures have played a crucial role in mitigating the impact of these incidents (Rebekah 2023). Fire safety systems, such as fire alarms and sprinklers, are fundamental components of fire prevention and response strategies in urban areas. 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). These systems play a critical role in early detection, containment, and evacuation during fire incidents.

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 to evaluate how fire alarms and sprinklers influence key outcomes such as property loss, fire containment, and evacuation success. Using data provided by the Ontario Fire Marshal (OFM), we examine variables such as the area of fire origin, ignition source, response times, and the presence of fire safety

---

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

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.

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. It tracks the date of the incident, the location to the nearest intersection, the ward in which the incident took place, the time TFS was alerted to the fire and the time TFS arrived at the scene. The dataset records the area of origin, building status, business impact, casualties, estimated dollar loss, time stamps for each actions (notified, arrived, controled), and whether there was a working alarm and sprinkler on site.

For privacy purposes personal information is not provided and exact address have been aggregated to the nearest major or minor intersection. Some incidents have been excluded pursuant to exemptions under Section 8 of Municipal Freedom of Information and Protection of Privacy Act (MFIPPA). 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 of 2018 to 2023. There are several new feature created due to a more effective relation with the time stamps. 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 dataset:

```
Rows: 7,311
Columns: 17
$ year                              <dbl> 2018, 20~
$ area_of_origin                    <chr> "75 - Tr~
$ estimated_dollar_loss             <dbl> 0, 2000,~
```

```
$ fire_alarm_system_impact_on_evacuation                              <chr> "9 - Und~
$ fire_alarm_system_presence                                          <chr> "9 - Und~
$ ignition_source                                                     <chr> "999 - U~
$ smoke_alarm_impact_on_persons_evacuating_impact_on_evacuation       <chr> "8 - Not~
$ sprinkler_system_presence                                           <chr> "9 - Und~
$ status_of_fire_on_arrival                                           <chr> "3 - Fir~
$ fire_under_control_time                                             <time> 14:20:0~
$ tfs_alarm_time                                                      <time> 14:13:3~
$ tfs_arrival_time                                                    <time> 14:18:0~
$ TFS_Notified_Till_Arrival                                           <dbl> 268, 352~
$ TFS_Duration                                                        <dbl> 113, 313~
$ alarm_date                                                          <date> 2018-02~
$ arrive_date                                                         <date> 2018-02~
$ control_date                                                        <date> 2018-02~
```

Table 1: Column descriptions of selected data

Variables	Descriptions
area__of__origin	OFM Area of Origin code and description
estimated_dollar_loss	Estimated Dollar Loss
final_incident_type	Final incident type
fire_alarm_system_impact_on_evacuation	OFM Fire Alarm System Impact on Evacuation code and description
fire_alarm_system_presence	OFM Fire Alarm System Presence code and description
ignition_source	OFM Ignition Source code and description
smoke_alarm_impact_on_persons_evacuating_impact_on_evacuation	OFM Smoke Alarm Impact on Persons Evacuating Impact on Evacuation code and description
sprinkler_system_presence	OFM Sprinkler System Presence code and description
status_of_fire_on_arrival	OFM Status of Fire On Arrival code and description
fire_under_control_time	Timestamp of fire under control
tfs_alarm_time	Timestamp of when TFS was notified of the incident
tfs_arrival_time	Timestamp of first arriving unit to incident

And also planes (**?@fig-planes**). (You can change the height and width, but don't worry about doing that until you have finished every other aspect of the paper - Quarto will try to make it look nice and the defaults usually work well once you have enough text.)
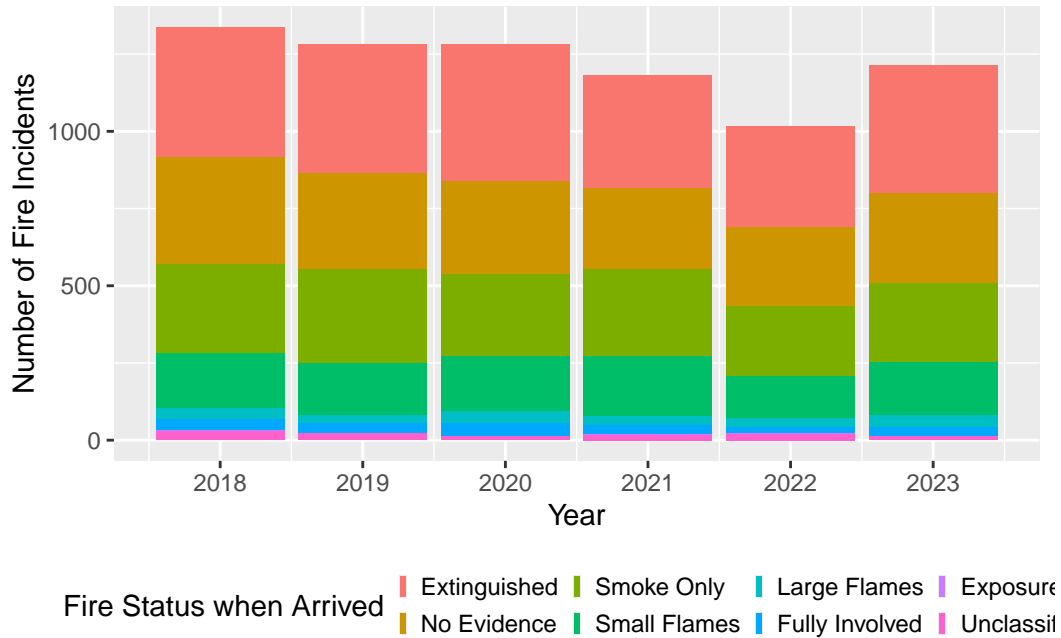
Figure 1: Distribution of incidents in each year by fire status

```
sort(unique(data$status_of_fire_on_arrival))
```

```
[1] "1 - Fire extinguished prior to arrival"
[2] "2 - Fire with no evidence from street"
[3] "3 - Fire with smoke showing only - including vehicle, outdoor fires"
[4] "4 - Flames showing from small area (one storey or less, part of a vehicle, outdoor)"
[5] "5 - Flames showing from large area (more than one storey, large area outdoors)"
[6] "7 - Fully involved (total structure, vehicle, spreading outdoor fire)"
[7] "8 - Exposure involved"
[8] "9 - Unclassified"
```

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.

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/.