

Sprinkler Systems and Residential Structure Fires - Revisited:

Exploring the Impact of Sprinklers for Life Safety and Fire Spread



Len Garis, Arpreet Singh, Joseph Clare, Sarah Hughan and Alex Tyakoff

October 2017

Revised February 2018

Executive Summary

- The purpose of this study is to examine fire-related casualties, fire outcomes, and casualty behavior for fires that occurred in residential properties, and to compare fires that occurred in buildings completely protected by sprinkler systems, with those fires that occurred in buildings without any sprinkler protection. This paper demonstrates that sprinklers significantly reduce fire-related casualties, minimize fire spread, reduce burden on fire departments when intervening, and also demonstrate benefits for the behaviors of building residents' in the event of a fire.
- Data was provided by the Canadian Association of Fire Chiefs, Council of Canadian Fire Marshals and Fire Commissioners through Statistics Canada, including all fires reported in the Provinces of British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, and New Brunswick between the years of 2005 and 2015.
- The authors analyzed 439,256 fire incidents with a focus on key characteristics of structure fire incidents (e.g., fire spread and fire department intervention) as well as fire-related casualties (i.e., deaths and persons injured) as a result of fire incidents.
- The overall data set retained and classified as residential contained the records of 140,162 fires, 1,440 deaths, and 9,142 injuries. This data was queried, and retained if it occurred in a residential building, and was classified as either completely sprinkler protected or completely without sprinkler protection (n=83,285). This refined data set resulted in 785 deaths and 5,618 injuries.
- Overall, 97% of the fires occurred in residential buildings without sprinkler protection. These fires resulted in 97% of the injuries and 99.2% of the deaths. Less than 1% (0.6%) of fires in single detached residential properties occurred in the presence of sprinkler protection. The death rate per 1000 reported residential fires was more than three times as high in fires with no sprinklers as in fires with sprinklers present.
- With sprinklers, the injury rate for all residential properties was 72.9, or 6.4% higher than the 68.5 without sprinklers. For single-detached properties, the sprinklered rate of 61.3 was 34% higher than the 45.7 rate with no sprinklers. The direction was favorable for apartments.
- Due to variations in the nature of size and spread of the fire, it was not always the case that the sprinkler system was required to activate to control fires in buildings with sprinkler protection. This does not reflect a failure of the sprinkler system as there are a range of fire control mechanisms that could be employed to prevent the fire expanding to the extent that the sprinkler system would activate. This explains why sprinkler systems were only required to control 19.5% of the fires in buildings with sprinkler protection. Sprinklers also controlled fires in 17.8% of the apartments and 28.3% of the single detached dwellings.
- From a fire department resource consumption perspective, residential fires in buildings without sprinkler protection required fire department intervention more often and to a

greater extent than fires in buildings with sprinklers. Fire departments were required to control fires in buildings without sprinkler protection 1.8 times more often.

- Fires in sprinkler protected buildings that were controlled by the sprinkler system were smaller and more contained relative to fires in buildings without sprinkler protection. Fires controlled by sprinklers were confined to the object, part room, or room of origin 88.4% of the time, which was a 1.35 times more frequent than for fires in buildings without sprinklers (65.1%). This difference was less pronounced for fires in apartment buildings: 88.3% of fires controlled by sprinklers were confined to at least the room of origin, compared to 81.0% of those in buildings without sprinklers. The difference was greatest for fires in single detached properties: 81.0% confined within the room of origin when controlled by sprinklers, compared to 53.8% when controlled by other means. Only 1.6% of fires in buildings that were extinguished by sprinkler systems ever extended beyond the building of origin.
- The increased likelihood of fatality for fires in buildings without sprinkler protection was exacerbated in the absence of a functioning smoke alarm, with 78% of deaths in buildings without sprinklers also occurring without an activated smoke alarm. In addition to this, the frequency at which injuries were sustained while building occupants were attempting to escape was significantly reduced in buildings with sprinkler protection.
- No serious firefighter injuries occurred in fires with sprinklers. Only 10% of the civilian injuries in fires with sprinklers were serious, compared to 23% of civilian injuries in fires without sprinklers.
- Overall, these results provide strong support for the position that residential sprinkler systems significantly reduce fire-related casualties, reduce the significance of fire spread, and reduce the demand placed on fire department resources. These protection systems work best together with smoke alarms. These findings, in combination with previous research produced by these authors, support a stance that campaigns to target fire prevention should be directed towards the highest-risk members of the community first: the elderly, impoverished, and vulnerable.

Background to Sprinkler Systems and Life Safety

The Purpose of this Research

Residential sprinkler systems are designed to automatically discharge to extinguish fires with the intent of giving building occupants time to escape. These systems, which have been available for over a century, have been developed to a point where they are able to react within 35 seconds of a fire starting. Within an industrial and commercial context these systems have been demonstrated to increase survival rates and reduce losses relative to buildings without sprinkler protection. Research originally undertaken by Ruegg and Fuller (1984) and reported by the United States (US) Center for Fire Research at the National Institute of Standards and Technology (NIST) in regards to one- and two-family dwellings demonstrated a 63 to 69% reduction in the death rate per thousand fires if sprinklers are added to dwellings that do or do not already have smoke alarms, respectively (Ruegg and Fuller 1984, p. 72).

In light of these findings, the official position of the US Fire Administration is “that all citizens should be protected against death, injury, and property loss resulting from fire in their residence. All homes should be equipped with both smoke alarms and automatic fire sprinklers, and all families should have and practice an emergency escape plan.”

These recommendations are even more important given the findings of research demonstrating that fires involving modern fixtures, furniture, and furnishings are growing faster than typically would have occurred in older buildings, likely meaning that the time available for residents to escape flaming fires is significantly reduced (Kerber 2012, pp. 865-891). Furthermore, FiRECAM™ simulation modeling results of Bénichou and colleagues from the National Research Council of Canada showed that sprinkler protection in the absence of improved response times provided better anticipated protection than faster fire department response in the absence of sprinkler protection (Bénichou, Yung, and Hadjisophocleous, 1999, p. 8).

Despite these findings, a review by Warda and Ballesteros (2007) determined there was insufficient evidence to conclude sprinklers are effective at preventing fires and fire-related injury in residential settings (pp. 97-115). Part of the reason for this conclusion may be that there are limitations associated with typical approaches to estimating the life safety benefits of sprinkler systems that arise from the national level estimates that are generated through analyses of the US Fire Administration (USFA) National Fire Incident Reporting System (NFIRS) database as discussed by Butry (2012). There are also questions related to the cost-effectiveness of sprinklers in the residential setting as further study and field experience is required.

Butry compared fire outcomes for sprinkler-protected buildings with outcomes in comparable buildings that lacked sprinkler protection. To control for the potential confound of a working smoke alarm, Butry ensured that all buildings in the analysis had a working smoke alarm located near the fire’s origin (pp. 480-494). This process demonstrated that sprinklers significantly reduce fire-related casualties (injuries and deaths) per 1,000 fires, in excess of the benefit provided exclusively by functioning smoke alarms, thus replicating earlier findings.

With this body of previous research in mind, the current research seeks to:

1. Replicate findings of the study titled “Sprinkler Systems and Residential Structure Fires, Exploring the Impact of Sprinklers for Life Safety and Fire Spread,” Garis and Clare (2013);
2. Determine how closely Butry’s fire-related casualty findings align with the outcomes of residential fires in buildings in the Provinces of British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and New Brunswick between the years of 2005 and 2015; and,
3. Utilize the additional fire incident information available in the National Fire Information Database to examine:
 - a) Casualty behavior;

- b) Fire spread; and,
- c) Fire department resources required to combat the fire.

Extrapolating from the previously discussed research findings, it is hypothesized that sprinklers will:

- a) Significantly reduce fire-related casualties;
- b) Minimize fire spread;
- c) Reduce burden on fire departments when intervening; and,
- d) Demonstrate benefits for the behaviors of building residents' in the event of a fire.

Identifying Relevant Cases for Analysis

Data was provided by the Canadian Association of Fire Chiefs, Council of Canadian Fire Marshals and Fire Commissioners through Statistics Canada, it includes all fires reported in the Provinces of British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, and New Brunswick between the years of 2005 and 2015. The authors analyzed 439,256 fire incidents with a focus on key characteristics of structure fire incidents (e.g., fire spread and fire department intervention) as well as fire-related casualties (i.e., deaths and persons injured) as a result of fire incidents.

The overall data set retained and classified as residential contained 140,162 fires¹, 1,440 deaths, and 9,142 injuries. This data was queried, and retained if it occurred in a residential building, and was classified as either completely sprinkler protected or completely without sprinkler protection (n=83,285). This refined data set contained the record of 785 deaths and 5,618 injuries. The scope of this research considered:

- The frequency of fires in all residential buildings, with separate analysis of patterns for apartments (29% of incidents) and single detached dwellings (30.4% of incidents);
- The outcomes for life safety in the presence of sprinkler systems; and,
- Fire performance and casualty behavior in the presence of sprinkler systems.

¹ In order to capture all the residential data, the residential variable in our analysis contained a combination of the major occupancy variable and the property classification variable.

Major occupancy inclusion: unspecified; row, garden, town housing; condominium, apartment, tenement; single detached duplex; duplex, 3-plex, 4-plex, semi-detached; mobile home/trailer park; residential with business/mercantile, up to 3 stories

Major occupancy exclusion: hotel, motel, lodge, hostel, boarding house, dormitory; educational institution (residential), camp site/RV park

Property classification inclusion: one and two family dwellings: apartment, tenement, flat, townhouse, condominium; rooming, boarding, lodging house; mobile home – 1 or 2 family unit

The demographic details of the residential fire deaths examined in this sample are displayed in Table 2, and the respective patterns for injuries are displayed in Table 3.

TABLE 1: FREQUENCY OF RESIDENTIAL STRUCTURE FIRES, DEATHS, AND INJURIES, OR ALL RESIDENTIAL PROPERTIES, APARTMENTS, AND SINGLE DETACHED DWELLINGS*

Property Classification	# Fires	% Total Fires	# Deaths	% Total Deaths	# Injuries	% Total Injuries
All residential properties	140,162	100.0%	1,440	100.0%	9,142	100.0%
Apartment	40,653	29.0%	359	24.9%	3,863	42.3%
Single detached	42,632	30.4%	426	29.6%	1,755	19.2%

*Note: Overall, 19,558 fire records were omitted from analyses as they did not have sprinkler information for the categories of residential, apartment or single detached dwellings.

TABLE 2: DEMOGRAPHIC INFORMATION FOR THE DEATHS THAT OCCURRED IN THE FIRES UNDER EXAMINATION*

Property Classification	% Male	% 6 years and under	% 65 and over*	% Firefighter
All residential properties	63.2%	4.6%	30.1%	0.1%
Apartment	56.8%	3.1%	33.4%	0.0%
Singled detached	72.8%	3.1%	27.2%	0.5%

*Note: Two firefighter deaths occurred in a single family residence. Sixty five and over means to a maximum of 100 years of age.

In 2016, children aged 6 and under represented 7.6% of the Canadian population and adults aged 65 years and older represented 16.9% of the population. With this in mind, it appears that young children were slightly under-represented in fire deaths (4.6% overall, see Table 2). In contrast, older members of society demonstrated a dramatically higher likelihood of death (30.1%) as a result of residential structure fire. This pattern was even greater for fatalities in apartment buildings, where 33.4% were aged 65 years and over (Canada Census, 2016).

TABLE 3: DEMOGRAPHIC INFORMATION FOR THE INJURIES THAT OCCURRED IN THE FIRES UNDER EXAMINATION

Property Classification	% Male	% 6 years and under	% 65 and over*	% Firefighter
All residential properties	66.1%	4.5%	5.1%	21.6%
Apartment	62.6%	5.6%	5.2%	17.3%
Single detached	64.7%	2.6%	7.8%	12.5%

*Note: To a maximum of 100 years of age.

These findings with respect to males and elderly fatalities are consistent with previous research focused on high-risk demographic characteristics for fire fatality. From a future planning perspective, these figures are indicative of the need to conduct risk-based, targeted fire-prevention campaigns, given that the proportion of seniors aged 65 years or over would continue to increase in the future. This group would represent between 23% and 25% of the population by 2036 and between 24% and 28% by 2061, compared to 14% in 2009 (Statistics Canada, 2017).

Outcomes for Life Safety with Sprinkler Protection

Disaggregating the information presented in Table 1 listed above, Table 4a displays the frequencies, and Table 4b (relative frequencies) of structure fires and fire-related deaths and injuries for residential properties as a function of sprinkler protection status. Some important summary findings from Table 4b include:

- Overall, 2.8% of fires at residential properties occurred in buildings with complete sprinkler protection. Ninety-seven percent of injuries and 99.2% of deaths overall occurred in properties that did not have sprinkler protection;
- Less than one tenth (8.1%) of fires in apartments occurred in sprinkler protected buildings. Overall, 97.2% of the deaths and 94.1% of the injuries in apartment buildings occurred without sprinkler protection; and,
- Less than one percent (0.6%) of the fires in single detached residential buildings occurred in the presence of sprinkler protection. All but one death, 99.8% of the deaths and 99.2% of the injuries that occurred in these single detached structures occurred in the absence of sprinklers.

TABLE 4A: RESIDENTIAL STRUCTURE FIRES, FIRE-RELATED DEATHS AND INJURIES BY SPRINKLER STATUS AND PROPERTY CLASSIFICATION

Property Classification	No Sprinkler Protection			Sprinkler Protection		
	# Fires	# Deaths	# Injuries	# Fires	# Deaths	# Injuries
All residential properties	126,330	1,406	8,658	3,580	12	261
Apartment	35,334	347	3,576	3,119	10	223
Single detached	35,314	406	1,613	212	1	13

TABLE 4B: RESIDENTIAL STRUCTURE FIRES, FIRE-RELATED DEATHS AND INJURIES BY SPRINKLER STATUS AND PROPERTY CLASSIFICATION RELATIVE FREQUENCIES

Property Classification	No Sprinkler Protection			Sprinkler Protection		
	%Fires	% Deaths	% Injuries	% Fires	% Deaths	% Injuries
All residential properties	97.2%	99.2%	97.1%	2.8%	0.8%	2.9%
Apartment	91.9%	97.2%	94.1%	8.1%	2.8%	5.9%
Single detached	99.4%	99.8%	99.2%	0.6%	0.2%	0.8%

Differences in the relative frequencies of fires in the presence of sprinkler protection as a function of property classification are to be expected, given the variations in building code standards and municipal bylaws that operate across Canada. It is important to provide some additional context about the fire incident that incurred a death in the residential building with sprinkler protection. From the available information, it is unclear whether the fatality occurred as a result of the fire, or whether the occupant may have died as a result of a separate cause. The fire was caused by smoker's material, confined to the room of origin, and was extinguished by the sprinkler system. Furthermore, the casualty report indicated that the age, condition, actions, cause of injury, and cause of failure to escape were all coded as 'unknown'. However, this case has been retained for analysis purposes to maintain consistency with the database.

Table 5 indicates the death rate per 1,000 fires and the injury rate per 1,000 fires for all residential properties, apartments, and single detached dwellings. The rate ratios columns

compare the rates for fires in buildings without sprinkler protection with those in buildings that were protected by sprinklers. Table 5 reveals that with sprinklers, the injury rate for all residential properties was 72.9, or 6.4% higher than the 68.5 without sprinklers. For single-detached properties, the sprinklered injury rate of 61.3 was 34% higher than the 45.7 rate with no sprinklers. The direction was favorable for apartments. This pattern was largely consistent for fires in apartment buildings without sprinkler protection (3.1 and 1.4 times greater). Sprinklered environments lead to a reduction in death and injuries.

TABLE 5: DEATH RATES (PER 1,000 FIRES), INJURY RATES (PER 1,000 FIRES), AND RATE RATIOS, BY SPRINKLER STATUS AND PROPERTY CLASSIFICATION

Property Classification	No Sprinkler protection		Sprinkler protection		Rate ratios (no sprinkler: sprinkler)	
	Death rate	Injury rate	Death rate	Injury rate	Death rate	Injury rate
All residential properties	11.1	68.5	3.4	72.9	3.3	0.9
Apartment	9.8	101.2	3.2	71.5	3.1	1.4
Single Detached	11.5	45.7	4.7	61.3	2.4	0.7

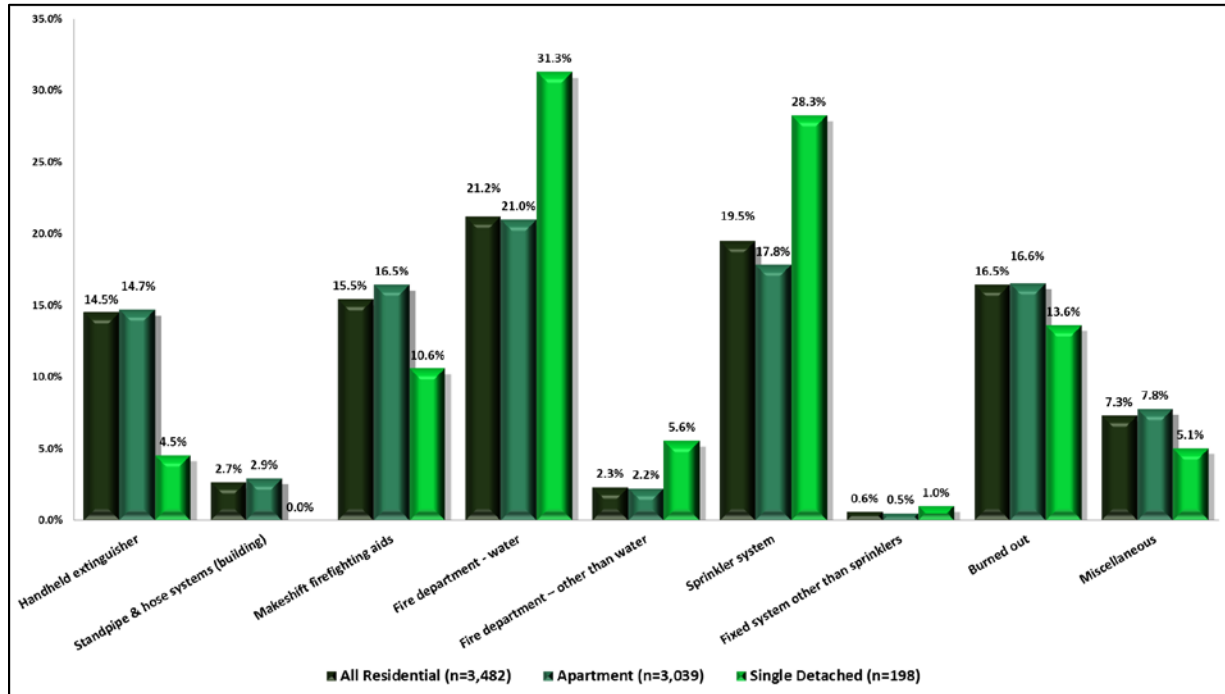
Understanding the Different Outcomes with Sprinkler Protection

Fire Performance – Method of Control

A broad range of methods were employed to control the fires in this sample and the relative frequency at which each was used is demonstrated in Figure 1. Figure 1 (a) displays the various methods of fire control for residential fires in properties with sprinkler protection (displayed separately for all residential property fires, apartment fires, and single detached dwelling fires). Figure 1 (b) displays the equivalent percentages for the residential structures without sprinkler protection.

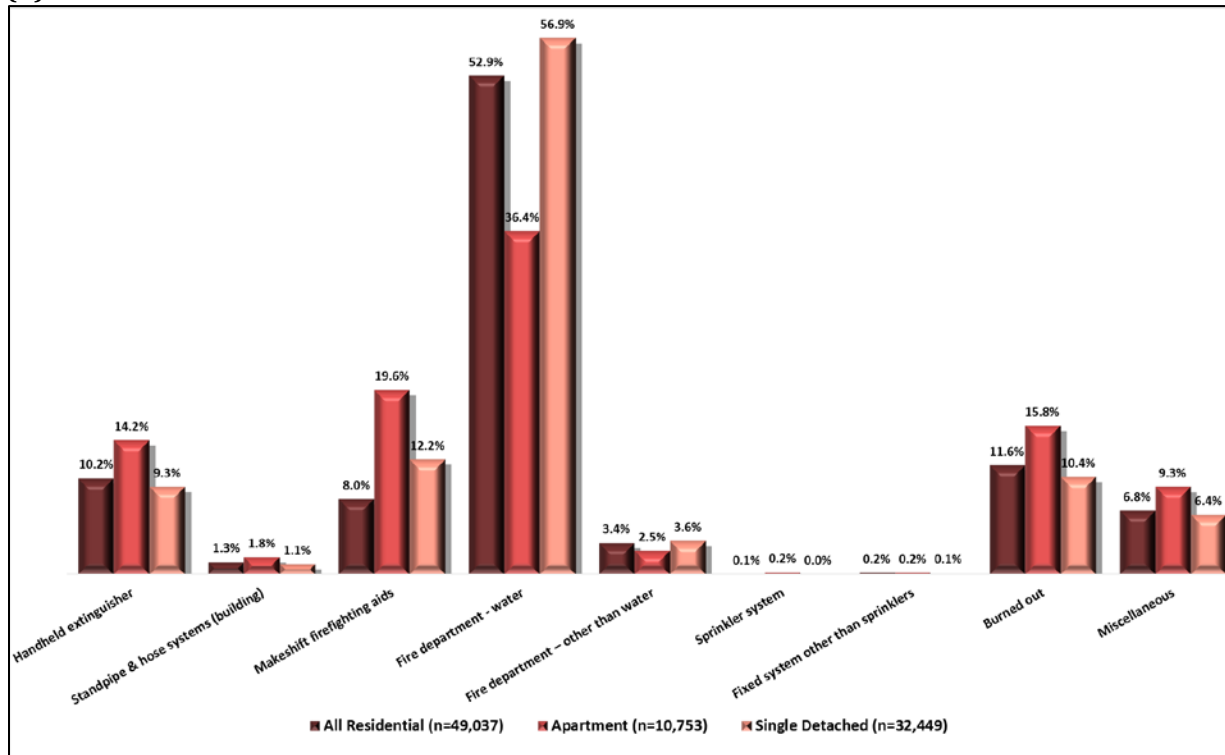
Due to variations in the nature of size and spread of the fire, it was not always the case that the sprinkler system was required to activate to control fires in buildings with sprinkler protection. This does not reflect a failure of the sprinkler system as there are a range of fire control mechanisms, including available fuel burned-out, removal of fuel, use of make-shift aids, and use of hand-held extinguishers that could be employed to prevent the fire expanding to the extent that the sprinkler system would activate. This explains why sprinkler systems were only required to control 19.5% of the fires in buildings with sprinkler protection. Sprinklers also controlled fires in 17.8% of the apartments and 28.3% of the single detached dwellings.

FIGURE 1: (A) METHOD OF FIRE CONTROL FOR SPRINKLER PROTECTED BUILDINGS BY PROPERTY CLASSIFICATION, AND (B) METHOD OF FIRE CONTROL FOR BUILDINGS WITHOUT SPRINKLER PROTECTION BY PROPERTY CLASSIFICATION*



*Note: Unknown, undetermined, not applicable, not available values not included in calculations

(B) NO SPRINKLER PROTECTION*



*Note: Unknown, undetermined, not applicable, not available values not included in calculations. There were at least a few fires in buildings coded as not having sprinklers where the fire was extinguished by sprinklers. This is minor in nature and the cases were retained.

As suggested by the patterns displayed across Figure 1 (a) and (b), there were some obvious differences in the broad methods used to control fires in residential buildings as a function of sprinkler protection status. These main patterns include:

- The fire department was required to use water to control fires 1.8 times more often in single detached dwellings without sprinkler protection (56.9% compared to 31.3% in sprinkler protected buildings); and,
- When the fire department was required to combat and extinguish the fire, this was required more frequently in buildings without sprinkler protection. As a proxy measure where the fire was extinguished, the fire department were required 1.3 times more often overall (43.9% of all fires in buildings without sprinkler protection, compared to 33.5% of fires in sprinkler protected buildings). This pattern was closer to equal for apartment fires, where incidents in buildings without sprinkler protection were similar (33.4% vs. 33.5% of fires, respectively), and,
- The frequency of hand-held extinguisher use to control fires was less for fires in apartments without sprinklers (14.2% vs. 14.7% in buildings with sprinklers) and greater for fires in single detached buildings without sprinklers (9.3% vs. 4.5%). Apartments with sprinklers are also required in some Canadian provincial jurisdictions to have extinguishers. Code requirements are a factor and they vary across provinces.

Fire Performance – Extent of Fire Spread

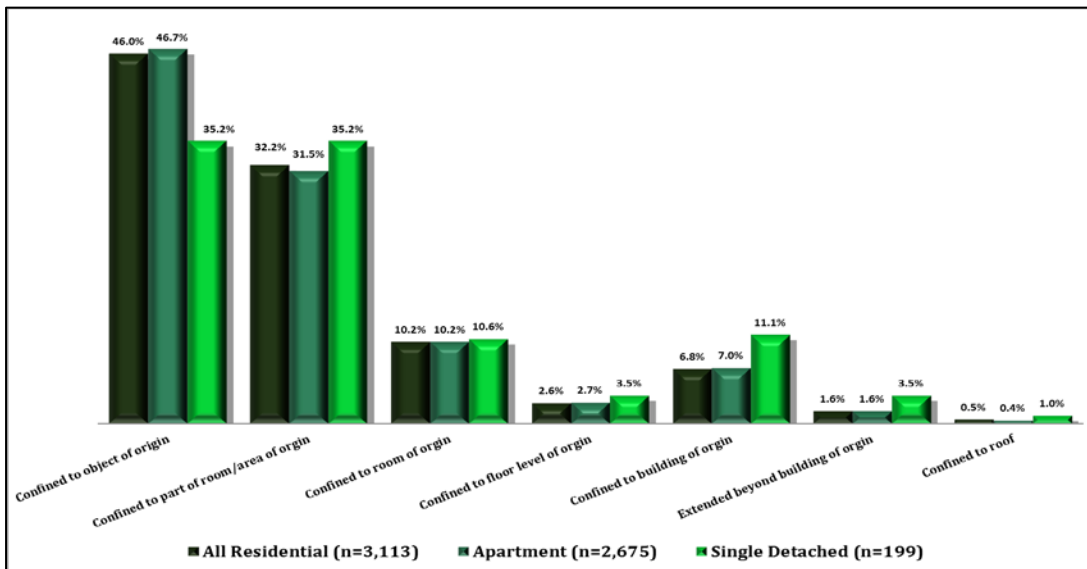
The varying extent to which fires spread throughout the residential buildings is displayed in Figure 2. Figure 2 (a) demonstrates the fire spread in buildings with sprinkler protection that operated. Figure 2 (b) shows the equivalent patterns of fire spread in residential buildings without sprinkler systems (Figure 3 examines the fire spread for the remaining fires in sprinkler protected buildings). As previously, the variations in fire spread are examined for all residential structure fires (excluding any values of not applicable), and then separately for the fires that occurred in apartment buildings and single detached dwellings, both with and without sprinkler protection.

As with the methods of fire control explored previously, there were some significant differences in the extent to which the fires spread between sprinkler-controlled fires and the fires that occurred in buildings without sprinkler protection. The main results, based on the percentages indicated in Figure 2 (a) and (b) are as follows:

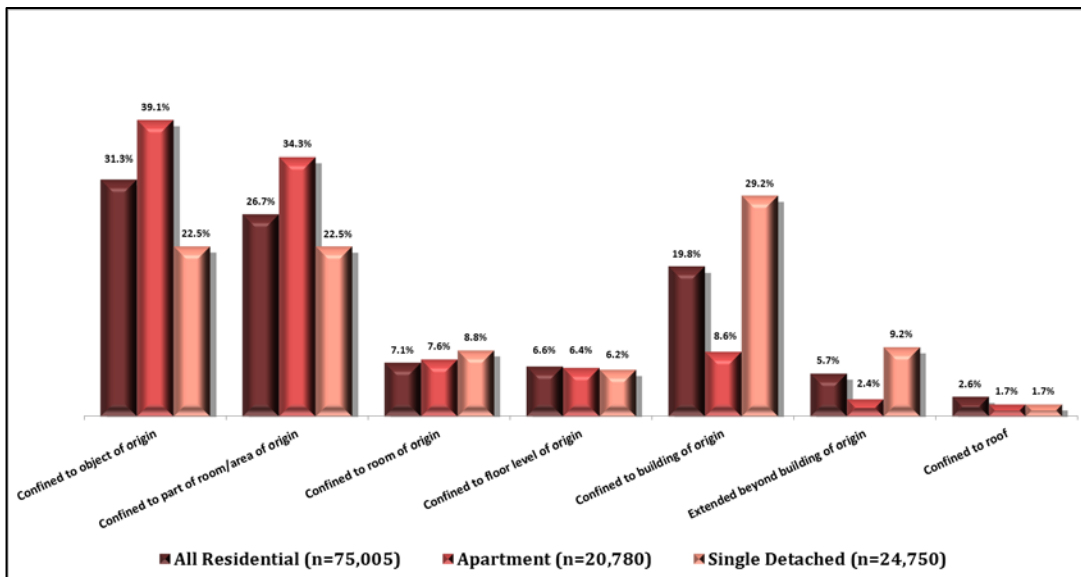
- Fires controlled by sprinklers were confined to the object, part room, or room of origin 88.4% of the time, which was a 1.35 times more frequent than for fires in buildings without sprinklers (65.1%). This difference was less pronounced for fires in apartment buildings: 88.3% of fires controlled by sprinklers were confined to at least the room of origin, compared to 81.0% of those in buildings without sprinklers. The difference was greatest for fires in single detached properties: 81.0% confined within the room of origin when controlled by sprinklers, compared to 53.8% when controlled by other means.

- Overall, fires controlled by sprinkler systems were less likely to extend as far as the floor of origin (2.6%) compared to fires in buildings without sprinklers (6.6%). This difference was observed for apartment fires and for fires in single detached dwellings;
- At all other extents of fire spread, there was an increased likelihood of the fire spreading to the building, beyond the building, and being confined to the roof for fires in buildings without sprinkler protection; and,
- Only 1.6% of fires in buildings that were extinguished by sprinkler systems extended beyond the building of origin.

FIGURE 2: (A) EXTENT OF FIRE SPREAD FOR SPRINKLER PROTECTED BUILDINGS (WHERE THE METHOD OF FIRE CONTROL WAS THE SPRINKLER SYSTEM) BY PROPERTY CLASSIFICATION, AND (B) EXTENT OF THE FIRE SPREAD FOR BUILDINGS WITHOUT SPRINKLER PROTECTION, BY PROPERTY CLASSIFICATION*



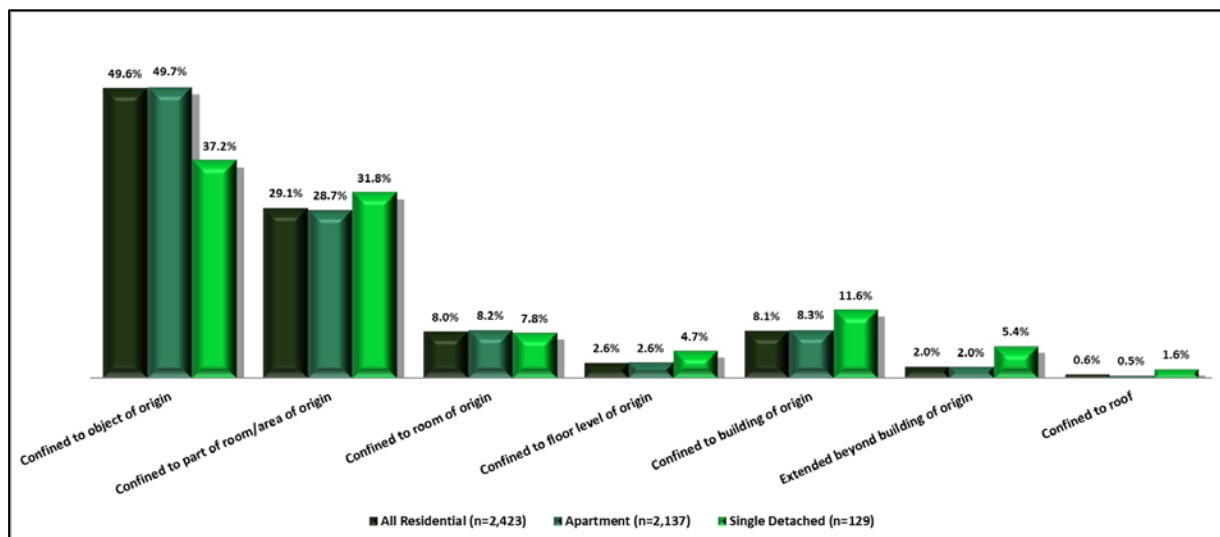
(B) NO SPRINKLER PROTECTION*



*Note: not applicable values not included in calculations

The extent of fire spread for fires in sprinkler protected buildings that were not controlled by the sprinkler system are indicated in Figure 3, below. Overall, 6 fires accounted for 2% of the relevant fires that occurred in the total residential properties that were protected by sprinklers were coded as having extended beyond the building of origin. Additional investigation of the area at which these fires originated revealed that they all started on the outside: 2 fires in a court, patio, or terrace area, 2 on exterior walls, 1 on an exterior balcony, and 1 exposure fire. Furthermore, 2 of the fires were coded as having been incendiary in origin. In short, these fires look like they originated outside of the building, which most likely put them beyond the reach of built-in fire protection systems. Separate research reveals that balcony fires in multi-residential buildings are more likely to have required visual sighting and or personal detection for fire discovery, more likely to have extended to the building or beyond, and more likely to have required fire department intervention to control the fire (Garis and Clare, in press). In contrast, only 30.4% of the 463 fires that extended beyond the buildings without sprinkler protection occurred in an outside area or as a result of an exposure.

FIGURE 3: EXTENT OF FIRE SPREAD FOR SPRINKLER PROTECTED BUILDINGS, WHERE THE METHOD OF FIRE CONTROL WAS NOT THE SPRINKLER SYSTEM BY PROPERTY CLASSIFICATION*



*Note: not applicable values not included in calculations

Behaviour of Fire-Related Casualties

It is useful to examine the behavior for residential fire-related casualties to see if there are any systematic differences in how people respond to fires in the presence or absence of sprinklers. Table 6 displays variations in the actions of the fire-related casualties for the incidents in buildings with and without sprinkler protection. When reviewing the actions leading to deaths in unsprinklered buildings, 12.8% occurred when the victims did not act and received delayed warning. In relation to injuries, the main findings of note include: more casualties were injured while attempting to escape from buildings without sprinkler protection (16.6% vs. 8.3% in buildings with sprinklers); and, when comparing buildings with or without sprinklers, there were relatively even distributions of casualties when looking at a combination of actions such as loss of judgement/panic, delayed warning, or failure to act.

TABLE 6: ACTION OF FIRE CASUALTY (INJURIES AND DEATHS) BY SPRINKLER PROTECTION STATUS

Action of Casualty	No Sprinkler Protection				Sprinkler Protection			
	# Injuries	% Injuries	# Deaths	% Deaths	# Injuries	% Injuries	# Deaths	% Deaths
Civilian attempted suppression	0	0.0%	17	1.2%	0	0.0%	0	0.0%
Fire setter	0	0.0%	30	2.1%	0	0.0%	0	0.0%
Injured while attempting to escape	1,440	16.6%	233	16.6%	34	13.0%	1	8.3%
Over-exertion, heart attack	23	0.3%	5	0.4%	2	0.8%	0	0.0%
Entered or remained for rescue purposes	397	4.6%	23	1.6%	9	3.4%	0	0.0%
Entered or remained for firefighting/ extinguishment	3,491	40.3%	17	1.2%	83	31.8%	0	0.0%
Entered or remained to save personal property	167	1.9%	8	0.6%	18	6.9%	0	0.0%
Loss of judgement or panic	687	7.9%	89	6.3%	15	5.7%	2	16.7%
Received delayed warning	65	0.8%	22	1.6%	2	0.8%	0	0.0%
Did not act	430	5.0%	157	11.2%	18	6.9%	1	8.3%
Unclassified	811	9.4%	117	8.3%	48	18.4%	0	0.0%
Unknown	1,147	13.2%	688	48.9%	32	12.3%	8	66.7%
Total	8,658	100.0%	1,406	100.0%	261	100.0%	12	100.0%

Note: The category civilian attempted suppression overlaps with entered or remained for firefighting/ extinguishment.

Table 7 shows that 56% of deaths in non-sprinklered properties were from smoke inhalation, but only 40% of deaths occurred in sprinklered properties. Simply, the leading cause of injury and death in all cases was smoke inhalation.

TABLE 7: CAUSE OF FIRE-RELATED CASUALTY (INJURIES AND DEATHS) BY SPRINKLER PROTECTION STATUS

Action of Casualty	No Sprinkler Protection				Sprinkler Protection			
	# Injuries	% Injuries	# Deaths	% Deaths	# Injuries	% Injuries	# Deaths	% Deaths
Smoke inhalation	1,241	41.9%	302	56.0%	112	42.9%	4	40.0%
Burn	1,072	36.2%	78	14.5%	81	31.0%	3	30.0%
Physical injury	161	5.4%	4	0.7%	3	1.1%	0	0.0%
Other	66	2.2%	42	7.8%	8	3.1%	0	0.0%
Unknown	421	14.2%	113	21.0%	57	21.8%	3	30.0%
Total	2,961	100.0%	539	100.0%	261	100.0%	10	100.0%

There were two firefighter casualties (deaths) as a result of the fires examined in the production of this report. To provide some additional information about the extent of injuries that were experienced by the casualties in this sample, Table 8 explores injury severity as a function of sprinkler protection status, for both firefighters and civilians. Although there were no significant differences in the severity of injury sustained (Table 8), the following summary trends are worth noting. Casualties who sustained injuries were: (a) 77.9% civilian, (b) 97.5% located in buildings without sprinkler protection, (c) only serious (≥ 3 days in hospital/ > 15 days off work) 22.60% of the time (for civilians with no sprinkler protection), (d) serious in the presence of sprinkler protection 9.6% of the time (for civilians), and (e) never involved a serious injury to a firefighter in the presence of sprinklers. When viewed as a rate per 1,000 fires as a function of sprinkler protection status, two patterns are worth highlighting:

- injury rate for firefighters was 1.6 times greater in buildings without sprinkler protection;
- injury rates for civilians were significantly higher than those for firefighters for fires that occurred in buildings with sprinklers (6.9 times more frequent) and without sprinklers (3.5 times more frequent); and,
- for context, the civilian injury rate is higher than the firefighter injury rate as civilians were present when fire started and before sprinklers operated. This heightened the risk of injury to civilians relative to firefighters who were not there at the beginning of the incident.

TABLE 8: SEVERITY OF INJURIES (%) AND INJURY RATES FOR CIVILIANS AND FIREFIGHTERS BY SPRINKLER PROTECTION STATUS

Severity of Injury	Civilian Injuries (n=6,927)		Firefighter Injuries (n=1,956)	
	No Sprinkler Protection	Sprinkler Protection	No Sprinkler Protection	Sprinkler Protection
Minor < 1 day in Hospital/off work	63.4%	54.8%	79.0%	51.5%
Light 1-2 days in Hospital/off work 1-15 days	14.0%	35.5%	5.9%	48.5%
Serious ≥ 3 days in hospital and/or off work > 15 days	22.6%	9.6%	15.1%	0.0%
Injury rate per 1000 fires	53.0	63.7	15.2	9.2

Civilian and Firefighter Injuries

There were 6,927 civilian injuries and 1,956 firefighter injuries, the percentage of civilian serious injuries noted in Figure 4, sprinklered buildings were observed in 10% of the cases as opposed to 23% for non-sprinklered environments. Firefighter serious injuries were not observed in a sprinklered building as opposed to 15% for non-sprinklered buildings.

FIGURE 4: PERCENTAGE OF INJURIES BY SEVERITY OF INJURY

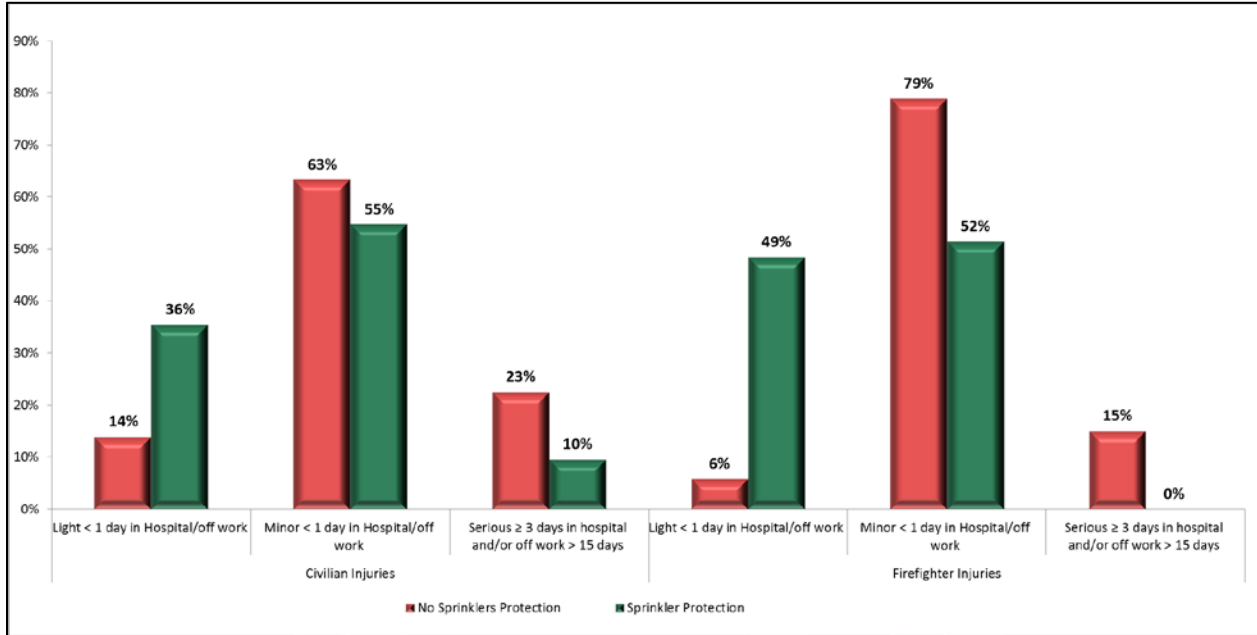
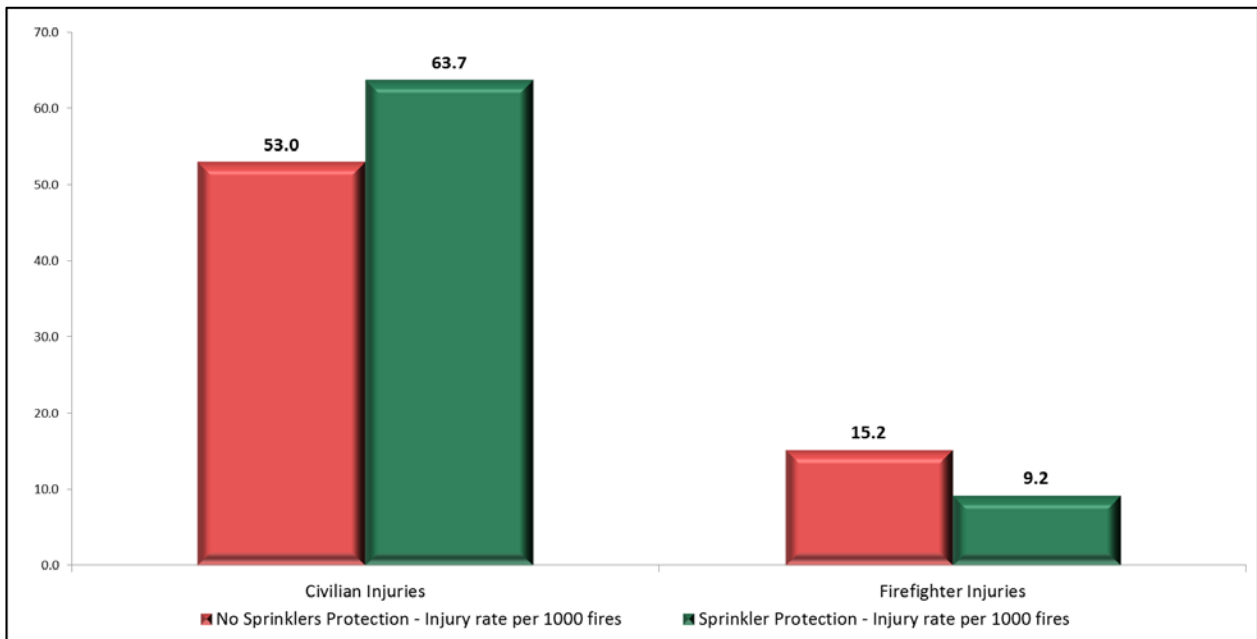


Figure 5 shows a reduction of a 15.2 injury rate per 1,000 fires to 9.2 for non-sprinklered to sprinklered rate for firefighters and an injury rate increase from 53 to 63.7 for civilians in non-sprinklered to sprinklered environments.

FIGURE 5: INJURY RATE PER 1,000 FIRES FOR NON SPRINKLER AND SPRINKLER PROTECTION



Conclusion

Overall, these results strongly indicate that residential sprinkler systems have a significant positive impact in reducing fire-related fatalities. The death rate per 1000 reported residential fires was more than three times as high in fires with no sprinklers as it was in fires with sprinklers present. Fire department resources were required less extensively to control fires in buildings that were protected by sprinklers. For the cases examined in this study, when sprinklers controlled fires, they never extended beyond the building of origin, and were contained to the room of origin more often than fires in buildings without sprinkler protection. Specifically, fires controlled by sprinklers were confined to the object, part room, or room of origin 88.4% of the time, which was 1.35 times more frequent than for fires in buildings without sprinklers (65.1%). In addition injuries occurred less frequently in fires that took place in buildings with sprinklers. No serious firefighter injuries occurred in fires with sprinklers. Only 10% of the civilian injuries in fires with sprinklers were serious, compared to 23% of civilian injuries in fires without sprinklers.

Based on the findings from this research and those previously released, it can be concluded that fire-related death rates per 1,000 reported fires reduce by:

- 43.7% with working smoke alarms, and;
- 79% with sprinkler systems.

With respect to the applied implications for these findings and targeting fire prevention and/or public safety resources, it is important to acknowledge the fact that the presence of both a sprinkler system and a functioning smoke alarm may be a proxy measure for affluence and relative social advantage. This pattern, in addition to the uneven distribution of risk known to be associated with not having a functioning smoke alarm, mean that targeted prevention efforts associated with sprinklers and smoke alarms should build on equivalent logic, focusing on elderly citizens, the impoverished, and the vulnerable members of society who need help first.

Sprinklers save lives. The death rate per 1000 fires in residences with sprinklers is less than one-third that of fires in unsprinklered residences. Sprinklers reduce the risk of serious injury to both civilians and firefighters. Sprinklers can control a fire before the fire department arrives. Fires controlled by sprinklers are more likely to be confined to the room of origin than fires in properties without sprinklers. Working smoke alarms provide an essential early warning yet they cannot control the fires. Sprinklers can, and do.

References

- [1] L.J. Warda and M.F. Ballesteros, *Interventions to prevent residential fire injury*, in *Handbook of Injury and Violence Prevention*, L. Doll, S. Bonzo, and J. Mercy, Editors. 2007. p. 97-115.
- [2] D.T. Butry, M.H. Brown, and S.K. Fuller, *Benefit-cost analysis of residential fire sprinkler systems, NISTIR 7451*, 2007, National Institute of Standards and Technology: Gaithersberg, MD.
- [3] U.S. Fire Administration. *USFA position on residential fire sprinklers*. 2008 [cited 2012 28 September]; Available from: http://www.usfa.fema.gov/about/position_statements/sprinklers_position.shtm.
- [4] N. Bénichou, D. Yung, and G. Hadjisophocleous, *Impact of fire department response and mandatory sprinkler protection on life risks in residential communities*, 1999, National Research Council: Ottawa. p. 8.
- [5] D.T. Butry, *Comparing the performance of residential fire sprinklers with other life-safety technologies*. *Accident Analysis and Prevention*, 2012. 48: p. 480-494.
- [6] M. Gilbert, M. Dawar, and R. Armour, *Fire-related deaths among aboriginal people in British Columbia, 1991-2001*. *Canadian Journal of Public Health*, 2006. 97(4): p. 300-304.
- [7] M. Wijayasinghe, *Making sense of smoke alarm data and home fire deaths*. *Alberta Fire News*, 2004. August: p. 16- 19.
- [8] L. Garis and J. Clare, *Significance of area of origin for fires that commence on the balconies of multi-residential buildings*, in press, Centre for Public Safety and Criminal Justice Research, School of Criminology and Criminal Justice, University of the Fraser Valley.
- [9] L. Garis and J. Clare, *Smoke alarms work, but not forever: posing the challenge of adopting multifaceted, sustained, interagency responses to ensuring the presence of a functioning smoke alarm*, 2012, Centre for Public Safety and Criminal Justice Research, School of Criminology and Criminal Justice, University of the Fraser Valley.
- [10] J. Clare, et al., *Reduced frequency and severity of residential fires following delivery of fire prevention education by on-duty firefighters: cluster randomised controlled study*. *Journal of Safety Research*, 2012. 43: p. 123.128.
- [11] K. Wuschke, J. Clare, and L. Garis, *Interpreting temporal and geographic clustering of fires within the context of environmental criminology theory*. *Fire Safety Journal*, 2013.
- [12] L.Garis and J Clare, *Fire outcomes by general construction type: A retrospective analysis of British Columbia reported fires 2014*, Centre for Public Safety and Criminal Justice Research, School of Criminology and Criminal Justice. University of the Fraser Valley.
- [13] L.Garis, Clare and Sarah Hughan, *Smoke alarms work, but not forever: revisited successes and ongoing challenges from BC.s working smoke alarm campaign 2015*, Centre for Public Safety and Criminal Justice Research, School of Criminology and Criminal Justice,

University of the Fraser Valley.

- [14] S. Kerber, *Analysis of changing residential fire dynamics and its implications on firefighter operational timeframes*. Fire Technology, 2012. 48: p. 865-891.
- [15] R. Ruegg and S. Fuller, *A Benefit-Cost Model of Residential Fire Sprinkler Systems*, NBS Technical Note 1203, Gaithersburg, Maryland: U.S. Department of Commerce, National Bureau of Standards, 1984.

Author Biographical Information

Len Garis is the Fire Chief for the City of Surrey, British Columbia, an Adjunct Professor in the School of Criminology and Criminal Justice & Associate to the Centre for Social Research at the University of the Fraser Valley (UFV), a member of the Affiliated Research Faculty at John Jay College of Criminal Justice in New York, and a faculty member of the Institute of Canadian Urban Research Studies at Simon Fraser University. Contact him at Len.Garis@ufv.ca

Arpreet Singh is a 2nd year Master of Public Health student at Simon Fraser University. He is currently working with Dr. Ian Pike at the BC Injury Research and Prevention Unit leading a project on residential fire injuries among children and youth. He started his research career studying socio-demographic and clinical characteristics associated with combination antiretroviral therapy adherence in people living with HIV/AIDS in 2015. He is considering a career in medicine in the near future. Contact him at arpreets@sfu.ca

Joseph Clare, Ph.D, formerly of the Surrey Fire Service, is a Senior Lecturer in Criminology at Murdoch University, and an international member of the Institute of Canadian Urban Research Studies, Simon Fraser University. Contact him at j.clare@murdoch.edu.au

Sarah Hughan is the Computer Specialist with Surrey Fire Services. She has 15 years of experience in municipal government, specializing in public works and public safety. She is an accredited firefighter, and possesses the Geographical Information System Professional (GISP) designation. Sarah attended the University of Waterloo and attained a Bachelor of Environmental Studies, a Minor in Management Studies, an IT Specialization and a Certificate of Excellence in GIS. She is currently enrolled in the part-time MBA program at Simon Fraser University. Contact her at SHughan@surrey.ca.

Alex Tyakoff is the Strategic Planning Analyst for the City of Surrey Fire Service, BC. He has 26 years' of experience in public safety research and analysis and worked as an urban planner. He possesses a Master of Science (MSc) degree in Planning from the School of Community and Regional Planning (SCARP), University of British Columbia. Alex also attended Simon Fraser University and attained a Bachelor of Arts Degree in Political Science. Contact him at Atyakoff@surrey.ca

Acknowledgements

Thank you to the Canadian Association of Fire Chiefs, Council of Canadian Fire Marshals and Fire Commissioners, Defense Research and Development Canada and Public Safety Canada. Without their contributions, this work would not have been possible. The authors wish to thank Statistics Canada, Canadian Centre for Justice Statistics for their invaluable efforts in developing the National Fire Information Database. This research made extensive use of NFID holdings.

Finally thank you to the National Fire Protection Association and The Co-operators Group Ltd. for supporting us to revisit this study.

