Deciphering Toronto Fire Incidents*

From Origins to Outcomes: Exploring Patterns and Economic Consequences of Urban Fires in Toronto

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In this study, we analyzed fire incident data in the Great Toronto Area (GTA) from 2011 to 2022. We focused on the origins of fires, the building status, and the total estimated financial losses. Our analysis determined that cooking and engine area are more prone to fires, while building under special conditions do not have a significant cause in fire incident. Additionally, we noticed that there is a substantial expense associated with fire incident every year. The analysis indicated that fire incidents substantially affect the economy and urban resources, emphasizing the importance of improving fire safety and urban planning in populous cities to reduce their frequency and impact.

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*Code and data are available at: https://github.com/Sinanma/Fire_Incidents_in_Toronto_up_to_2022.git.

1 Introduction

A report by the International Association of Fire Chiefs (IAFC) highlights the extensive economic impact of fire incidents, noting that in the United States alone, "the total cost of fire was estimated at $328 billion in 2010, which is approximately 2.2% of the U.S. GDP" (International Association of Fire Chiefs 2023). These number underscores the financial significance of our study, since it is not a problem happening only in the US, but all over the world. The significance of this research lies in its potential to guide urban planning and fire safety strategies.

Fire incidents in urban environments not only have a significant threat to individual safety, but also to the economic and infrastructural stability of the city. Since the Greater Toronto Area (GTA) has a high population density, the impact of fire incidents can be particularly significant, affecting a large diversity of residents. This background affirms the necessity of analyzing fire incidents, the analysis of which can provide insights about the economic causes and consequences to help with urban safety design.

This study develops a deep analysis of the data of the fire incidents that Toronto Fire Service(TFS) have responded to between 2011 and 2022 published onto `opendatatoronto` (Gelfand 2022). We focus on identifying the origins of fires, examining the conditions of involved buildings, and quantifying the total estimated financial losses. Our analysis found that fires are more likely to start in cooking and engine areas, while buildings under special conditions aren't major contributors to fire incidents. We also noticed a significant yearly financial cost due to these fires, highlighting the economic impact and the importance of targeted fire safety measures.

The paper is organized as follows: After the introduction, the Data section outlines the dataset and analysis methods, focusing on three key aspects: area of origin, building status, and yearly loss estimation. The Overview section provides the general information of this dataset. The Results section presents our findings, pointing out the relationships between fire incidents and key aspects, supported by tables. Finally, the Data Visualization section uses graphical representations to further elucidate relationships from previous section, providing a clear visual understanding of the data.

2 Data

2.1 Overview

In the fire incident dataset, our analysis focus on three pivotal aspects:

1. Relationship between Area of Origin and Number of Incident (Table 1, Figure 1)
2. Relationship between Building Status and Number of Incident (Table 2, Figure 2)

3. Yearly Total Loss Estimated in Dollar from 2011 to 2022 (Table 3, Figure 3)

Each element provides crucial data points for understanding fire incidents' impact on urban safety and financial support.

The dataset used in this analysis is from `opendatatoronto` (Gelfand 2022), with title of *Fire Incidents*. Data was collected, filtered, cleaned, and analyzed using statistical programming software R (R Core Team 2022). The following R packages was used in this paper: `tidyverse` (Wickham et al. 2019); `knitr` (Xie 2023); `janitor` (Firke 2023); `here` (Müller 2020). Part of coding knowledge from *Telling Stories with Data* (Alexander 2023).

2.2 Results

2.2.1 Relationship between Area of Origin and Number of Incident

The first table (Table 1) lists the number of fire incidents (greater than 1000) by area of origin. From the table we notice cooking areas or kitchens have the most number of incidents of 3819, emphasizing the high risk associated with these spaces. Engine areas follow with 2,724 incidents, indicating a significant fire risk in mechanical spaces. Other areas needs some attention include trash storage, porches and balconies. This information directs attention to potential high-risk zones for fire safety interventions.

We create a summary statistic on relationship between Area of Origin and Number of Incident using `summarise()`, `filter` and `arrange` from `tidyverse` (Wickham et al. 2019). We use `kable()` from `knitr` (Xie 2023) to create Table Table 1.

Table 1: Distribution of Fire Incidents by Area of Origin in GTA

Area of Origin	Number of Incidents
24 - Cooking Area or Kitchen	3819
81 - Engine Area	2724
44 - Trash, Rubbish Storage (inc garbage chute room, garbage/industri	1466
64 - Porch or Balcony	1401
22 - Sleeping Area or Bedroom (inc. patients room, dormitory, etc)	1214

2.2.2 Relationship between Building Status and Number of Incident

The second table (Table 2) lists the number of fire incidents by building status. The majority of incidents occur in buildings with 'Normal' status (13,604), with a fewer for buildings under renovation or construction. This suggests that fire incidents are more likely to occur in operational buildings rather than those undergoing changes. Understanding the status when fires incident occur can bring up more effective building codes and safety regulations.

We create a summary statistic on relationship between Building Status and Number of Incident using `summarise()`, `filter` and `arrange` from `tidyverse` (Wickham et al. 2019). We use `kable()` from `knitr` (Xie 2023) to create Table Table 2.

Table 2: Distribution of Fire Incidents by Building Status in GTA

Building Status	Number of Incidents
01 - Normal (no change)	13604
02 - Under Renovation	661
03 - Under Construction	215
09 - Undetermined	126
05 - Abandoned, vacant (long term)	106
04 - Under Demolition	20

2.2.3 Yearly Total Loss Estimated in Dollar from 2011 to 2022

The third table (Table 3) lists the total estimated dollar loss from fire incidents for each year from 2011 to 2022. The highest loss occurred in 2019, with a significant decrease in 2020, which may correlate with various factors, such as fire prevention strategies, changes in reporting practices. etc. Summary statistics here is important for understanding the financial impact of fire incidents and can provide information towards fire prevention and response.

We create a summary statistic on yearly loss estimated due to fire incident using `summarise()`, `filter` and `arrange` from `tidyverse` (Wickham et al. 2019); `comma()` from `scales`(Wickham, Pedersen, and Seidel 2023); and `kable()` from `knitr` (Xie 2023) to create Table Table 3.

Table 3: Annual Estimated Loss due to Fire Incidents in Toronto (2011-2022)

Year	Total Estimated Dollar Loss
2022	88,675,867
2021	84,039,521
2020	70,524,176
2019	119,116,686
2018	77,291,443
2017	77,320,995
2016	60,803,825
2015	42,223,795
2014	61,145,851
2013	52,232,801
2012	42,482,142
2011	50,014,115

2.3 Data Visualization

Data visualization is powerful tool in our analysis, transforming complex datasets into clear, insightful graphs that to show the changes and trends.

2.3.1 Relationship between Area of Origin and Number of Incident

The graph (Figure 1) illustrates the distribution of fire incident by area of origin, we notice that Area 24 from (Table 1), which is cooking area, and Area 81, which is the engine area are more prone to fire incidents. It underscores cooking and engine areas are high-risk zones for fire outbreaks due to the presence of heat sources and flammable materials.

The visual representation through a pie chart is particularly effective for displaying the proportional distribution of incidents across different areas. It allows us to quickly identify which areas are most affected and benefit to fire prevention and safety measures.

We create a visualized pie chart (Figure 1) on relationship between area of origin and number of incident using using `ggplot()` from (Wickham et al. 2019).

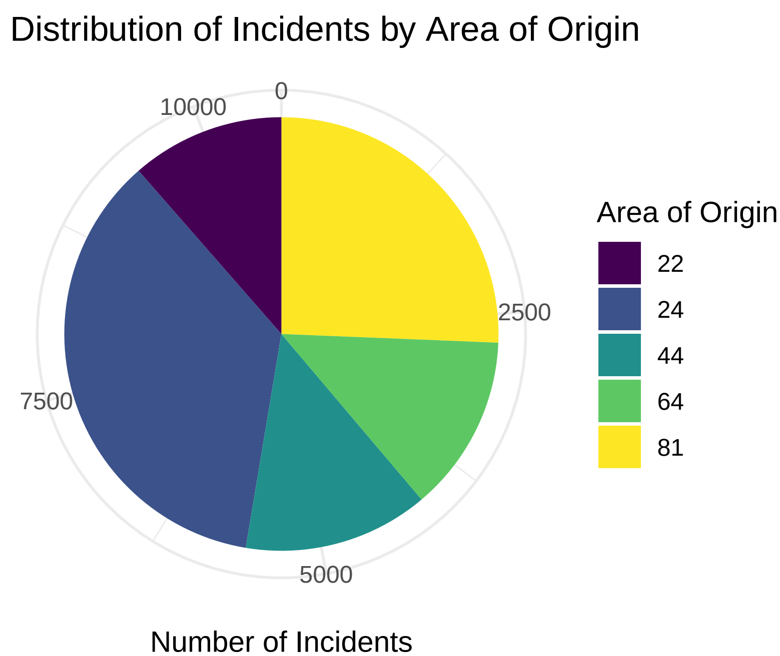

Figure 1: Distribution of Fire Incidents by Area of Origin in GTA

2.3.2 Relationship between Building Status and Number of Incident

The graph (Figure 2) illustrates the distribution of fire incident by building status, we notice that Status 01 from (Table 2) representing normal status is more susceptible to fire incident. This suggests that regular occupancy and daily activities, which are more common in buildings with normal status, might carry a higher risk of fire incidents.

For other statuses such as buildings under construction, renovation, etc. have fewer fire incidents. This could be due to a reduced activity that could potentially start a fire, or possibly stricter adherence to fire codes and monitoring during these non-standard conditions.

We create a visualized pie chart (Figure 2) on relationship between building status and number of incident using by `ggplot()` from (Wickham et al. 2019).

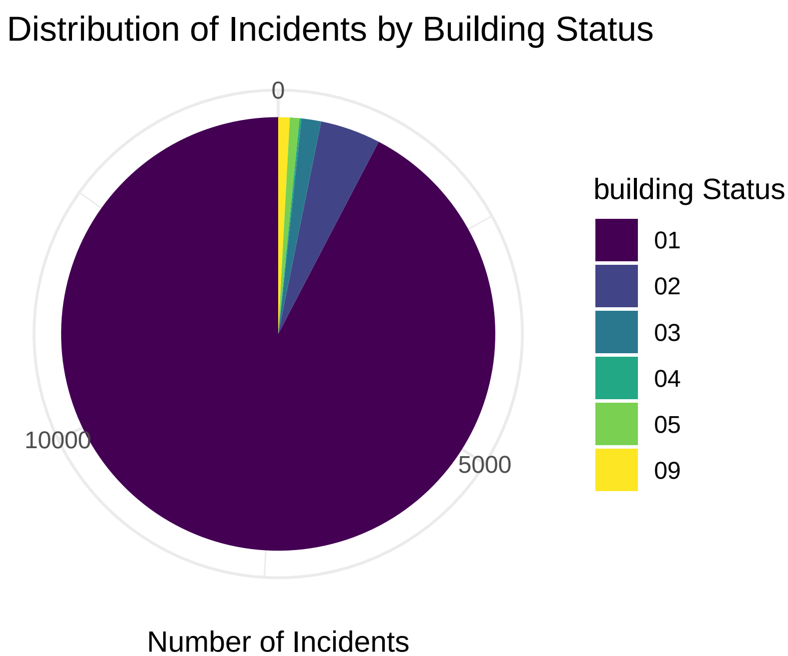

Figure 2: Distribution of Fire Incidents by Building Status in GTA

2.3.3 Yearly Total Loss Estimated in Dollar from 2011 to 2022

The graph (Figure 3) illustrates the economic impact of fire incidents in the GTA from 2011 to 2022, with each bar corresponding to a different year, distinguished by color. The bar chart provides an intuitively visual representation of yearly trends, contributing to the analysis of annual patterns. This visualization of data is crucial for understanding the financial consequences of fire incidents.

For instance a pronounced peak in 2019, signifies a year with particularly high losses. Following this peak, there is a decline in 2020. The decrease in 2020 may suggest positive outcomes from policies implemented, changes in infrastructure, and fewer high-cost incidents.

We create a visualized bar chart (Figure 3) on yearly loss estimated due to fire incident by `ggplot()` from (Wickham et al. 2019).

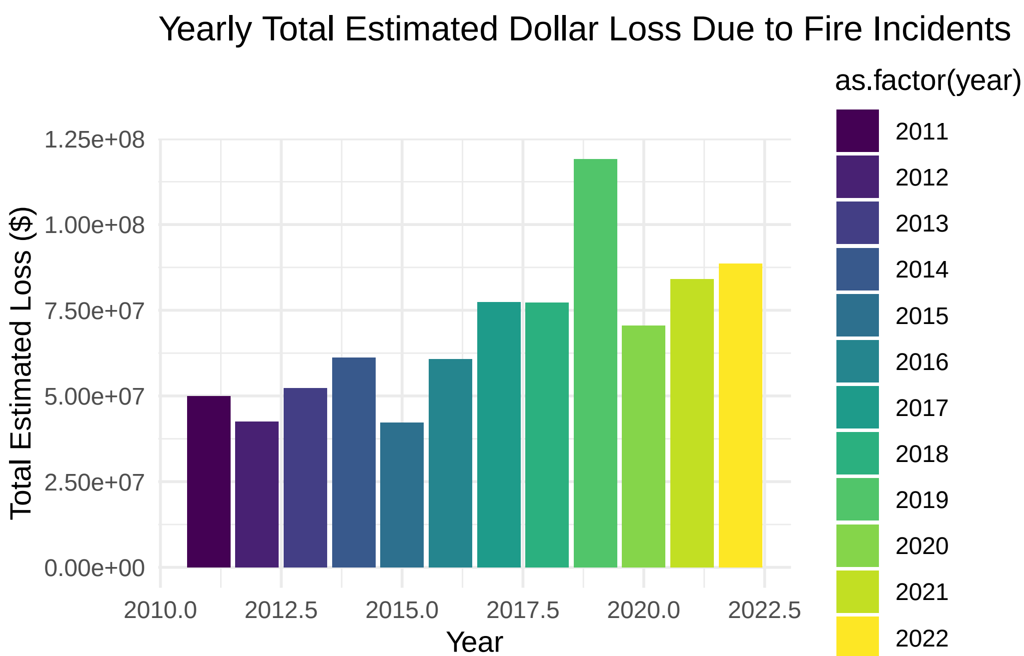

Figure 3: Annual Estimated Loss due to Fire Incidents in Toronto (2011-2022)

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