Examining the Relationship Between Firefighter Injuries and Fatalities in the Built Environment:

A case for reducing the risk to firefighters through adequate firefighting experience, working smoke alarms and sprinkler coverage in buildings

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Executive Summary

The purpose of this study is to describe firefighter injuries and deaths in structure-related fires and to investigate the underlying connection between building properties, including fire safety measures, and their effects on the risk to firefighters responding to a fire event. For the first time, comprehensive fire-related data across Canada is available in the form of the National Fire Information Database (NFID). Using this new dataset, in conjunction with a literature review and an Association of Worker Compensation Boards of Canada (AWCBC) dataset, this report explores the impact of building properties (e.g. construction material, height) and fire safety measures (e.g. sprinklers, fire alarms) on firefighter casualties. For the purposes of this report, casualties represent both injuries and deaths.

Review of literature extracted only six studies that were relevant to the scope of this study. Only two publications, both retrospective studies using data from the United States, directly associated structural properties with firefighter injuries and deaths. One study analyzing firefighter fatality reports in the United States found that roughly 17% of the reported fatalities were structure-related, with common causes of death including the collapse of building components crushing firefighters, falling through floors or rooftops, and rapid flashover (Hodous et al. 2004). Another study showed that fires originated from below ground level or 10-49 feet above ground level were found to increase the odds of a firefighter being injured (Fabio et al. 2002).

Between the years of 2005 and 2014, there were a total of 177,626 structural fire incidents across the provinces of British Columbia, Alberta, Saskatchewan, Manitoba, and Ontario. The majority of these structural fires occurred on residential properties (72%). In the overlapping years of 2006 and 2014, between the AWCBC and NFID datasets, there were a total of 2,268 firefighter casualties (8 deaths)due to these structural fires, which made up 20.4% of the 11,100 work-related firefighter casualties, as reported by the number of accepted fatality and time-loss claims.

The general poor data quality in the NFID, as evidenced by high proportions of missing or unknown entries, severely limited the ability to fully interpret and form conclusions. In addition, the lack of data on structural integrity, such as weakening or failing of structural support, prevented its use as the intuitive link between risk to firefighters and building properties and safety measures. However, the NFID presented data in such scale and detail that were not previously available, the findings derived from it are still the best to date and important for elucidating associations between risk to firefighters, building properties and fire safety measures.

Analysis of the NFID did not find evidence that building properties, such as construction material and height, affected risk to firefighters, but rather these risks were affected by fire safety measures, such as fire detection devices, smoke alarms, and sprinklers. The best-case scenario for reducing firefighter casualties would be adequate firefighting experience, when automatic fire detection systems are in place, when fire detection devices are present, when automatic fire extinguishing equipment are working properly, when working smoke alarms are functioning properly, and when the building has sprinkler coverage.

This report supports the following recommendations:

- Improving the data quality of the NFID to allow for more solid interpretations, conclusions, and recommendations to be formed:
    - Standardize data collection across Canada to reduce the number of missing and unknown data fields across the provinces;
    - Collect information on variables found in the victim file for all firefighter dispatches instead of just those that resulted in injuries and deaths, in order to better estimate risk;
    - Have the ability to link with AWCBC or WorkSafeBC datasets to improve data quality;
    - Direct resources to increase the overall quality of the NFID in order to reduce inconsistencies, coding errors, and missing data, as the NFID is a rich source of information;
    - Collect data on structural integrity, such as weakening and failing of structural supports, in order to better investigate its role related to firefighter casualties.

- Further research required to test and expand on the findings from this study:
    - Findings in this study should be reinforced when better quality data, either through improving the NFID or otherwise, becomes available;
    - Pilot studies, perhaps carried out by a selection of fire departments, are recommended to collect better quality data to better reinforce some of the findings in this report;
    - Poisson regression model is recommended as it directly associates risk or rate of firefighter casualties to building properties and fire safety measures;
    - As fire spread fits well as an intermediate variable, it can be used as a surrogate to firefighter casualties if resources are lacking;
    - Data on structural integrity, such as weakening and failing of structural supports, due to fire should be collected and investigated as an intermediate variable.

Introduction

Each year, Canadian firefighters suffer injuries and deaths while responding to fire incidents. These are tragic events that result from several factors, such as equipment limitations, training and experience issues, industrial disease, and the dangers inherent in working near and within failing structures. This latter element has led for calls in some sectors to make changes to Canada's Building Code to make structures more resilient and safer for both occupants and first responders in the event of a fire.

While it is undoubtedly true that structural failures lead to injuries and deaths among first responders, it is not clear how extensive the problem truly is. There is currently a lack of systematic research on the risk posed by structural properties in comparison with other causes. Furthermore, where those losses occur, even less is known about how the inherent safety systems, age, structural composition, and overall building architecture contribute to the casualties associated with an incident. Having empirical evidence relating to these matters would help guide the process of identifying the real determinants of firefighter injuries and deaths so they can be acted upon.

A primary reason for the lack of evidence in Canada linking structural form and integrity to firefighter injuries and deaths is that relevant data are limited. Where data are available, they are disbursed across a variety of sources. Furthermore, fire-related injuries and deaths are relatively rare compared with other types of industrial incidents. Thus, data from small jurisdictions, or even a single province, may not be sufficient to identify the underlying relationships.

With the advent of the National Fire Information Database (NFID), this problem can be addressed since a larger data aggregation provides a larger sample of events. In combination with the Association of Worker Compensation Boards of Canada (AWCBC), which has information on workplace accidents and fatalities, the ability to tease out "true" underlying causal relationships has improved.

This study aims to investigate the underlying connection between building properties, including fire safety measures, and their associations with firefighter casualties through both a review of the literature as well as the available datasets. By combining both reviews, this study provides greater understanding and evidence to help guide stakeholders in their decisions toward building code policies in order to reduce the risks to firefighters.

Purpose

The purpose of this study is to describe structure-related injuries and deaths directly affecting firefighters in Canada for the ten-year period, 2005-2014. This study provides stakeholders with evidence in order to help guide their efforts to develop, implement and evaluate building codes aimed at reducing casualties (injuries and deaths) to firefighters during fire events.

The specific objectives of this study are, through literature and data reviews: (1) to determine the extent to which Canadian firefighters suffer casualties due to structure-related fire incidents; (2) to determine whether building properties, including fire safety measures, are associated with the risk of casualty among firefighters; and (3) to evaluate the role of fire spread as an intermediate variable.

Literature Review

METHODOLOGY

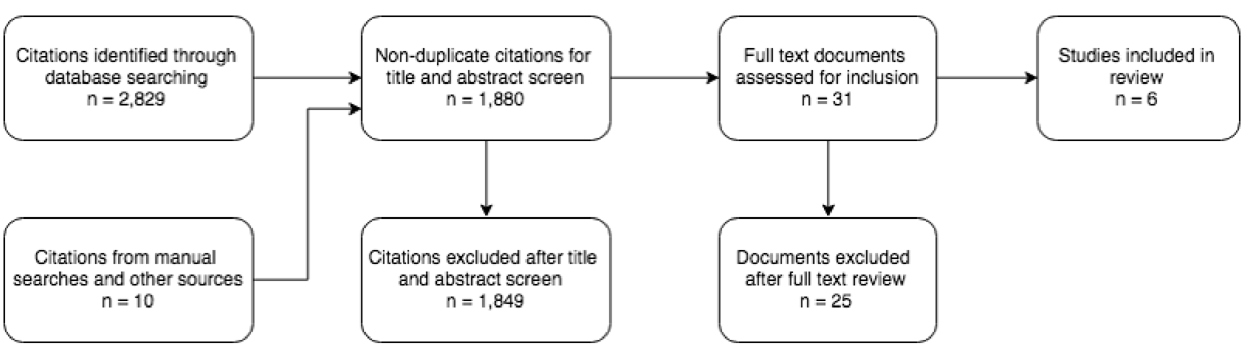
A systematic search for studies pertaining to firefighter casualties associated with building structural properties, including fire safety measures, was performed using the following databases: MEDLINE, EMBASE, CINAHL, Web of Science, Engineering Village, Proquest, and des Libris. The searches were conducted up to February, 2018 and were restricted to documents written in English. The following search terms and their variations were included in the search strategy: firefighter, injury, death, mortality. Terms pertaining to building, structural, and fire-safety characteristics were not included in the search strategy so as to increase the sensitivity of the initial search. Citations found through manual searches of reference lists, personal collections, correspondence collections, and Google Scholar searches were also included.

Following the removal of duplicates, the retrieved citations underwent a preliminary title and abstract screening for relevance to firefighter casualties and building properties. Those deemed relevant were selected for full text review and the CASP cohort study checklist was applied (Critical Appraisal Skills Programme, 2017). For studies to be included in this review, they must have either: 1) directly investigated firefighter injuries or deaths associated with structural building properties or fire-safety measures such as sprinkler systems or smoke alarms, or 2) investigated injuries or deaths to both firefighters and civilians (overall fire-related casualties) associated with the aforementioned factors. Studies describing a single fire incident were excluded in favor of larger cohort studies as they were deemed too specific and circumstantial to provide information on the overall patterns and trends for this report.

RESULTS

From a total of 1,880 non-duplicate citations retrieved through the searches, 31 studies underwent a full-text review for eligibility, and 6 studies met our inclusion criteria (Figure 1).

FIGURE 1. IDENTIFICATION OF STUDIES PERTAINING TO FIREFIGHTER CASUALTIES AND BUILDING PROPERTIES AND/OR FIRE SAFETY MEASURES



Three of the studies specifically analyzed firefighter injuries and deaths separate from civilians, whereas 3 analyzed overall injuries and deaths occurring at residential fires. Table 1 provides a brief summary of the studies included in this review.

TABLE 1: SUMMARY OF STUDIES SELECTED

Study	Country Study Years	Sample Population	Data Source(s)	Methodology	Relevant Findings
Fabio et al. (2002)	USA 1993-1997	Firefighters injured at structural fires	NFIRS	Retrospective Case – Control	Risk factors for firefighters at structural fires included: - Fires originating below ground level (vs. ground level) OR = 1.12, 95% CI 1.05 – 1.19 - Fires originating 10-49 ft above ground level (vs. ground level) OR = 1.12, 95% CI 1.09 – 1.16 - Fires originating >49 ft above ground level decreased the odds of firefighter injury (vs. ground level) OR = 0.57, 95% CI 0.49 – 0.66
Hodous et al. (2004)	USA 1998-2001	Firefighter line-of-duty deaths (excluding 11/09/01 World Trade Center deaths)	USFA database, NIOSH FFFIPP reports	Retrospective Analysis	A total of 410 firefighter deaths occurred, with 68 deaths being structure related, specifically: - 17 deaths due to building collapse - 15 deaths due to flashover/rapid fire progression Common structure-related causes included collapse of building components onto firefighters causing crushing injuries and falls through floors or rooftops
Garis & Clare (2014)	BC, Canada 2008 - 2013	Residential fire injuries and deaths (firefighters and civilians)	BC OFC	Retrospective Analysis	Analysis of 11,875 building fires resulting in 772 injuries and 107 deaths revealed that: - Buildings made from ‘protected combustible construction’ (e.g. wood protected by plaster) accounted for 65.8% of all fires, 75% of all injuries, and 30% of all deaths - When analyzing incidents with functioning smoke alarms and complete sprinkler protection systems only, building construction material made little difference to fire spread,

					injury rate, or death rate
Cohen & Garis (2018)	BC, Canada 1988 - 2016	Residential fire injuries and deaths (firefighters and civilians)	BC OFC	Retrospective Analysis	Analysis of 39,724 residential building fires resulting in 4,023 injuries and 490 deaths revealed that: - 40% of fires occurred in structures built before 1975, 60% in structures built in 1975 or later - Buildings constructed in 1975 or later had a greater proportion of installed sprinkler systems and smoke alarms compared to structures built before 1975 - Rates of injuries and deaths are higher in buildings constructed prior to 1975 than in buildings built in 1975 even after controlling for sprinkler systems and smoke alarms
Garis et al (2018)	Canada 2005-2015	Residential fire injuries and deaths (firefighters and civilians)	CAFC, CCFMFC, Statistics Canada	Retrospective Analysis	Analysis of 83,285 residential building fires resulting in 5,618 injuries and 785 deaths across 6 Canadian provinces revealed that: - Overall mortality rate per 1000 reported residential fires was over 3 times greater in building fires without sprinklers than buildings with sprinklers - The firefighter-specific injury rate was 1.6 times greater in building fires without sprinkler protection than in buildings with sprinklers

NFIRS = National Fire Incident Reporting System
USFA = United States Fire Administration
NIOSH FFFIPP = National Institute of Occupational Safety and Health Fire Fighter Fatality Investigation and Prevention Program
BC OFC = British Columbia Office of the Fire Commission
CAFC = Canadian Association of Fire Chiefs
CCFMFC = Council of Canadian Fire Marshals and Fire Commissioners
OR = Odds ratio
CI = Confidence interval

Impact of Building Structural Characteristics on Firefighter Casualties

A building's structural characteristics can include, but is not limited to, the number of stories or height of the structure, the specific materials used in the construction of the building, the age of the building, and different building codes that were met. With this in mind, it comes as no surprise that structural firefighting comes with its own unique difficulties and challenges as firefighters must consider issues related to route of access, transport of equipment, structural stability, ventilation, escape, and fire spread in the context of each building. A study analyzing firefighter fatality reports in the US found that roughly 17% of the reported fatalities were structure-related, with common causes of death including the collapse of building components crushing firefighters, falling through floors or rooftops, and rapid flashover (Hodous et al. 2004). Though this study did not analyze specific characteristics of buildings or include the many firefighter and first-responder lives lost during the structural collapse of the US World Trade Center on September 11, 2001, it does however demonstrate that structural fires represent a substantial occupational hazard and cause of firefighter mortality.

Only a few studies were found to have investigated specific building characteristics on the risk of firefighter injury (Fabio et al. 2002; Garis & Clare 2014; Cohen & Garis 2018). In a study analyzing 1.3 million structural fire incidents in the US, the odds of a firefighter being injured increased when fires originated below ground level (OR = 1.12, 95% CI 1.05 – 1.19) or if fires originated 10-49 feet above ground level (OR = 1.12, 95% CI 1.09 – 1.16), and decreased when fires originated higher than 49 feet above ground level (OR 0.57, 95% CI 0.49 – 0.66) (Fabio et al. 2002). These findings may be explained by how fires in building basements and fires in higher stories were, in general, associated with difficulties in access and escape. On the other hand, the authors suggest that the decreased odds of injury for fires originating 49 feet above ground level (e.g. high-rise buildings) may be due to building codes that require higher elevation floors to have fire detection and safety measures, although this was not directly investigated in this study.

Conversely, a study analyzing all fire-related casualties (firefighter and civilian) found that there were little to no differences with respect to injury and death rates when comparing combustible, protected-combustible, non-combustible, and protected non-combustible construction materials, provided that the structures were equipped with sprinkler protection systems and smoke alarms (Garis & Clare 2014). Though this study did not examine firefighter injuries and deaths specifically, it does suggest, however, that the presence of fire safety measures was the more important factor with respect to reducing injuries and deaths as opposed to the building construction material.

Lastly, research has shown that the age of buildings can affect the risk for fire-related casualties. A study analyzing residential fires in buildings built before and after the year 1975 found that even after controlling for the presence of functioning sprinkler systems and smoke alarms, rates of fire-related casualties (firefighter and civilian) were higher in pre-1975 building fires compared to post-1975 building fires (Cohen & Garis 2018). Though the construction material differences were not investigated or controlled for in this study, the authors suggest that the possible differences may be attributed to enhanced building codes, construction materials, as well as safety requirements that were commonly found in newer buildings.

Though the documented research on building structural characteristics and firefighter morbidity and mortality is limited, the available evidence suggests that factors such as building height, construction material, and age can play a role in a firefighter's risk for injury or death while in the line-of-duty. Further research is needed to investigate the impact of factors such as building codes and newer construction materials, such as those used in sustainable/green buildings.

Impact of Fire Safety Measures on Firefighter Casualties

Fire safety measures include fire extinguishing systems, such as sprinklers, and fire detection systems, such as smoke alarms. It is also important to recognize that while both systems are considered fire safety measures, a distinction should be made that while detection systems, such as smoke alarms, can act as an early detection for fires, they cannot control the spreading fire in any way. On the other hand, extinguishing systems, such as sprinklers, not only detect fires, but also control and prevent fires from spreading.

Research has shown that 95% - 97% of residential fires occur in buildings without any sprinkler protection and account for an overwhelming majority of fire-related injuries and deaths (Garis & Clare 2016; Garis et al. 2018). A study analyzing 140,162 residential fires in 6 Canadian provinces found that the firefighter casualty rate was 1.6 times higher (15.2 vs. 9.2 casualties per 1,000 residential fires) when buildings did not have a sprinkler system compared to those that did (Garis et al. 2018). The same study also showed that fires that occurred in buildings with sprinkler protection were more likely to be confined to the area or room of origin and less likely to require fire departments to combat and extinguish the fire. These findings suggest that sprinkler systems play a pivotal role in reducing the risk for injury and death for firefighters as they can reduce and contain the spread of fires thereby making it safer for firefighters to approach and combat the fire if needed.

Smoke alarms have also been found to be an important factor in reducing fire-related injuries and deaths. A study analyzing 42,701 residential fires in British Columbia, Canada found that 28% of fires occurred in buildings with no smoke alarm installed, resulting in 32% and 37% of the fire-related injuries and deaths, respectively (Garis & Clare 2016). The same study also showed that smoke alarms and sprinkler systems work synergistically to reduce the rate of fire-related casualties, the need for fire department intervention, and the spread of fire beyond the room of origin. However, it is important to reiterate that smoke alarms only function as an early detection method as opposed to a method of controlling fires. As such, the evidence suggests that the greatest risk reduction for firefighter injuries and deaths comes instead from sprinkler systems.

Data Review

METHODOLOGY

Data Sources

Three datasets were analyzed as part of this report: (1) Association of Worker's Compensation Boards of Canada (AWCBC); (2) Worker's Compensation Board of British Columbia (WorkSafeBC); and (3) National Firefighters Information Database (NFID).

The AWCBC is a national database that included accepted time-loss claims due to injury and fatality claims for firefighters over the years of 2006 to 2015. Aggregated time-loss claims data were provided for all provinces and territories, whereas fatality claims data were provided for all provinces and territories except for Nunavut, Northwest Territories, Newfoundland, and Prince Edward Island.

WorkSafeBC is a provincial database that included accepted time-loss and fatality claims data for firefighters, in British Columbia only, over the years of 2006 to 2015. In contrast to the aggregated nature of the AWCBC dataset, the WorkSafeBC dataset contained de-identified data at the claims level.

The NFID is a novel database containing fire incidents and victims reported by the Fire Commissioners and Fire Marshal Office from seven different jurisdictions from across Canada – British Columbia (BC), Alberta (AB), Saskatchewan (SK), Manitoba (MB), Ontario (ON), New Brunswick (NB) and the Canadian Armed Forces (CAF). The database included fire information from 2005 to 2015. However, not all jurisdictions provided data for all years. BC, AB, MB, NB and CAF provided all 11-years, ON provided data for 10-years, 2005 to 2014; and SK provided data for 4-years, 2012 to 2015. The NFID was separated into two main files that were merged. The incident file represented a single fire incident attended by a fire service within the reporting jurisdiction between 2005 and 2015. The victim file, for both civilians and firefighters, represented either a single death or a single person injured as a result of the fire incident. A single fire incident, therefore, may have multiple injuries and/or deaths.

Inclusion Criteria

For the AWCBC and WorkSafeBC datasets only accepted work-related claims submitted by firefighters were included in the analysis.

For the NFID dataset, only data reported by BC, AB, SK, MN, and ON from 2005-2014 was used. This was because other provinces provided incomplete incident and/or victim datasets and ON, which contributed to the majority of the counts, did not report for 2015. In addition, only those incidents that were related to structural fires, on properties classified as assembly, institutional, residential, business, mercantile, industrial, and storage, were included in the analysis.

Variable Selection and Data Cleaning

For the AWCBC and WorkSafeBC datasets, *Nature of Injury* was used to select claims due to traumatic injuries. This included open wounds, surface wounds, bruises, burns, intracranial injuries, effects of environmental conditions, and other traumatic injuries to bones, nerves, spinal cord, muscles, tendons, ligaments, and joints (Appendix A). This variable was used to capture acute injuries, such as those that incurred from line-of-duty events, as opposed to long-term conditions, such as chronic diseases and overuse injuries.

The AWCBC dataset contained aggregated fatalities and time-loss claims counts separated by nature of injury, province, and year of claim. Any non-zero number equal to or less than 3 was replaced with an "X" to protect personal identification. For the purposes of this analysis, all cells marked with "X" were replaced with a randomly generated integer between and including 1 and 3. As a result, the total counts would be different from, but similar to, the actual total counts.

For the NFID, the primary outcome of interest was firefighter injuries and deaths. Injuries and deaths were re-coded from the *Nature of Casualty* variable. Death was defined as death, while injury was defined as follows: minor injury (less than 1 day in hospital or time off work); light injury (hospitalized 1-2 days and/or time off work 1-15 days); serious injury (hospitalized 3+ days and/or time off work 16+ days); and injury, seriousness unknown. For the purposes of this study, a casualty was defined as an injury or death.

Main predictors of interest were variables related to building properties and fire safety measures, which were separated into construction properties (material, height, and year of construction), presence of safety measures (automatic fire detection systems, fire detection devices, fixed systems other than sprinklers, sprinkler protection), performance of safety measures (initial fire detection by device, automatic extinguishing equipment, smoke alarm device), and protection facilities (manual, and outside). Building height (measured in stories) and year were taken as continuous variables. Height was also limited to under 50-stories due to possible outlier effects. General construction was recoded into 3-levels: non-combustible, protected combustible or heavy timber, and exposed combustible to reflect three levels of combustibility of construction material. All the other building-related variables were recoded into binary variables. Presence of safety measures and protection facilities were coded as either present or not present. Performance of safety measures were coded to be either working properly (if it activated or activation was not required) or not (if it did not activate or was not present).

Other variables of interest were property class, extent of fire spread, subsequent crew size, firefighter gender, firefighting experience, and firefighter status. Property class was recoded to residential and other structure-related property classes, which included assembly, institutional, residential, business, mercantile, industrial, and storage. Subsequent crew size (persons) and firefighter experience (years) were each taken as a count variable, while firefighter status was recoded as full-time or not. These variables were mainly used for controlling purposes in the modeling component of this report.

Fire spread was coded as an ordinal variable, coded into 6 levels (1 = confined to object of origin; 2 = confined to part of room/area of origin; 3 = confined to room of origin; 4 = confined to floor level of origin; 5 = confined to building of origin; 6 = extended beyond building of origin). This variable was modeled as both a predictor and an outcome in order to investigate its role as an intermediate variable.

Please see appendix A for more detailed categorization of the variables selected for this study.

Scope of Problem

To estimate the scope of the problem, total casualty counts were tallied from AWCBC, WorkSafeBC, and NFID datasets in the overlapping provinces (BC, AB, SK, MN, and ON) and years (2006 to 2014). From the claims datasets, accepted firefighter workplace claims were used to represent the total number of firefighter casualties at the workplace and traumatic injuries was used to represent only the acute ones. From the NFID, the total number of firefighter casualties was used to estimate firefighter casualties in the line-of-duty, and the number of firefighter casualties in the structure-related property classes was used to estimate firefighter casualties due to a structural fire.

Firefighter and Civilian Distributions and Rates

Firefighter and civilian casualty counts and rates were calculated for each property class and for each building property and fire safety measure. The rate per 1,000 fire incidents was calculated using the number of firefighter casualties divided by the number of fire incidents in the specific category multiplied by 1,000. These rates were then compared between firefighters and civilians to determine whether the building properties and fire safety measures had similar effects on both populations.

Building Properties and Safety Measures

Three models were used to quantify the association between firefighter casualties and building properties and fire safety measures.

The first model was a Poisson regression model (Model 1) that associated the building properties and fire safety measures to the rate of firefighter casualties. The outcome variable was the number of firefighter casualties at a fire incident. The total number of firefighters that responded to the scene of the fire, as represented by the subsequent crew size variable, was used as the offset. Predictors of interest were all the variables related to building properties and fire safety measures. It is important to note that the rate represented in this model is a true rate, where the exposure is the actual number of firefighters exposed to a fire incident, as opposed to per fire incident as mentioned in previous section. Due to the aggregated nature of the outcome variable, this model cannot account for any individual firefighter variables, such as age, gender, status, and experience.

The second model was a logistic regression model (Model 2) that associated the building properties and fire safety measures to the odds of a fire event resulting in at least one firefighter casualty. The outcome variable was a binary variable as to whether the fire incident resulted in at least one firefighter casualty. Predictors of interest were all the variables related to building properties and fire safety measures. Again, due to the aggregated nature of the outcome variable, this model cannot account for any individual firefighter variables, such as age, gender, status, and experience.

The third model was also a logistic regression model (Model 3), but it associated the building properties and fire safety measures to the odds of a serious casualty over minor casualties. The outcome variable was a binary variable as to whether a firefighter casualty was classified as serious (resulted in at least 3 days hospitalized or 16 days off work or death) or minor (less than 1 day hospitalized or off work). Predictors of interest were all the variables related to building properties and fire safety measures. In addition, individual firefighter variables could be included in this model and controlled for. These included age, gender, status, and experience. Please note that this model only takes the subset of the data where there was a firefighter casualty.

For each of the models, univariate analyses were first conducted on each of the predictor variables of interest. Associations that were significant, at $p<0.1$, in the univariate analyses were then put into a full multiple regression model, while correcting for property class. The variables that were associated with the outcome of interest in the full model at $p<0.05$ were deemed to be significant.

Linkage to Fire Spread

In order to investigate the role of fire spread as an intermediate variable between firefighter injuries and building properties and fire safety measures, it was modeled as both a predictor and outcome variable.

As a predictor, the same three models indicated above were used to determine the association of fire spread with the rate of firefighter casualty (Model 1), the odds of a fire incident resulting in at least one firefighter casualty (Model 2), and the odds of a serious casualty over a minor one (Model 3). Here, fire spread was the only predictor of interest and property class as the control variable, so no univariate analyses were conducted.

As an outcome variable, an ordinal regression model was used to associate the building properties and fire safety measures on the fire spread. Similar to the analyses above, univariate analyses were first conducted and associations that were significant at $p<0.1$ were put into a full multiple regression model, while correcting for property class. Associations at $p<0.05$ in the full model were deemed to be significant.

RESULTS

Data Quality and Limitations

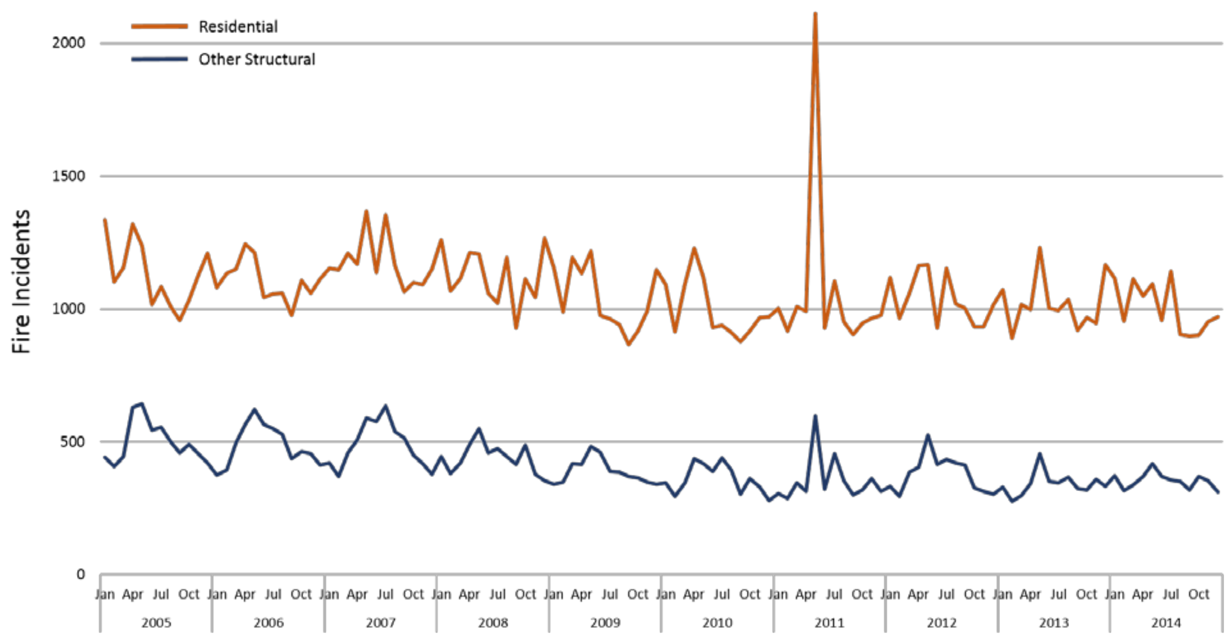
Due to the aggregated and de-identified nature of the AWCBC and WorkSafeBC datasets, respectively, linkage to building properties and fire safety measures was not possible. As the data from the two datasets were very similar and that WorkSafeBC, containing only BC data, was a subset of the AWCBC data, only numbers from the AWCBC dataset were reported. It should also be noted that by using random allocation for the suppressed cells, the counts reported were not true counts, but were similar enough and well within 5% margin of error.

From the NFID, all the building variables of interest had large proportions of data that were either missing or unknown. On average, the variables had 62% (SD 14%) of data that were either missing or unknown (Appendix B). The variable for having fixed systems other than sprinklers had over 88% of its data as either missing or unknown, while height of building had the least missing or unknown, at 39%. However, the quality of the height variable was also questionable as although the unit of measurement was in storeys, the number 8 was used to code all non-structure-related fires, such as vehicle and wildfires. Even after filtering out the non-structure-related fires by using property class, the distribution of the height variable still had elevated numbers of 8's (Appendix C). This was problematic as there were buildings that are eight stories and higher.

Fire Incidents

Between 2005 and 2014, there were a total of 177,626 structure fire incidents across the provinces of BC, AB, SK, MN, and ON. Among these fire incidents, 128,400 (72%) were from residential properties and 49,226 (28%) were from other structure-related property classes.

FIGURE 2: NUMBER OF FIRE INCIDENTS REPORTED IN RESIDENTIAL AND OTHER STRUCTURAL PROPERTY CLASSESS IN BC, AB, SK, MN, ON FROM 2005-2014.



From Figure 2, a minor decreasing trend over the years and seasonality effects, with more fires in the summer months and fewer fires in the winter months, can be seen. There was a noticeable spike in the number of structural fire incidents, particularly residential fires, in 2011 and this was attributable to a single fire event in Slave Lake, Alberta.

Scope of the Problem

From the AWCBC, there were a total of 15,905 work-related time-loss and fatality claims that were classified as traumatic casualties, illnesses, and disease-related firefighter claims in Canada from 2006-2015. Whereas from the NFID, there were a 2,612 firefighter casualties due to fire incidents on structural properties in the provinces of BC, AB, SK, MN, and ON between the years of 2005 and 2014.

Using the overlapping years of 2006 to 2014 and provinces of BC, AB, SK, MN, and ON, there were 11,100 firefighter work-related time-loss and fatality claims. Among those, 9,699 (87.4%) were traumatic in nature, 2,659 (24.0%) were caused by responding to fire incidents, and 2,268 (20.4%) were due to responding to fire incidents on structural properties (see table 2).

TABLE 2: NUMBER AND PERCENTAGE OF CASUALTIES AS REPORTED FROM AWCBC (ALL ACCEPTED CLAIMS AND TRAUMATIC CLAIMS ONLY) AND NFID (ALL FIRE INCIDENTS AND FIRE INCIDENTS IN STRUCTURE-RELATED PROPERTY CLASSES ONLY), IN BC, AB, SK, MN, ON FROM 2006-2014.

Casualties from	Number of Casualties	%
All claims	11,100	100.0
Traumatic claims	9,699	87.4
All fire incidents	2,659	24.0
Structure-related fire incidents	2,268	20.4

Firefighter and Civilian Distributions and Rates

The casualty rates of firefighters were similar when comparing residential properties and other structure-related property classes at 15.3 and 14.0 casualties per 1,000 fire incidents, respectively (Appendix D). The casualty rates for civilians were higher than firefighters and the rates for residential properties (63.7 per 1,000 fire incidents) were three-times the rates of other structural property classes (19.5 per 1,000 fire incidents).

TABLE 3: NUMBER OF FIRE INCIDENTS, FIREFIGHTER CASUALTY COUNTS AND RATES, AND CIVILIAN CASUALTY COUNTS AND RATES PER STRUCTURE-RELATED PROPERTY CLASSIFICATION GROUPS.

Property Classification Group	Fire Incidents (#)	Proportion (%)	Firefighter		Civilian	
			Casualties (#)	Casualty Rate (per 1,000 inc)	Casualties (#)	Casualty Rate (per 1,000 inc)
Residential	128,400	72.3	1,963	15.3	8,183	63.7
Other Structure-related zones	49,226	27.7	691	14.0	962	19.5

Compared to civilians, firefighters had fewer serious casualties (12.3% were deaths or serious injuries compared to 33.1% in civilians), higher proportion due to physical causes instead of smoke and burn (26.2% due to physical causes compared to 2.1% in civilians), and a higher proportion were among males (Table 4).

TABLE 4: NUMBER AND PROPORTION OF CASUALTIES IN FIREFIGHTER AND CIVILIAN POPULATIONS BY NATURE OF CASUALTIES, GENDER, AND PROBABLE/POSSIBLE CAUSE IN STRUCTURE-RELATED FIRES.

Variable	Label	Firefighter		Civilian	
		Casualties (#)	Proportion (%)	Casualties (#)	Proportion (%)
Nature of Casualties	Death	8	0.3	1,328	15.5
	Minor injury	2,197	76.3	4,325	50.3
	Light injury	154	5.4	989	11.5
	Serious injury	344	12.0	1,512	17.6
	Injury, seriousness unknown	1	0.0	29	0.3
	Unknown	174	6.1	408	4.8
Gender of Victim	Male	2,410	83.7	5,150	60.0
	Female	154	5.4	3,336	38.8
	Unknown	314	10.9	103	1.2
Probable/Possible Cause	Smoke inhalation	60	11.8	1,584	48.3
	Burn	38	9.5	1,130	34.4
	Physical injury	133	26.2	68	2.1
	Other	59	11.6	81	2.5
	Unknown	217	42.8	420	12.8

In residential properties, firefighters had reduced casualty rates when the fire was detected by a fire safety device, when fixed systems other than sprinklers were present, when the building was made of protected combustible or heavy timber material, when manual fire protection was present, when smoke alarms did not function properly or were not present, and when there was sprinkler coverage in the building. In comparison, civilians had increased casualty rates when fire detection devices were present, when fixed systems other than sprinklers were present, when the building was made of protected combustible or heavy timber material, when smoke alarms were functioning properly or not needed, and when there was no sprinkler coverage in the building. Cases with no outside fire protection and fixed systems other than sprinklers had too few counts for meaningful comparisons (Table 5).

TABLE 5: NUMBER OF FIRE INCIDENTS, FIREFIGHTER CASUALTY COUNTS AND RATES, AND CIVILIAN CASUALTY COUNTS AND RATES PER BUILDING PROPERTY AND FIRE SAFETY MEASURE IN RESIDENTIAL PROPERTY ZONES.

Variable	Label	Fire Incidents (#)	Firefighter			Civilian		
			Casualties (#)	Proportion (%)	Casualty Rate (per 1,000 inc)	Casualties (#)	Proportion (%)	Casualty Rate (per 1,000 inc)
Automatic fire detection system	No central alarm	37,474	487	68.2	13.0	2,783	67.9	74.3
	Central alarm present	16,976	227	31.8	13.4	1,314	32.1	77.4
Initial detection	Non-device detection or no detection	66,488	948	94.2	14.3	4,139	90.5	62.3
	Device detection	7,036	58	5.8	8.2	437	9.6	62.1
Fire detection devices	No detection devices	9,324	206	16.0	22.1	608	12.6	65.2
	Detection devices present	49,855	1,085	84.0	21.8	4,207	87.4	84.4
Fixed system other than sprinklers	No other fixed systems	14,730	140	97.2	9.5	1,241	94.4	84.2
	Other fixed systems present	672	4	2.8	6.0	73	5.6	108.6
General construction	Non-combustible	2,432	20	6.7	8.2	161	5.5	66.2
	Protected combustible + heavy timber	29,371	197	66.3	6.7	2,302	78.3	78.4
	Exposed combustible	8,688	80	26.9	9.2	477	16.2	54.9
Manual fire protection facilities	No manual fire protection	22,798	187	65.2	8.2	1,801	59.8	79.0
	Manual fire protection present	16,147	100	34.8	6.2	1,211	40.2	75.0
Outside fire protection	No outside fire protection	633	2	0.6	3.2	23	0.7	36.3
	Outside fire protection present	50,599	317	99.4	6.3	3,283	99.3	64.9
Performance of automatic extinguishing equipment	Equipment did not operate or not present	62,417	1,139	96.4	18.2	4,138	95.3	66.3
	Equipment operated or did not require operation	2,910	42	3.6	14.4	203	4.7	69.8
Performance of smoke alarm device	No smoke alarm or not activated	37,605	570	43.1	15.2	2,509	40.6	66.7
	Smoke alarm activated or not enough smoke to activate	43,064	754	57.0	17.5	3,664	59.4	85.1
Sprinkler protection	No sprinkler protection	70,246	1,122	97.2	16.0	5,055	95.8	72.0
	Sprinkler protection present	3,623	32	2.8	8.8	223	4.2	61.6

In other structural property classes, firefighters had increased casualty rates when fixed systems other than sprinklers were present, when manual fire protection was not present, when automatic fire extinguishing equipment was functioning properly or not needed, when smoke alarms were functioning properly or not needed, and when there was no sprinkler coverage in the building. In comparison, civilians had increased rates when automatic fire detection systems were present, when the fire was detected by a fire safety device, when fixed systems other than sprinklers were present, when the building was made of non-combustible material, when manual protection was present, when automatic fire extinguishing equipment was functioning properly or not needed, when smoke alarms were functioning properly or not needed, and there was sprinkler coverage in the building. Cases of no outside fire protection had too few counts for meaningful comparisons (Table 6).

TABLE 6: NUMBER OF FIRE INCIDENTS, FIREFIGHTER CASUALTY COUNTS AND RATES, AND CIVILIAN CASUALTY COUNTS AND RATES PER BUILDING PROPERTY AND FIRE SAFETY MEASURE IN NON-RESIDENTIAL STRUCTURE-RELATED PROPERTY CLASSES.

Variable	Label	Fire Incidents (#)	Firefighter			Civilian		
			Casualties (#)	Proportion (%)	Casualty Rate (per 1,000 inc)	Casualties (#)	Proportion (%)	Casualty Rate (per 1,000 inc)
Automatic fire detection system	No central alarm	10,255	166	56.3	16.2	226	46.9	22.0
	Central alarm present	8,234	129	43.7	15.7	256	53.1	31.1
Initial detection	Non-device detection or no detection	25,266	345	87.8	13.7	561	86.3	22.2
	Device detection	3,634	48	12.2	13.2	89	13.7	24.5
Fire detection devices	No detection devices	8,473	169	50.2	19.9	236	45.8	27.9
	Detection devices present	7,957	168	49.9	21.1	279	54.2	35.1
Fixed system other than sprinklers	No other fixed systems	4,871	58	79.5	11.9	191	79.3	39.2
	Other fixed systems present	851	15	20.6	17.6	50	20.8	58.8
General construction	Non-combustible	5,089	44	34.9	8.6	184	53.2	36.2
	Protected combustible + heavy timber	4,653	39	31.0	8.4	100	28.9	21.5
	Exposed combustible	4,745	43	34.1	9.1	62	17.9	13.1
Manual fire protection facilities	No manual fire protection	3,518	37	26.6	10.5	65	16.6	18.5
	Manual fire protection present	11,060	102	73.4	9.2	326	83.4	29.5
Outside fire protection	No outside fire protection	241	1	0.7	4.1	0	0.0	0.0
	Outside fire protection present	18,416	148	99.3	8.0	405	100.0	22.0
Performance of automatic extinguishing equipment	Equipment did not operate or not present	17,950	257	76.7	14.3	394	65.8	21.9
	Equipment operated or did not require operation	4,747	78	23.3	16.4	205	34.2	43.2
Performance of smoke alarm device	No smoke alarm or not activated	20,492	290	69.4	14.2	441	61.7	21.5
	Smoke alarm activated or not enough smoke to activate	7,450	128	30.6	17.2	274	38.3	36.8
Sprinkler protection	No sprinkler protection	16,797	254	90.1	15.1	370	74.5	22.0
	Sprinkler protection present	3,928	28	9.9	7.1	127	25.6	32.3

Building Properties and Fire Safety Measures

For Model 1 (a Poisson regression model), which associated the building properties and safety measures with the casualty rate of firefighters, the variables for fixed systems other than sprinklers, general construction, manual protection, and outside protection could not be modeled as they were not reported by ON and SK, while the subsequent crew size variable used as the exposure offset required for this model was only reported by ON and SK. In addition, there were too few properties with sprinkler coverage for proper modeling. All other building property and safety measure variables were significant in the univariate analysis and went into the full model (Appendix E).

The full model contained 13,356 incidents. After controlling for property classes, having automatic fire detection system, fire detection devices, and working automatic extinguishing equipment (trend) reduced casualty rates in firefighters by 38.8%, 37.0%, and 34.3%, respectively (Table 7).

TABLE 7: RATE RATIO AND 95% CONFIDENCE INTERVALS OF PREDICTORS FROM MODEL 1. BUILDING HEIGHT WAS IN STORIES AND RESIDENTIAL USED AS REFERENCE FOR PROPERTY CLASSIFICATION GROUP. SIGNIFICANT VARIABLES (P<0.05) ARE IN BOLD AND TRENDS (P<0.1) ARE IN ITALICS.

Variable	Rate Ratio (95% CI)	P-value	Notes
Automatic fire detection system	**0.612 (0.453, 0.829)**	**0.0015**	**Having automatic fire detection system in place reduced casualty rate by 38.8%**
Initial detection	0.982 (0.647, 1.491)	0.9325	Initial detection by device was not associated with casualty rate
Fire detection devices	**0.630 (0.450, 0.880)**	**0.0068**	**Having fire detection devices reduced casualty rate by 37.0%**
Building height	0.997 (0.975, 1.020)	0.8171	Building height was not associated with casualty rate
Performance of automatic extinguishing equipment	*0.657 (0.418, 1.033)*	*0.0690*	*Working automatic extinguishing equipment reduced casualty rate by 34.3% (trend)*
Performance of smoke alarm device	1.174 (0.832, 1.657)	0.3610	Working smoke alarms were not associated with casualty rate
Property classification group	0.942 (0.728, 1.271)	0.7835	Residential used as reference

In Model 2 (the first logistic regression model), which associated the building properties and safety measures with the odds of a fire event resulting in at least one firefighter casualty, only the variables for initial detection by device, manual protection, performance of smoke alarm, sprinkler coverage, and year of construction were significant and went into the full model (Appendix E).

The full model had 15,326 fire incidents without casualties and 116 incidents with at least one injury. Reduced odds of a casualty event were significantly associated with initial detection by device (61.2%) and newer buildings (0.8% per year), but having activated smoke alarms and sprinkler protection increased odds of casualties (50% and 93%, respectively). In addition, attempts were made to add fire status on arrival and crew size into the model to control for fire intensity and/or exposure, but there were no valid observations due to the lack of overlap in the reporting jurisdictions (Table 8).

TABLE 8: ODDS RATIO AND 95% CONFIDENCE INTERVALS OF PREDICTORS FROM MODEL 2. YEAR OF CONSTRUCTION IN YEARS AND RESIDENTIAL USED AS REFERENCE FOR PROPERTY CLASSIFICATION GROUP. SIGNIFICANT VARIABLES (P<0.05) ARE IN BOLD AND TRENDS (P<0.1) ARE IN ITALICS.

Variable	Odds Ratio (95% CI)	P-value	Notes
Initial detection	**0.388 (0.182, 0.825)**	**0.0139**	**Initial detection by device reduced odds of a casualty event by 61.2%**
Manual fire protection facilities	0.729 (0.463, 1.148)	0.1724	Having manual fire protection facilities was not associated with odds of a casualty event
Performance of smoke alarm device	*1.502 (0.998, 2.260)*	*0.0509*	*Working smoke alarms increased odds of a casualty event by 50.2% (trend)*
Sprinkler protection	**1.928 (1.128, 3.296)**	**0.0164**	**Having sprinkler protection increased odds of a casualty event by 92.8%**
Year of construction	**0.992 (0.985, 0.999)**	**0.0342**	**Newer buildings reduced odds of a casualty event by 0.8% per year**
Property classification group	1.193 (0.758, 1.880)	0.4458	Residential used as reference

In Model 3 (the second logistic regression model), which associated the building properties and safety measures with the odds of a serious casualty over a minor one, only the variables for fire detection systems, year of construction, firefighter age, and firefighting experience were significant. Since firefighter age and years of experience were highly correlated, only firefighter years of experience went into the full model (Appendix E).

The full model had 982 cases of minor casualties and 192 cases of serious casualties. Having fire detection systems was not significantly associated with the odds of serious casualties over minor ones in firefighters. However, firefighting experience (0.3% per every five years of experience) reduced the odds of serious casualty in firefighters (Table 9).

TABLE 9: ODDS RATIO AND 95% CONFIDENCE INTERVALS OF PREDICTORS FROM MODEL 3. YEARS OF FIREFIGHTING EXPERIENCE PER EVERY 5 YEARS, FEMALE AS REFERENCE FOR GENDER OF VICTIM, AND RESIDENTIAL USED AS REFERENCE FOR PROPERTY CLASSIFICATION GROUP. SIGNIFICANT VARIABLES (P<0.05) ARE IN BOLD AND TRENDS (P<0.1) ARE IN ITALICS.

Variable	Odds Ratio (95% CI)	P-value	Notes
Fire detection devices	1.439 (0.843-2.456)	0.1817	Having fire detection devices was not associated with odds of a serious injury over a minor injury
Gender of victim	2.647 (0.623-11.249)	0.1872	Gender of victim was not associated with odds of a serious injury over a minor injury
Firefighting years of experience	**0.997 (0.995-0.999)**	**0.0004**	**More firefighting experience reduced odds of a serious injury over a minor injury by 0.3% per every 5 years**
Property classification group	*0.651 (0.397-1.067)*	*0.0884*	*Residential used as reference*

Linkage to Fire Spread

Modeling fire spread as a predictor variable, it was found to significantly increase the rate of firefighter casualties (61% per increase in fire spread category) and also odds of a fire incident with at least one firefighter casualty (49% per increase in fire spread category). Fire spread was coded into 6 categories (1 = confined to object of origin; 2 = confined to part of room/area of origin; 3 = confined to room of origin; 4 = confined to floor level of origin; 5 = confined to building of origin; 6 = extended beyond building of origin). In addition, the effect is multiplicative, such that a fire event that resulted in the fire extending beyond building of origin (category 6) would, on average, result in 1,082% higher casualty rate and 734% higher odds of a casualty event compared to a fire event where the fire was confined to the object of origin (category 1). Fire spread was not associated with the odds of a serious casualty over a minor one (Table 10).

TABLE 10: RATE RATIO AND ODDS RATIOS (AND 95% CONFIDENCE INTERVALS) FROM THE THREE MODELS OF CHOICE WITH FIRE SPREAD AS PREDICTOR WHILE CONTROLLING FOR PROPERTY CLASS. SIGNIFICANT VARIABLES (P<0.05) ARE IN BOLD AND TRENDS (P<0.1) ARE IN ITALICS.

Variable	Model 1		Model 2		Model 3	
	Rate Ratio (95% CI)	P-value	Odds Ratio (95% CI)	P-value	Odds Ratio (95% CI)	P-value
Extent of fire	**1.610 (1.547, 1.675)**	**0.0001**	**1.490 (1.439, 1.544)**	**0.0001**	1.028 (0.911, 1.160)	0.6536
Property classification group	0.907 (0.751, 1.096)	0.3135	**0.825 (0.705, 0.965)**	**0.0159**	0.760 (0.463, 1.248)	0.2781

Modeling fire spread as an outcome, significant associations were found between reduction of fire spread and having automatic fire detection systems, having fire detection devices, building made of more exposed and combustible materials, manual fire protection, working automatic extinguishing equipment, working smoke alarms, while controlling for property class (Table 11).

TABLE 11: LINEAR ESTIMATES WITH 95% CONFIDENCE INTERVALS OF PREDICTORS FROM GENERAL LINEAR MODEL WITH FIRE SPREAD AS THE OUTCOME VARIABLE. SIGNIFICANT VARIABLES (P<0.05) ARE IN BOLD AND TRENDS (P<0.1) ARE IN ITALICS.

Variable	Estimate (95% CI)	P-value	Notes
Automatic fire detection system	**-0.315 (-0.421, -0.210)**	**0.0001**	**Having automatic fire detection system reduced fire spread by 0.315 categories**
Initial detection	-0.074 (-0.218, 0.071)	0.3082	Initial detection by device was not associated with fire spread
Fire detection devices	**-0.439 (-0.536, -0.342)**	**0.0001**	**Having fire detection devices reduced fire spread by 0.439 categories**
Fixed system other than sprinklers	-0.059 (-0.210, 0.092)	0.4340	Having fixed system other than sprinklers was not associated with fire spread
General construction	**0.441 (0.380, 0.502)**	**0.0001**	**More flammable materials increased fire spread by 0.441 categories**
Building height	0.006 (-0.008, 0.019)	0.4059	Building height was not associated with fire spread
Manual fire protection facilities	**-0.509 (-0.592, -0.427)**	**0.0001**	**Having manual fire protection facilities reduced fire spread by 0.509 categories**
Outside fire protection	-0.076 (-0.385, 0.232)	0.6206	Having outside fire protection was not associated with fire spread
Performance of automatic extinguishing equipment	**-0.275 (-0.433, -0.118)**	**0.0005**	**Working automatic extinguishing equipment reduced fire spread by 0.275 categories**
Performance of smoke alarm device	**-0.313 (-0.400, -0.225)**	**0.0001**	**Working smoke alarms reduced fire spread by 0.313 categories**
Sprinkler protection	-0.107 (-0.267, 0.053)	0.1819	Having sprinkler protection was not associated with fire spread
Property classification group	**0.255 (0.169, 0.340)**	**0.0001**	**Residential used as reference**

Discussion

DATA QUALITY DISCLAIMER

Considering the limitations indicated due to the data quality, caution should be used when interpreting the results presented in this report. Due to the great number of missing and unknown data in a non-randomized fashion, there may be bias in the data. Thus, the results and interpretations from the analysis in this report should not be taken as the gold standard of evidence to support major policy changes. Despite these limitations, the NFID presented data in great scale, detail, and linkage of information that were not available in the past, it allowed for associations to be modeled. As such, the results presented in this report, though novel and important, should be taken as one component of a collection of evidence to be used for educating, supporting, and guiding stakeholders in their decision making.

SCOPE OF THE PROBLEM

There were 11,100 accepted firefighter workplace casualty claims between the years of 2006 and 2014 in the provinces of BC, AB, SK, MN, and ON. Structure-related firefighter casualties made up 20.4% of total workplace casualties among firefighters and 23.4% of all traumatic casualties. These figures were similar to the structure-related fatalities making up 17% of all deaths and 31% of all traumatic deaths, as reported by Hodous et al. (2004).

FIREFIGHTERS AND CIVILIAN DISTRIBUTIONS AND RATES

The casualty rates among firefighters were quite similar across the property classes, at 15.3 per 1,000 fire incidents in residential property classes compared to 14.0 in other structural property classes. Civilian casualty rates in residential property classes were more than three-times greater, at 63.7 per 1,000 fire incidents, than in other structural property classes, at 19.5. The difference in casualty rates among civilians was likely due to a combination of a difference in exposure, where civilians were likely to spend more time in residential areas, and building requirements, where a higher standard of fire safety measures was required for commercial and industrial buildings. The similarity in firefighter casualty rates across different properties was likely due to their training to combat fires across different property classes and scenarios.

Firefighting training was also reflected in the low number of deaths (0.3% in firefighters versus 15.5 in civilians) and reduced seriousness of injuries overall (76.3% were minor injuries in firefighters compared to 50.3% in civilians). In addition, proper firefighting equipment likely contributed to the reduced proportion of firefighter casualties that were due to smoke and burns (21.3 %) when compared to civilians (82.7%). The difference in the proportion of male casualties (83.7% in firefighters compared to 60.0% in civilians) was likely due to the gender disparity in the profession as opposed to an inherent difference between the populations.

In residential property classes, general construction affected firefighter and civilian casualty rates in opposite directions. Civilian rates were highest when the building was constructed of protected combustible or heavy timber material, but lowest among firefighters. The opposite relationship was seen for exposed combustible material, where civilian rates were lowest and firefighter rates were highest. There was insufficient data at present to properly explain this phenomenon and merits further investigation. Whether the fire was initially detected by a fire safety device, sprinkler protection had the greatest effect on reducing firefighter casualty rates (42.2% and 44.7%, respectively). Sprinkler protection also decreased civilian casualty rates, but to a smaller effect (14.5%). Surprisingly, having fire detection devices and working smoke alarms greatly increased the casualty rates among civilians (29.4% and 27.5%, respectively). It is hypothesized that increased awareness of a fire increases the likelihood of civilians trying to combat the fire, thus resulting in more casualties.

In commercial and industrial zones, general construction material had no effect on firefighter casualty rates, whereas sprinkler protection had the greatest effect on reducing the casualty rates by 52.8%. Gradation effect can be seen on the civilian rates, where rates were lowest for buildings built from exposed combustible material (13.1 per 1,000 incidents) and highest for those built from non-combustible material (36.2 per 1,000 incidents). This counterintuitive effect can be seen on all the fire safety measures as well, as having fire detection devices, fixed systems other than sprinklers, manual protection, working automatic fire extinguishing equipment, working smoke alarms, and sprinkler protection all resulted in increased civilian casualty rates. This may be a function of bigger structures that accommodate more people having more fire safety devices equipped, thus resulting in more casualties per incident. Unfortunately, this difference in exposure cannot be controlled for in this type of descriptive analysis and should be further investigated in a future study.

BUILDING PROPERTIES AND FIRE SAFETY MEASURES

Modeling the building properties and fire safety measures with firefighter casualties allowed for the significance of any associations to be tested. Each model had their own advantages and disadvantages, enabling the viewing of results from different perspectives. There were sufficient counts for all three models to achieve statistical power, but care should be taken in their interpretations due to large amounts of missing data that were not random in nature.

Model 1, a Poisson regression model, allowed for using a direct measure of casualty rate or risk to firefighters, as a true exposure, as the number of firefighters at the fire scene was captured. However, due to lack of overlapping reporting jurisdictions, variables of interest related to year of construction, general construction, manual protection, outside protection, and sprinkler protection could not be modeled. Among those variables that went into the full model, having automatic fire detection systems, having fire detection devices and having working automatic extinguishing equipment both reduced casualty rates. Working smoke alarms also had a trend towards reducing casualty rates. When all three safety measures were present, casualty rates were reduced by 74.6%.

Model 2, a logistic regression model, allowed for the inclusion of some variables not modeled in Model 1, specifically, the year of construction, general construction, manual protection, and outside protection. From the full model, it was found that the odds of a casualty event were reduced when the fire was initially detected by a device (61.2%) and in newer buildings (0.8% per year). However, having sprinkler protection and working smoke alarms (trend only) increased the odds of a casualty event. When sprinklers and working smoke alarms were both present, the odds increased by 189.6%. This may be a misleading finding, as buildings with sprinklers and working smoke alarms may tend to be larger, where fires that do occur in them would be bigger and require more firefighters to respond, increasing the risk of at least one firefighter casualty. Attempts were made to control for the number of firefighter exposed or size of fire, but due to data quality issues, neither variable had sufficient counts that overlapped with the rest of the variables in the model.

Both Model 1 and Model 2 used aggregated counts, so individual firefighter variables, such as experience, gender, age, and status could not be controlled for. Model 3 used individual entries, thus enabling the use of these variables. Model 3 suggested that none of the building properties or fire safety measures affected the odds of a serious casualty over a minor one. Firefighting experience played the only significant role. This effect was small though, as for every five years of firefighting experience, the odds of a serious casualty decreased by only 0.3%.

Taken together, the findings suggested that fire safety measures matter more than building properties such as construction material and height, as demonstrated in previous, albeit limited, literature. Even though newer buildings appeared to play a role in reducing casualties, the effect may be better explained by newer buildings having more fire safety measures as a requirement or being better maintained than purely just the year of construction itself. The best-case scenario for reducing firefighter casuatlies is adequate firefighting experience, when automatic fire detection systems are in place, when fire detection devices are present, when automatic fire extinguishing equipment are working properly, when working smoke alarms are functioning properly, and when the building has sprinkler coverage.

LINKAGE TO FIRE SPREAD

The modeling of fire spread as an intermediate variable suggested that it was a likely connector between the building properties and fire safety measures and firefighter casualties. For each increase in category of fire spread, casualty rates increased by 61.0% and the odds of a casualty event by 49.0%. Fire spread did not have an effect on the seriousness of the casualty.

Buildings constructed from more exposed and combustible material increased fire spread, and all the fire safety measures reduced fire spread. Neither building height nor sprinkler protection had a significant effect on the fire spread. However, due to possible collinearity effects, this lack of effect should not be considered as conclusive. Interestingly, although construction material did have an effect on fire spread, it did not have a direct effect on firefighter casualties. This may suggest that although fire spread plays a significant role in firefighter casualties, other contributors may be present as well, such as weakening and failing of structural integrity of the buildings. Unfortunately, there were no available data on weakening or failing of structural integrity due to a fire, thus, this variable would need to be collected and investigated in its role as a possible intermediate variable, in comparison with fire spread, in a future study.

OTHER LIMITATIONS

In addition to the limitations due to data quality, there were other limitations associated with this study. There was a lack of evidence, in both literature and data collection, on weakening and failing structural integrity of buildings in general. Intuitively, failing structures would directly affect the risk to firefighters and without data, this association cannot be empirically investigated. Randomizing of counts in the AWCBC dataset due to low counts also introduced noise into the results. However, the effects would be small due to the low margin of error. Lastly, there was evidence for collinearity between some of the variables for building properties and fire safety measures, such as presence of fire detection devices and the performance of smoke alarms. Thus, care should be taken in the interpretation when our models report significance in one but not the other.

Conclusions

Prior to this report, there was very little evidence linking building properties with firefighter casualties. In the literature reviewed, only two publications were found that contained results directly associating structural properties with firefighter casualties. One only studied fatalities, the second did not have building properties as a main focus, and neither were based on Canadian data. The current study showed Canadian firefighter casualty and structure-related data for the period 2005 to 2014 across the provinces of BC, AB, SK, MN, and ON. The general lack of data quality, as evidenced by high proportions of missing or unknown entries, severely limits the ability to fully interpret the results and form conclusions. However, the NFID presented data in such scale and detail that were not available in the past, the findings derived from it are still the best to date and important for elucidating associations between risk to firefighters with building properties and fire safety measures. Analysis of the NFID did not find evidence to support the notion that building properties, such as construction material and height, affected risk to firefighters, but rather these risks were affected by fire safety measures, such as fire detection devices, smoke alarms, and sprinklers. The best-case scenario for reducing firefighter casualties is adequate firefighting experience, when automatic fire detection systems are in place, when fire detection devices are present, when automatic fire extinguishing equipment are working properly, when working smoke alarms are functioning properly, and when the building has sprinkler coverage. In addition, fire spread was found to fit well as an intermediate variable.

Recommendations

Despite data limitations, the NFID still provides the best-to-date data and the findings of this study supports the following recommendations.

Improving the data quality of the NFID to allow for more solid interpretations, conclusions, and recommendations to be formed:

- Standardize data collection across Canada to reduce the number of missing and unknown data fields across the provinces;
- Collect information on variables found in the victim file for all firefighter dispatches instead of just those that resulted in injuries and deaths, in order to better estimate risk;
- Have the ability to link with AWCBC or WorkSafeBC datasets to improve data quality;

- Direct resources to increase the overall quality of the NFID in order to reduce inconsistencies, coding errors, and missing data as the NFID is a rich source of information;
- Collect data on structural integrity, such as weakening and failing of structural supports, in order to better investigate its role related to firefighter casualties.

Further research required to test and expand on the findings from this study:

- Findings in this report should be reinforced when better quality data, either through improving the NFID or otherwise, becomes available;
- Pilot studies, perhaps carried out by a selection of fire departments, are recommended to collect better quality data to better reinforce some of the findings in this report;
- Poisson regression model is recommended as it directly associates risk or rate of firefighter casualties to building properties and fire safety measures;
- As fire spread fits well as an intermediate variable, it can be used as a surrogate to firefighter casualties if resources are lacking;
- Data on structural integrity, such as weakening and failing of structural supports, due to fire should be collected and investigated as an intermediate variable.

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Appendices

APPENDIX A – VARIABLES CODING

Conversion between AWCBC Nature of Injury variable coding and the traumatic/non-traumatic categories used for the analyses in this report.

	Code	Label
Traumatic	00	Traumatic injuries and disorders, uns.
	01	Traumatic injuries to bones, nerves, spinal cord
	02	Traumatic injuries to muscles, tendons, ligaments, joints, etc.
	03	Open wounds
	04	Surface wounds and bruises
	05	Burns
	06	Intracranial injuries
	07	Effects of environmental conditions
	08	Multiple traumatic injuries and disorders
	09	Other traumatic injuries and disorders
Non-traumatic	12	Nervous system and sense organs diseases
	13	Circulatory system diseases
	14	Respiratory system diseases
	15	Digestive system diseases and disorders
	16	Genitourinary system diseases and disorders
	17	Musculoskeletal system and connective tissue diseases and disorders
	18	Disorders of the skin and subcutaneous tissue
	20	Infectious and parasitic diseases, uns.
	21	Bacterial diseases
	22	Viral diseases
	23	Other arthropod-borne diseases
	26	Infectious diseases peculiar to the intestines
	29	Other infectious and parasitic diseases
	30	Neoplasms, tumors, and cancer, uns.
	31	Malignant neoplasms and tumors (cancers, carcinomas, sarcomas)
	32	Benign neoplasms and tumors
	39	Neoplasms, tumors, and cancer, n.e.c.
	41	Symptoms
	49	Other symptoms, signs and ill-defined conditions, n.e.c.
	52	Mental disorders or syndromes
	59	Other diseases, conditions and disorders, n.e.c.
	80	Multiple diseases, conditions, and disorders

Conversion between original NFID coding and the recoded variables used for the analyses in this report.

Variable	Description	Original NFID		Recoded for Analysis	
		Code	Label	Code	Label
AUTODET	Automatic fire detection system	01	No central alarm	0	No central alarm
		02	Single stage central alarm	1	Central alarm present
		03	Single stage central alarm, connection to remote monitoring agency		
		04	Two stage central alarm		
		05	Two stage central alarm, connection to remote monitoring agency		
		06	Central alarm with voice		
		07	Central alarm with voice, connection to remote monitoring agency		
		11	Alarm present, type unknown or not reported		
		08	Not applicable (vehicle, outside area, etc.)	.	Missing, not applicable
		00	Alarm present, type unknown or not reported		
DETECT	Initial detection	07	Visual sighting or other means of personal detection	0	Non-device detection or no detection
		08	No initial detection (burned out before detection)		
		01	Smoke alarm device	1	Device detection
		02	Smoke detector device		
		03	Heat alarm device		
		04	Heat detector device		
		05	Automatic sprinkler system		
		06	Automatic system other than sprinkler		
		11	Specialty detector (includes flame, beam line)		
		00	Initial detection - unknown	.	Missing, not applicable, unclassified
		09	Initial detection – unclassified		
		88	Not applicable (e.g. vehicle, outdoor, person)		
FIREDET	Fire detection devices	20	No detection devices	0	No detection devices
		01	Smoke detectors	1	Detection devices present
		02	Smoke detectors, heat detectors and smoke detectors in return air ducts		
		03	Heat detectors and smoke detectors in return air ducts		
		04	Heat detectors		
		05	Smoke detectors and specialty detectors		

Variable	Description	Original NFID		Recoded for Analysis	
		Code	Label	Code	Label
		06	Heat detectors and specialty detectors		
		08	Heat detectors, smoke detectors and specialty detectors		
		09	Detector type, other		
		10	More than one type present, not specified		
		11	Sprinkler, water flow detection		
		00	Cannot be determined	.	Missing, not applicable
		07	Not applicable (vehicle, outside area, etc.)		
FIREEXT	**Extent of fire**	01	Confined to object of origin	1	Confined to object of origin
		02	Confined to part of room/area of origin	2	Confined to part of room/area of origin
		03	Confined to room of origin	3	Confined to room of origin
		04	Confined to floor level of origin	4	Confined to floor level of origin
		05	Confined to building of origin	5	Confined to building of origin
		06	Extended beyond building of origin	6	Extended beyond building of origin
		07	Confined to roof	.	Missing, not applicable
		08	Not applicable - vehicle or outside area		
		09	Extent of fire – unclassified		
		14	Spread beyond room of origin		
		15	Multi-unit dwelling – Spread beyond room of fire origin, same floor, outside unit		
		16	Multi-unit-dwelling – Spread beyond room of fire origin, same floor, separate unit		
		17	Spread beyond floor of fire origin, different floor		
		18	Spread to entire structure		
		20	Spread beyond suit or apartment, same floor		
		21	Spread to additional suit or apartment, same floor		
		00	Extent of fire - unknown		

Variable	Description	Original NFID		Recoded for Analysis	
		Code	Label	Code	Label
FIXEDSYS	**Fixed system other than sprinklers**	4	No fixed system	0	No other fixed systems
		1	Fixed system other than sprinkler - supervised or watchman service	1	Other fixed systems present
		2	Fixed system other than sprinkler - alarm to fire departments		
		3	Fixed system other than sprinkler - unsupervised, local alarms only		
		5	Dry chemical system		
		6	Special hazard system, other		
		9	Fixed system other than sprinkler - unclassified		
		0	Cannot be determined	.	Missing, not applicable
		8	Not applicable - vehicle, outside area, etc.		
GENCONST	**General construction**	4	Non-combustible construction - exposed steel	0	Non-combustible
		5	Protected non-combustible construction - protected steel or concrete		
		2	Protected combustible construction - wood protected by plaster	1	Protected combustible + heavy timber
		3	Heavy timber construction		
		1	Combustible construction - open wood joist	2	Exposed combustible
		0	General construction – unknown	.	Missing, not applicable, unclassified
		8	General construction - not applicable		
		9	General construction - unclassified		
MANPROT	**Manual fire protection facilities**	7	No manual fire protection	0	No manual fire protection
		2	Extinguishers and standpipe system	1	Manual fire protection present
		4	Extinguishers		
		6	Standpipe system		
		9	Unclassified		
		0	Cannot be determined	.	Missing, not applicable, unclassified
		8	Not applicable - outside area, etc.		

Variable	Description	Original NFID		Recoded for Analysis	
		Code	Label	Code	Label
OUTPROT	Outside fire protection	8	Not applicable - no outside fire protection	0	No outside fire protection
		1	Municipal hydrant protection and fire department	1	Outside fire protection present
		2	Municipal hydrant protection and no fire department		
		3	Municipal fire department only		
		5	Private hydrant protection and fire department		
		6	Private hydrant protection and no private fire department		
		7	Private fire department only		
		0	Cannot be determined	.	Missing, unclassified
		9	Unclassified		
PERFORM	Performance of automatic extinguishing equipment	2	Equipment should have operated but did not	0	Equipment did not operate or not present
		5	Equipment did not operate - unclassified		
		7	Equipment did not operate – reason unknown		
		8	No equipment present in room or area of origin of fire		
		1	Equipment operated	1	Equipment operated or did not require operation
		3	Equipment present but fire too small to require operation		
		0	Performance of automatic extinguishing equipment - unknown	.	Missing, not applicable
		9	Performance of automatic extinguishing equipment - unclassified		
PROPGRP	Property classification group	3000	Residential	0	Residential
		1000	Assembly	1	Other structure-related property
		2000	Institutional		
		4000	Business & personal service		
		5000	Mercantile		
		6000	Industrial manufacturing companies		
		7000	Storage properties		
		0000	Unknown, undetermined, not applicable, not available	.	Missing, unclassified, not structure-related
		8000	Special property & transportation equipment		
		9000	Miscellaneous property		

Variable	Description	Original NFID		Recoded for Analysis	
		Code	Label	Code	Label
SADPERF	Performance of smoke alarm device	00	No smoke alarm	0	No smoke alarm or not activated
		03	Alarm in room of origin – not activated – non-suitable location		
		04	Alarm in room of origin – not activated – battery dead		
		05	Alarm in room of origin – not activated – no battery		
		06	Alarm in room of origin – not activated – AC not connected/disabled		
		07	Alarm in room of origin – not activated – mechanical failure		
		08	Alarm not in room of origin – not activated – battery dead		
		09	Alarm not in room of origin – not activated – no battery		
		10	Alarm not in room of origin – not activated – AC not connected/disabled		
		11	Alarm not in room of origin – not activated – mechanical failure		
		51	Alarm location unknown – not activated - non-suitable location		
		52	Alarm location unknown – not activated – no battery or battery dead		
		53	Alarm location unknown – not activated – AC not connected/disabled		
		54	Alarm location unknown – not activated – mechanical failure		
		55	Alarm location unknown – not activated – reason unknown		
		70	Alarm in room of origin – not activated – other reason		
		71	Alarm in room of origin – not activated – reason unknown		
		80	Alarm not in room of origin – not activated – other reason		
		01	Alarm in room of origin - activated	1	Smoke alarm activated or not enough smoke to activate
		02	Alarm not in room of origin - activated		
		12	Not enough smoke to activate smoke alarm		
		50	Alarm location unknown – activated		
		88	Not applicable	.	Missing, not applicable, unclassified
		99	Smoke alarm activation - unknown		

Variable	Description	Original NFID		Recoded for Analysis	
		Code	Label	Code	Label
SPRINPRO	Sprinkler protection	7	No sprinkler protection	0	No sprinkler protection
		1	Complete sprinkler protection - supervised or watchman service	1	Sprinkler protection present
		2	Complete sprinkler protection - alarm to fire department		
		3	Complete sprinkler protection - unsupervised, local alarms only		
		4	Partial sprinkler protection - supervised or watchman service		
		5	Partial sprinkler protection - alarm to fire department		
		6	Partial sprinkler protection - unsupervised, local alarms only		
		0	Cannot be determined	.	Missing, not applicable, unclassified
		8	Not applicable - vehicle, outside area, etc.		
		9	Sprinkler protection - unclassified		

APPENDIX B – DATA QUALITY

Building properties and fire safety measures as reported per province: 1 indicates the province reported on the variable; 0 indicates the province did not.

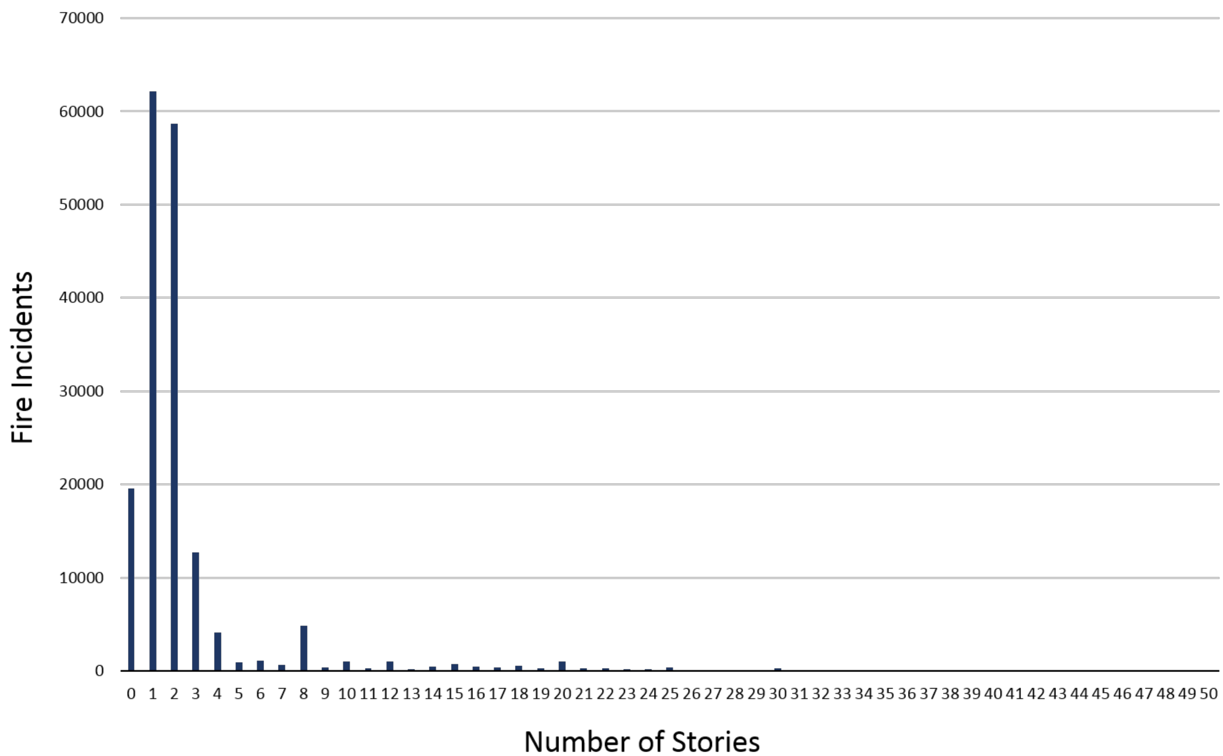
Variable	Description	BC	AB	SK	MN	ON	Total
AUTODET	Automatic fire detection system	1	1	0	1	1	4
DETECT	Initial detection	1	1	0	1	1	4
FIREDET	Fire detection devices	0	1	1	0	1	3
FIXEDSYS	Fixed system other than sprinklers	0	1	1	0	1	3
GENCONST	General construction	1	1	0	1	1	4
HEIGHT	Building height	1	1	1	1	1	5
MANPROT	Manual fire protection facilities	1	1	0	1	1	4
OUTPROT	Outside fire protection	1	1	0	1	0	3
PERFORM	Performance of automatic extinguishing equipment	1	1	0	1	1	4
SADPERF	Performance of smoke alarm device	1	1	1	1	1	5
SPRINPRO	Sprinkler protection	1	1	1	1	1	5
YEARCONS	Year of construction	1	1	0	0	0	2

Number and proportion of missing or unknown data per building properties and fire safety measures variable.

Variable	Description	Missing (#)	Unknown (#)	Missing or Unknown (%)
AUTODET	Automatic fire detection system	7,633	216,245	52.2
DETECT	Initial detection	7,633	214,761	51.8
FIREDET	Fire detection devices	127,172	196,750	75.5
FIXEDSYS	Fixed system other than sprinklers	127,172	252,697	88.5
GENCONST	General construction	245,944	20,502	62.1
HEIGHT	Building height	10,773	157,537	39.2
MANPROT	Manual fire protection facilities	7,633	275,837	66.0
OUTPROT	Outside fire protection	299,714	0	69.8
PERFORM	Performance of automatic extinguishing equipment	141	281,678	65.7
SADPERF	Performance of smoke alarm device	6,363	197,537	47.5
SPRINPRO	Sprinkler protection	141	222,732	51.9
YEARCONS	Year of construction	298,134	25,908	75.5

APPENDIX C – DISTRIBUTION OF HEIGHT VARIABLE

Histogram for the height variable showing elevated number of fire incidents for buildings that are exactly 8 stories high.



APPENDIX D – INCIDENTS, FIREFIGHTER CASUALTY COUNTS, AND RATES PER PROPERTY CLASS

Fire incidents, firefighter casualty counts, and rates per property classification

Property Classification	Fire Incidents (#)	Casualties (#)	Casualty Rate (per 1,000 incidents)
Assembly	12,377	128	11.0
Institutional	2,585	30	13.2
Residential	128,400	1,963	15.8
Business	2,691	35	15.6
Mercantile	8,369	128	16.6
Industrial	7,585	137	18.7
Storage	15,619	233	15.2
Special & Transportation	161,097	294	1.8
Miscellaneous	30,080	175	6.0

APPENDIX E – BUILDING PROPERTIES AND SAFETY MEASURES UNIVARIATE RESULTS

Model 1 (Poisson Regression Model) univariate results associating building properties and fire safety measures with firefighter casualty rates.

Variable	# Obs	Rate Ratio (95% CI)	P-value
Automatic fire detection system	25,119	0.507 (0.428, 0.600)	0.0001
Initial detection	36,140	0.640 (0.499, 0.819)	0.0004
Fire detection devices	40,341	0.769 (0.667, 0.886)	0.0003
Fixed system other than sprinklers	*	*	*
General construction	*	*	*
Building height	49,382	0.971 (0.958, 0.984)	0.0001
Manual fire protection facilities	*	*	*
Outside fire protection	*	*	*
Performance of automatic extinguishing equipment	41,871	0.581 (0.442, 0.765)	0.0001
Performance of smoke alarm device	39,436	0.794 (0.691, 0.911)	0.0010
Sprinkler protection	*	*	*
Year of construction	*	*	*
Property classification group	50,460	0.828 (0.716, 0.956)	0.0103

Model 2 (Logistic Regression Model) univariate results associating building properties and fire safety measures with odds of a fire event resulting in at least one firefighter casualty.

Variable	# Obs	Odds Ratio (95% CI)	P-value
Automatic fire detection system	71,508	0.889 (0.759-1.041)	0.1430
Initial detection	100,743	0.722 (0.574-0.910)	0.0057
Fire detection devices	73,787	0.975 (0.852-1.115)	0.7112
Fixed system other than sprinklers	20,705	1.141 (0.659-1.976)	0.6369
General construction	54,016		0.9241
Protected combustible > Non-combustible		0.969 (0.695-1.351)	0.7293
Exposed combustible > Non-combustible		1.021 (0.703-1.482)	0.7972
Building height	170,416	1.006 (0.995-1.017)	0.2659
Manual fire protection facilities	52,541	0.662 (0.528-0.829)	0.0003
Outside fire protection	68,817	1.445 (0.463-4.507)	0.5259
Performance of automatic extinguishing equipment	86,355	0.918 (0.738-1.141)	0.4405
Performance of smoke alarm device	106,365	1.124 (1.005-1.257)	0.0407
Sprinkler protection	92,756	0.444 (0.322-0.612)	0.0001
Year of construction	34,925	0.992 (0.987-0.998)	0.0038
Property classification group	177,626	0.773 (0.695-0.860)	0.0001

Model 3 (Logistic Regression Model) univariate results associating building properties and fire safety measures with odds of serious casualties over minor ones.

Variable	# Obs	Odds Ratio (95% CI)	P-value
Automatic fire detection system	809	1.053 (0.670-1.655)	0.8239
Initial detection	1,157	1.086 (0.562-2.097)	0.8063
Fire detection devices	1,500	1.822 (1.226-2.709)	0.0030
Fixed system other than sprinklers	197	1.493 (0.311-7.179)	0.6168
General construction	292		0.3296
Protected combustible > Non-combustible		2.567 (0.574-11.486)	0.1373
Exposed combustible > Non-combustible		1.558 (0.301-8.075)	0.9611
Building height	2,454	0.997 (0.967-1.023)	0.6941
Manual fire protection facilities	291	0.547 (0.245-1.224)	0.1422
Outside fire protection	*	*	*
Performance of automatic extinguishing equipment	*	*	*
Performance of smoke alarm device	1,548	1.239 (0.926-1.658)	0.1492
Sprinkler protection	1,190	0.407 (0.097-1.707)	0.2191
Year of construction	218	0.978 (0.959-0.996)	0.0192
Gender of victim	2,241	1.353 (0.713-2.571)	0.3552
Age of victim	2,428	0.997 (0.996-0.998)	0.0001
Firefighter status	2,027	0.938 (0.685-1.286)	0.6929
Fire fighting years of experience	2,131	0.997 (0.996-0.998)	0.0001
Property classification group	2,459	0.692 (0.528-0.906)	0.0075

APPENDIX F – FIRE SPREAD UNIVARIATE RESULTS

Ordinal Regression Model univariate results associating building properties and fire safety measures with categories of fire spread.

Description	# Obs	Rate Ratio (95% CI)	P-value
Automatic fire detection system	57,295	-1.218 (-1.247, -1.190)	0.0001
Initial detection	75,718	-0.810 (-0.851, -0.770)	0.0001
Fire detection devices	53,027	-0.416 (-0.446, -0.386)	0.0001
Fixed system other than sprinklers	19,441	-0.965 (-1.067, -0.863)	0.0001
General construction	43,155		0.0001
Protected combustible > Non-combustible		0.660 (0.609, 0.711)	0.0001
Exposed combustible > Non-combustible		1.417 (1.359, 1.476)	0.0001
Building height	93,749	-0.055 (-0.058, -0.052)	0.0001
Manual fire protection facilities	42,856	-0.872 (-0.905, -0.840)	0.0001
Outside fire protection	48,613	-0.639 (-0.793, -0.484)	0.0001
Performance of automatic extinguishing equipment	58,170	-0.943 (-0.988, -0.898)	0.0001
Performance of smoke alarm device	69,918	-0.696 (-0.720, -0.672)	0.0001
Sprinkler protection	73,818	-0.709 (-0.753, -0.665)	0.0001
Year of construction	53,172	*	*
Property classification group	96,231	-0.189 (-0.214, -0.164)	0.0001

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