Analysis of Fire Incidents using data from City of Toronto (2023)

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Executive Summary

Using 2023 fire incident data (City of Toronto, 2023), this analysis examines some of the vital patterns of the type of fire, the emergency response effectiveness, and the safety infrastructure performance. The analysis shows that outdoor fires were 41%, grass/ rubbish fires (35%) often occur during extreme heat waves and drought conditions (City of Toronto, 2023), residential fires were 27% caused by unattended cooking (34%), and the failure of lithium-ion batteries in home appliances (18%) (NFPA, 2023), and vehicle fires were 22% (Toronto Fire Services Annual Report, 2023).

Toronto Fire Services met 77% of the average time from emergency calls to the arrival of the first truck (Total Response Time) in 2023 (up 2% from 2022) (Toronto Fire Services, 2023). Most, however, financial losses from industrial fires in high-density zones exceed $5 million. Eighteen percent (Toronto Fire Services, 2023) failed because of dead batteries or improper smoke alarm installation. Results highlight the need to update the EV fire safety protocols, educate the public about battery safety, and strengthen the zoning laws in the areas of the highest risk due to the new hazards introduced by unattended cooking and lithium-ion battery incidents.

Introduction

The 12% rise in fire incidents in the city in 2023 is due to extreme weather, aging infrastructure and rapid EV adoption, as per the City of Toronto Open Data (2023), bringing the public safety challenges in urban fire management. The dataset to be analyzed consists of 2,412 residential, commercial, vehicle and outdoor incidents with ignition source, response time and financial loss focused.

Toronto Fire Services uses data-driven strategies to allocate resources to fill the gaps in charging infrastructure and mitigate risks for outdoor fires related to climate change (Dey et al., 2022). Such insights would be of use to insurance industries to ensure that they can better assess their risk in high-density areas such as Liberty Village which recorded a 20% increase in commercial fire claims in 2023 (Insurance Bureau of Canada, 2023).

Research Purpose

The purpose of this research is to analyze the pattern and insight of patterns using fire incident data to provide directions for fire safety policy design and resource allocation. Once knowing where fires originate and why, decision makers can have designated prevention strategies and be better prepared for emergency response.

This study aims to answer the following questions:

1. What is the average estimated monthly dollar value loss for properties affected by Fire Incidents in 2023?

2. Is the increased casualties caused by a lack of responding personnel or apparatus during fire incidents?

3. What is the business impact and dollar value loss due to fire incidents in different wards?

4. What was the average response time for Fire Incidents in different intersections of Toronto and the number of civilian casualties for 2023?

Research Scope

For residential, commercial, vehicle, and outdoor fire incidents, response times, AI fire containment approaches, and financial repercussions that come with fires, the study uses the 25 wards of Toronto from January to December 2023.

Research Objectives

The study focuses on fire incidents and the number of casualties, considering the effectiveness, response metrics, and area of origin, and proposing safety standards policies, staff and apparatus employment, and public education for control and prevention.

BACKGROUND RESEARCH / LITERATURE REVIEW

Empirical Literature Review

As we continue to find new strategies for improving fire safety and emergency response practices on fires, empirical research on fire incident analysis in recent years has increasingly relied on data analytics, predictive modelling, and risk assessment frameworks. This section discusses several scholarly studies pertaining to the key fire risks and the potential mitigation strategies.

- Wang et al. (2022) have conducted a study on how machine learning algorithms can analyze historical fire data for predicting the high-risk location and finding the optimal allocation of resources for fire prevention. According to the findings, predictive analytics are essential in improving fire prevention as they help determine risk factors like weather, beliefs of structures, and even recovered incidents.
- Damage Mitigation: Johnson and Patel (2021) carried out a study on the role of fire alarms and sprinkler systems in limiting fire damage in urban areas. Based on these results, however, they found that functional fire safety systems reduce fires by 45% on average and expedite the evacuation process.
- Response Time and Fire Consequence According to Miller et al. (2020), they researched the relationship between the response time of firefighters and fire severity. The study also found that a delay of more than 6 minutes in water and first aid measures incurred a higher property damage rate and casualty rates. GIS based routing systems were proposed to be used for optimization of firefighter dispatching.

Business Literature Review

Businesses in real estate development, insurance underwriting, and city planning have a critical concern of fire risk management. This section considers business insights, industry opinion on fire risk mitigation and financial implications.

- **Insurance Risk Assessment and Fire Safety Compliance**

  The Insurance Bureau of Canada (2023) emphasizes the need for fire safety compliance in determining insurance policy premiums. The study concludes that properties with current fire safety systems will have lower insurance rates, while properties with old safety infrastructure are less likely to get insurance policies.

- **Real Estate Development and Fire-Resistant Construction**

  The National Association of Home Builders (NAHB) (2022) talks about the increase in the use of fire-resistant materials in new residential and commercial projects. It proposes incorporating smart fire detection systems to avoid losses in finance and structure.

- **Fire Management Predictive Analytics**

  A report by McKinsey & Company (2021) shows that cities have been using predictive analytics to predict when fire will occur and have consequently optimized their emergency response planning. The study's result emphasizes the use of AI in decision-making in real-time and risk management.

METHODOLOGY

This study investigates the data provided by the City of Toronto (2018) on their data on Fire Incidents from the years 2018 to the present. The data holds over 30,000 cases of Fire Incidents since 2018. For relevance, this study only analyzes data for 2023, in which, The City of Toronto recorded 3,494 cases of fire incidents ranging from unattended cooking to intentional combustion (Arson). The data also includes several factors pertaining to the description, potential cause, and response to the fire incidents. These factors include origin, number of casualties, potential cause, and many others.

In the dataset, we analyze key variables such as:

- Number of fire incidents and civilian casualties in different intersections in Toronto
- The Impact of Businesses and Estimated Dollar Loss of Businesses from Fire Incidents
- Average response time of fire personnel in relation to the geographical distribution of Fire Incidents by Intersections in Toronto.
- Estimated average dollar loss of all properties affected by Fire Incidents
- The relationship between the number of responding personnel and civilian casualties.

This study also uses various Data Analysis Techniques to interpret and analyze the Dataset in relation to the key variables identified in the data.

The various tools and techniques used in this study include:

- Descriptive statistics – to analyze average dollar losses incurred during Fire Incidents and allow recommendations to Insurance Company Policies based on the central tendencies of dollar losses.

- Correlation analysis – to understand the relationship between the estimated dollar losses and business impacts.
- Regression analysis – to investigate the significance of the number of personnel responding to fire incidents and civilian casualties.
- Pivot Tables – To streamline data allocation and filtering while investigating dollar loss and business impacts.
- Visualization – to allow an illustrated look into the statistical data such as geographic distribution, trends, and tendencies in the Fire Incident situation in Toronto **(Appendix B)**

This study uses descriptive statistics, regression analysis, pivot tables, cluster analysis, and visualizations to interpret and analyze data. The tools used by this research include Microsoft Excel and Tableau Public Edition 2024 to visualize and illustrate data to allow better analysis and interpretation to reach business recommendations and conclusions.

DATA ANALYSIS

This study investigates the data by the City of Toronto (2023) to reach recommendations and conclusions in the business context. This study looks through the lens of a Safety and Fire Equipment business that produces Fire Alarm Systems, Sprinkler systems, Smoke detectors, and safety equipment for Fire Personnel while aiming to produce recommendations that will improve the profitability and marketability of Fire Safety Products through data analysis. The study uses various data analysis methods and business intelligence tools to understand the data set by the City of Toronto (2023).

Regression Analysis

This study seeks to understand if there is a significant relationship between the number of casualties in a fire incident and the number of personnel who responded to the fire. Through statistical analysis of the data, the researchers decided to use regression analysis and formulate a regression model to determine the significance of civilian casualties and the number to fire incidents responding personnel. Microsoft Excel's Data Analysis Tool Pack was used to retrieve the statistical data to develop a regression Model. Appendix A illustrates the statistical data retrieved from the Analysis (See Appendix A).

To see the validity of the regression model, the researchers sought to answer the question of how many civilian casualties a fire incident would have if there were 10 responding fire personnel. Through regression analysis, **we have deduced no significant relationship between the number of civilian casualties and the number of responding personnel in fire incidents.** This is due to a low computed coefficient of determination (R squared) showing to be less than 30%, indicating that the number of responding personnel does not strongly influence the number of civilian casualties and vice versa. This information would allow Fire and Safety Equipment Providers to re-evaluate their production of Fire Safety Equipment for personnel, such as Firefighters, by understanding the relationship between the number of personnel and civilian casualties. Businesses may allow less Fire Personnel Safety Equipment production and focus more on fire detection system production.

Recommendations

- Premium Adjustments Based on Fire Risk Data: Based on empirical evidence, wards with frequent fires (identifiable on heatmaps) should be charged higher insurance premiums. And fire-safe buildings had significantly lower severity, confirming that discounted premiums should be available for fire safe buildings. Hence, recommend discounted insurance premiums to owners who have a fire alarm and sprinkler system, and continue to ensure the upkeep of a fire safety inspection package and in fire zones where there is a higher frequency of fire, increase premiums.
- Claim Risk Management: Empirical evidence shows that fire loss is reduced by a large amount when the fire safety systems are functional and well maintained and vice versa as illustrated in the bar chart impact of fire safety systems on fire damage. The recommendation is that insurance companies offer lower premiums for buildings equipped with functional fire alarms and sprinkler systems. Also, it requires an annual fire safety inspection to maintain insurance eligibility.

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APPENDICES

Appendix A. Regression Analysis

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.239024156
R Square	0.057132547
Adjusted R Square	0.05684626
Standard Error	0.2358086
Observations	3494

what is the predicted number of casualties for a fire incident with 10 responding fire personnel?

0.02

Regression model:

Civilian Casualties= 0 + 0.0018*Number of Responding Personnel

ANOVA

	df	SS	MS	F	Significance F
Regression	1	11.76930475	11.7693	211.6565	1.34E-46
Residual	3493	194.2306953	0.055606		
Total	3494	206			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Number_of_responding_personnel	0.001800138	0.000123734	14.54842	1.34E-46	0.00155754	0.002042737	0.00155754	0.002042737

Appendix B. Dashboard

https://public.tableau.com/app/profile/nor.kumar.bista/viz/FireIncidentTFS/Dashboard1