An Analysis of a Rising Trend in Dollar Loss in Fire Incidents With and Without Sprinkler Systems in Toronto over a decade (2011-2022)*

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A Fire Incidents dataset was used to assess the general trend in dollar loss in fire incidents and also assess the impact of existence of sprinkler systems installed across the city of Toronto. Based on the analysis, a general rise over the years in the dollar loss in fire incidents as well as a massive amount of loss to property was found wherever sprinkler systems were not installed. This paper suggests that an installation of sprinkler systems will help reduce the impact of fire incidents on loss to property in Toronto.

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*Code and data are available at: https://github.com/Ary4m3n/fire-incidents.git

1 Introduction

The Great Fire of Toronto in 1904 caused mass destruction. The fire demolished around 20 acres of the industrial area in the city of Toronto, demolishing at least 98 buildings, causing a dollar loss of $10 million and leaving numerous thousands unemployed (Bradburn 2020). Since then we have seen an improvement in city codes and policies, better civil planning and extensive training of firefighters (Pandas 2022). Till date, the Toronto Fire Services report approximately 10,000 fires each year which is of immense concern to the city of Toronto and its residents (Ohrn 2019).

The Fire Incidents data of Toronto includes incident reports of fire incidents as defined by the Ontario Fire Marshal from 2011-2022 (Data 2024). This paper delves deeper into the trend of estimated dollar loss in fire incidents in the city of Toronto from 2011-2022 and also analyses the impact of an installation of sprinkler systems on the dollar loss. The aim of the paper is to analyse the impact of better planning, specifically an installation of sprinkler systems, on the extent of loss faced by the residents of Toronto.

In this paper, Fire Incidents data (Data 2024) was used to first explore if there is a trend in the estimated dollar loss over the years, and then was used to find any correlation between better civil planning, i.e. the installation of sprinkler systems and a lesser loss of property. It was found that there is a general rising trend in the dollar loss between 2011 and 2022. The paper also found that the dollar loss was drastically higher for fire incidents where there was no sprinkler system installed. This leads us to make an important judgement that better civil planning helps reduce the impact of such unfortunate events.

This paper is structured using the following sections: Data, Results and Discussion In the Data (Section 2) section, the data source of the dataset from Open Data Toronto (Data 2024) is discussed and the data cleaning process is outlined. In the Results (Section 3) section, the paper summarizes the data findings and relevant graphs of the trends observed. The paper ends with the Discussion (Section 4) section, where the findings of the paper have been analysed and delved deeper into, and a further scope for the paper has been discussed.

2 Data

The data analysed in this paper was from Open Data Toronto (Data 2024). The data was cleaned and analysed using the open source `R` programming language (R Core Team 2022). R libraries and packages such as `opendatatoronto` (Gelfand 2022), `tidyverse` (Wickham et al. 2019), `janitor` (Firke 2023), `ggplot2` (Wickham 2016), `knitr` (Xie 2023), `readr` (Wickham, Hester, and Bryan 2023), `gridExtra` (Auguie 2017) and `dplyr` (Wickham et al. 2023). In the

following sections, we will discuss the raw data (Section 2.1) and then move on to discussing the data cleaning process (Section 2.2).

2.1 Raw Fire Incidents Data

The raw data for this paper was obtained from Open Data Toronto (Data 2024) and we specifically looked at the Fire Incidents Data provided by the Ontario Fire Marshal from 2011-2022. We also looked at another data set related to this topic, Fire Services Incident Data (Data 2019) but that data set firstly was last refreshed in 2019 and had been retired and replaced with the data set we used.

The raw data had loads of information (that was mainly unnecessary to us for this paper), which mainly included the area of origin, casualities, persons rescued, estimated dollar loss, fire incident type, fire timing, intersection (location), cause, sprinkler system presence etc. For this paper specifically, to observe and analyse the trend in dollar loss and the effect of better civil planning (i.e. existence of sprinkler systems), we did not require such a plethora of variables. The raw data set contains 2,357,639 data entries and 43 variables. Due to the size of the dataset, we could not include a table outlining the structure of the dataset.

In the next section (Section 2.2), we will outline the data-cleaning process and also show the first few rows of the cleaned data.

2.2 Cleaning Fire Incidents Data

As stated above in (Section 2.1), we cleaned the data to cater to our needs of analyzing the trend in dollar loss and the effects of better civil planning. Specifically, we only kept 3 variables, the estimated dollar loss, the year in which the incident took place and sprinkler system presence which outlines whether a sprinkler system had been installed in the place where the incident took place. Table 1 shows the structure of the cleaned data by presenting the first 6 datapoints or rows.

Here, in order to obtain this cleaned data table, I got the year of the incident from the `alarm_time` variable in the raw data and cleaned the sprinkler system presence column to only show 4 unique statuses, "No sprinkler system", "Full sprinkler system present", "Undetermined" and "NA" as shown clearly in Table 1 using `R` (R Core Team 2022). Table 1 shows the head of the cleaned data.

Table 1: Cleaned Data showing Dollar loss over 2011-2022 with indication of Sprinkler System

Dollar Loss	Year	Sprinkler System Presence
15000	2018	NA
50	2018	NA
0	2018	Undetermined

Dollar Loss	Year	Sprinkler System Presence
1500	2018	NA
2000	2018	No sprinkler system
100000	2018	No sprinkler system

Now that we have cleaned our raw fire incidents data and have generated a clean table. We will go on to the Results section (Section 3) and look at the trend generated for the dollar loss over the years, 2011-2022 (Section 3.1), and then look at the effect of the presence of sprinkler systems on the property or dollar loss (Section 3.2).

3 Results

3.1 Trend in Dollar Loss over 2011-2022 in Fire Incidents

Table 2 shows the table of the total estimated dollar loss over the years 2011-2022 in the city of Toronto in fire incidents. The table presents three columns: year, dollar loss and dollar loss in millions. The years range from 2011-2022, and the subsequent columns present the total estimated loss of property (dollar loss) in that specific year. For plotting simplicity, we introduced the dollar loss in millions variable here because it makes the plot (Figure 1) more coherent and easy for interpretation.

Table 2: Total Estimated Dollar Loss per year (2011-2022)

Year	Dollar Loss	Dollar Loss in Millions
2011	50014115	50.01411
2012	42482142	42.48214
2013	52232801	52.23280
2014	61145851	61.14585
2015	42223795	42.22380
2016	60803825	60.80383
2017	77320995	77.32099
2018	77291443	77.29144
2019	119116686	119.11669
2020	70524276	70.52428
2021	84039521	84.03952
2022	88676002	88.67600

Figure 1 shows the bar plot of the Table 2 where the Dollar Loss in millions is plotted against the years 2011-2022.

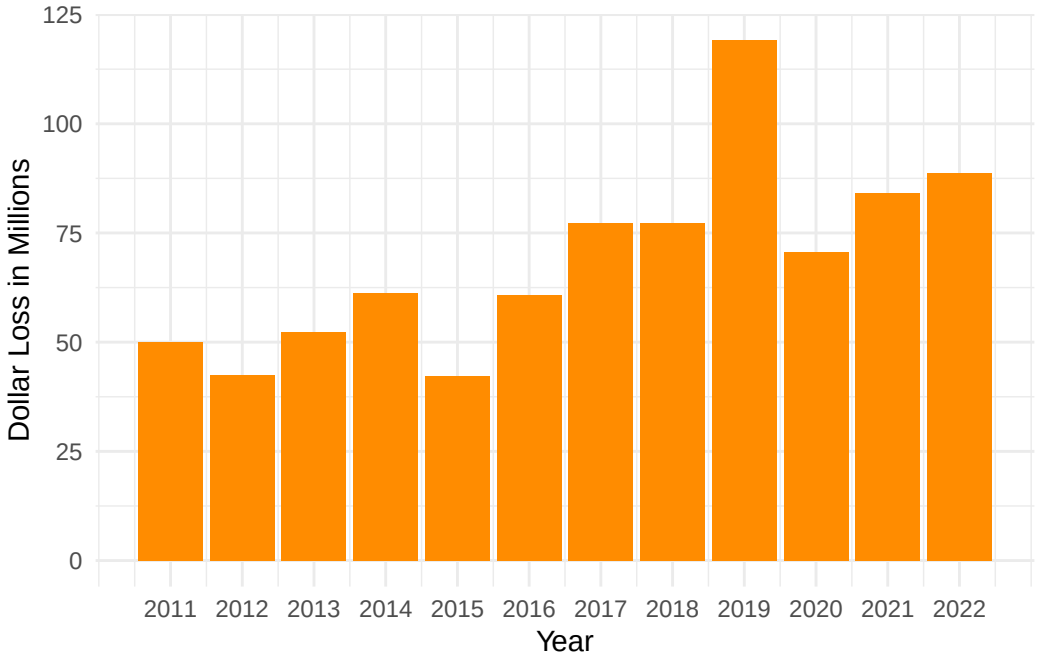

Figure 1: Year vs Dollar Loss ($million) in Fire Incidents in Toronto (2011-2022)

We can clearly observe an increasing trend in the dollar loss in fire incidents in the city of Toronto over the years in Figure 1. The plot starts from showing a dollar loss of approximately $50 million in 2011, and about $40 million in 2012. The plot peaks in 2019 where it reports an estimate dollar loss of about $120 million. The plot them shows a dollar loss of approximately $85 million in 2021, and about $90 million in 2022, indicating a general rising trend over the decade. We will delve deeper into the implications and impact of this trend over the years in the Discussion Section (Section 4).

3.2 Effect of presence of Sprinkler Systems on Dollar Loss

Table 3 shows the table of Dollar Loss over the years in the presence of proper sprinkler systems. As shown in Table 2, the table presents three columns: year, dollar loss and dollar loss in millions, where the dollar loss in millions has been used to plot the bar graph in Figure 2.

Table 3: Total Estimated Dollar Loss over 2011-2022 with Full Sprinkler System Present

Year	Dollar Loss	Dollar Loss in Millions
2011	3826290	3.826290
2012	8488092	8.488092
2013	3872366	3.872366

Year	Dollar Loss	Dollar Loss in Millions
2014	6040676	6.040676
2015	3054784	3.054784
2016	4082601	4.082601
2017	2949971	2.949971
2018	4864365	4.864365
2019	5949001	5.949001
2020	5466891	5.466891
2021	7583691	7.583691
2022	5888177	5.888177

Table 4 shows the table of Dollar Loss over the years when there were no sprinkler systems present and has the same columns as Table 3. This table, i.e. Table 4 and Table 3 have been used to plot Figure 2

Table 4: Total Estimated Dollar Loss over 2011-2022 with No Sprinkler System Present

Year	Dollar Loss	Dollar Loss in Millions
2011	37276365	37.27636
2012	22779879	22.77988
2013	35350140	35.35014
2014	31118999	31.11900
2015	25615889	25.61589
2016	38632389	38.63239
2017	37853068	37.85307
2018	43650217	43.65022
2019	94093947	94.09395
2020	41548697	41.54870
2021	39780346	39.78035
2022	53476753	53.47675

Figure 2, on the left (in red), shows the dollar loss each year in fire incidents where **full sprinkler system** was present, and on the right shows the dollar loss each year in fire incidents where **no sprinkler system** was present. Just by looking at the plots, we observe that there is a significant difference between there being full sprinkler system installed and there being no spinkler system installed. This along with the implications of such civil planning with further be delved deeper into in the Discussion Section (Section 4).

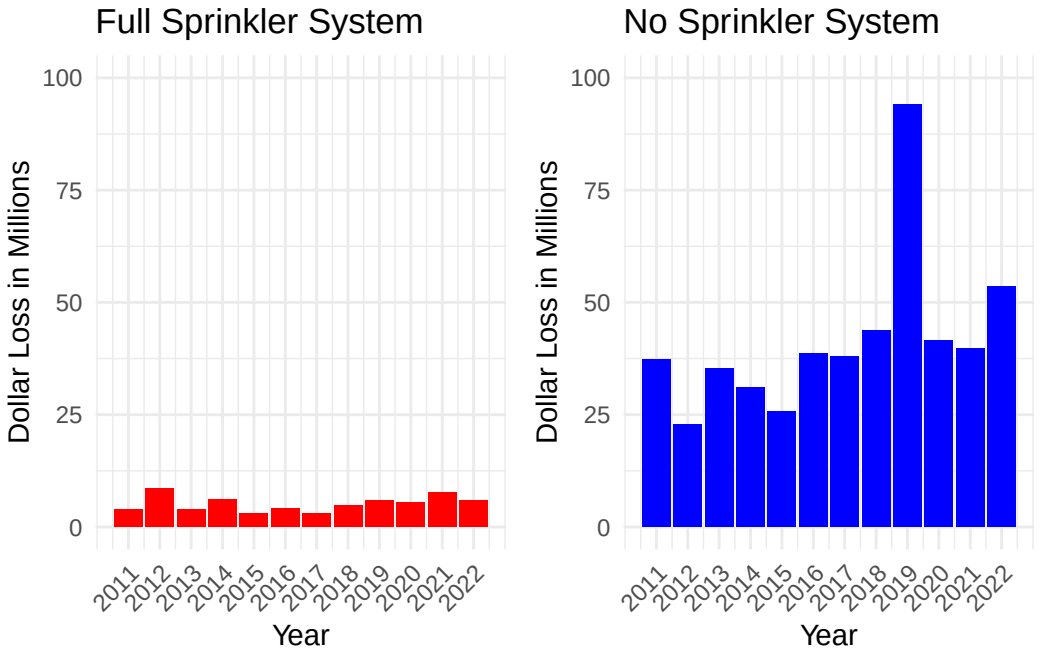

Figure 2: Year vs Dollar Loss ($million) in Fire Incidents in Toronto (2011-2022): With (red) and Without (blue) Sprinkler Systems

4 Discussion

4.1 Trend in Dollar Loss over 2011-2022 in Fire Incidents

As seen in Figure 1 and communicated in Section 3.1, we observe a general rising trend over the years from 2011-2022 in the dollar loss or property loss in Fire Incidents in Toronto. The data tends to skew more towards the latter years where as reported in Section 3.1, there was a dollar loss of approximately $90 million in 2022 versus $50 million in 2011. As a general trend it is very evident to the reader that there is a general increase over the years.

Let us now delve deeper into the possible reasons of such a trend. Firstly, i believe that as the population increases over the years there are more chances of there being fire incidents. As the city of Toronto gets more densely populated there is a higher chance or probability of there being a fire incident than when it was less densely populated. Secondly, the city of Toronto has evolved over the years by constructing skyscrapers, apartments, offices etc. for the residents to live and work in. As the number buildings in general increase around us, there will consequently be more chances of there being fire incidents than before. Finally, we can not ignore that with an improvement in infrastructure of the city, i.e. building better roadway systems or highways, there has been an influx of residents of surrounding areas to come to Toronto to work. This can also lead to there being more fire incidents such as unfortunate car or vehicle fires.

All together, there may be numerous reasons to such a rise in the trend over the years, but the three stated above give a good idea of what those reasons might revolve around.

4.2 Effect of presence of Sprinkler Systems on Dollar Loss

As seen in Figure 2 and communicated in Section 3.2, we observe a clear difference in the dollar loss over the years in the case of there being a presence of full sprinkler system and there being no sprinkler system. We see that while in the case of full sprinkler system being present the dollar loss is at max around $15 million, on the other hand in the case of no sprinkler system present the dollar loss reaches a maximum of around $95 million too. Generally, we see that the dollar loss amounts when there is no sprinkler system present are significantly higher than when there is one present.

When we delve deeper into the possible reasons of such a trend, we find a few prominent and obvious ones. Remarkably, such a major difference is observed because of the obvious reason that if there is a sprinkler system present, it will help extinguish the fire before the first responders or fire fighters come to scene and take the measures to cease the fire. This will consequently save the infrastructure from experiencing severe damages and hence reduce the general dollar loss or property loss caused in that specific incident. On the other hand, in the case that there is no sprinkler system present, we will have to wait for the fire fighters to arrive on the scene of the incident and then act, by when the fire could have already caused major damages to the infrastructure.

Figure 2 also speaks to the importance of such essential civil planning that might prevent major structural damages or property losses from happening.

4.3 Weaknesses and Further Scope

While working on the paper we came across a few weaknesses that could be built on to make the report even more coherent. Firstly, we observed that in the case of the figures presented in Table 3 and Table 4 and the plot in Figure 2, there might have been lesser data points for the case of full sprinkler system present that maybe caused the figures for the dollar loss to be generally lesser than for the case of no sprinkler system.

Additionally, the variable of presence of sprinkler system also included **NA** and **Undetermined** statuses which were not accounted for in this report. These two fields would include incidents such as vehicle fires, where the criterion of there being a sprinkler system is not applicable as they can not exist in vehicles in general. In this report, as we are generally looking at the impact of better civil planning we chose to ignore the aforementioned statuses.

As a further scope, an extension to this report could include taking into account the NA and Undetermined statuses as well when analyzing the data. Then, we can look more into the response times of the first responders and analyse the impact of good training in reducing

property damage or dollar loss. Another extension could also be looking at intersections where majority of the fire incidents have taken place and analyse how to better plan the neighborhood in a way as to reduce property loss in the future. All of these extensions can be easily made using the same raw data set as used in this paper.

In conclusion, we have observed a general rising trend in the dollar loss over the years in fire incidents in the city of Toronto and have also observed that with better civil planning, specifically installing sprinkler systems, we can prevent from major property damage from taking place.

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