

Sprinkler Systems and Fire Outcomes in Multi-Level Residential Buildings



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Executive Summary

1. This paper summarizes the findings from an evaluation of the historical fire protection performance of sprinkler systems in multi-level residential buildings in British Columbia (BC), with the intent of anticipating how the fire safety systems should perform in six-story mid-rise wood-frame buildings, permitted in BC since 2009.
2. The 1,942 fire incidents analysed occurred between October 5, 2006 and October 5, 2011 in apartment/townhouse structures in BC that were either completely sprinklered or completely unsprinklered. Overall, 565 (29.1%) fire incidents occurred in completely sprinklered buildings. The incident reports associated to these fires were submitted by 101 different reporting locations in the province, spanning municipal areas, non-municipal areas (both with and without fire protection), and First Nations band areas.
3. The areas of origin for the fires in sprinklered and unsprinklered buildings were highly comparable, with the greatest percentage (around 40%, overall) originating from kitchen/cooking areas.
4. As a function of the size/spread of the fire, it was not always the case that sprinklered buildings required activation of the sprinkler system to control the fire. The sprinkler protection systems in sprinklered buildings extinguished 21.6% (n = 122) of the fires, and the Fire Department was required significantly less often to control fires in sprinklered buildings (19.5% of fires, compared to 39.0% in unsprinklered buildings). Furthermore, when the Fire Department did respond to fires in sprinklered buildings, significantly fewer resources were deployed, with multiple hose lines utilised in only 3.9% of cases, compared with 14.4% of cases in unsprinklered buildings.
5. The 21.6% of fires in sprinklered buildings that were controlled by the sprinkler systems never extended beyond the floor of origin, and were contained to the room of origin 96.2% of the time. In comparison, 18.8% of the fires in unsprinklered buildings extended beyond the room of origin, and 12.7% extended beyond the floor of origin.
6. Death and injury were significantly less frequent in sprinklered buildings. The odds of a death in an unsprinklered building fire was 11.9 times greater than for fires in sprinklered buildings, with death rates of 1.8 deaths per 1,000 fires in sprinklered buildings compared to 21.1 deaths per 1,000 fires in unsprinklered buildings. The odds of an injury in an unsprinklered building fire was 2.9 times greater than for fires in sprinklered buildings, with injury rates of 44.2 per 1,000 fires in sprinklered buildings compared to 127.1 injuries per 1,000 fires in unsprinklered buildings.
7. Career and composite Fire Departments responded to 96.8% of these fire incidents. There was no indication of a rural/urban distinction in the performance of sprinkler systems, as fires in sprinklered buildings responded to by volunteer/paid-on-call and unclassified fire services were contained to the room of origin 100% of the time.
8. When extrapolating these findings to anticipate how the fire safety systems should perform in the 6-story mid-rise wood-frame buildings that have been permitted in BC since 2009 following amendments to the BC Building Code (BCBC) it is assumed that the risk posed by the new structures will be reduced relative to the fire incidents evaluated within this paper because:
 - (a) All of the buildings constructed under the amended legislation will be fully-sprinklered to be compliant with the NFPA 13 standard, in addition to being constructed with a range of other in-built fire-protection systems, such as non-combustible exterior cladding, and use of electromagnetic, hold-open door devices that release in the event of a fire.
 - (b) Previous research has not identified a relationship between fire safety inspections and fires/injuries/deaths, reducing concerns about the potential inability for rural/remote communities to be able to meet the same standards/frequency of fire safety inspections as the larger, career-based departments in the metropolitan.

The Purpose of this Research

This report summarizes the findings of an evaluation of the historical fire protection performance of sprinkler systems in multi-level residential buildings in British Columbia with the intent of anticipating how the fire safety systems should perform in six-story, mid-rise, wood-frame buildings, permitted since 2009. The analysis utilised all post-fire incident inspection reports submitted to the BC Office of the Fire Commissioner between October 5, 2006 and October 5, 2011.¹

Identifying Relevant Cases for Analysis

There were two parts to the process involved with identifying the relevant cases for this analysis. First, the overall set of 37,492 fires was sorted to identify only those incidents involving a property classified as “Apartment, townhouse”.² Second, acknowledging that sprinkler protection across buildings falls onto a continuum, these “Apartment, townhouse” incidents were filtered to retain only those incidents that occurred in buildings that either had complete sprinkler protection or no sprinkler protection.³ As a result of this screening process, 1,942 incidents were retained, with the overall frequencies of fires, injuries and deaths by property classification, and sprinkler protection presented in Table 1.

TABLE 1: FIRES, INJURIES, AND DEATHS BY PROPERTY CLASSIFICATION AND SPRINKLER PROTECTION STATUS

Property Classification	Sprinklered				Unsprinklered			
	# Fires	% Fires	# Death	# Injury	# Fires	% Fires	# Death	# Injury
3 to 4 units with business	5	0.9%	0	0	63	4.6%	1	5
3 to 4 units no business	13	2.3%	0	1	168	12.2%	4	10
5 to 20 units with business	27	4.8%	0	0	128	9.3%	1	18
5 to 20 units no business	77	13.6%	1	4	423	30.6%	7	44
> 20 units	431	76.3%	0	20	581	42.3%	16	92
Unclassified	12	2.1%	0	0	14	1.0%	0	6
Total	565	100.0%	1	25	1,377	100.0%	29	175

Overall, 565 (29.1%) of the fires occurred in buildings with complete sprinkler protection, which accounted for 3.4% of the deaths and 14.3% of the injuries.⁴ In addition, the fires in the sprinkler protected buildings

¹ This report is not designed to comment on the risk associated with wood-frame buildings during the construction phase. For a discussion of these issues, and for an approach to managing these risks, see the Construction Fire Safety Plan Bulletin (most recently revised July, 2011) designed to assist owners, contractors, and workers on the requirements of a construction fire safety plan (CFSP) by providing a brief overview of existing information that has been developed and released elsewhere. This report can be found at at www.surrey.ca/files/DCT_Construction_Fire_Safety_Plan_Bulletin_w_Form_078A.pdf

² Property classification values: PR3210; PR3220; PR3230; PR3240; PR3250; and PR3290.

³ Sprinkler protection values: complete protection established by combining SP1000; SP2000; and SP3000; and no sprinkler protection established from SP7000.

⁴ Two of the fire incidents were originally coded as unsprinklered; however, the method of fire control indicated that they were extinguished as a result of the sprinkler system. These incidents (#209973 and #217509) were removed from subsequent analysis as it is unclear to what extent the buildings were sprinklered.

incurred 37.4% less damage (average estimated loss \$49,510 per fire) compared to fires in unsprinklered buildings (average estimated loss \$79,136 per fire).

In order to understand how representative this data set is of all British Columbian fire incidents, the frequencies of reporting locations, fires, deaths, and injuries are presented in Table 2. Overall, 101 reporting locations in the province submitted reports that were organized into municipal areas, non-municipal areas (both with and without fire protection), and First Nations band areas. The overwhelming majority of these fires occurred in municipal areas, resulting in 96.7% of the deaths and 99.5% of the injuries.

TABLE 2: FREQUENCIES OF REPORTING LOCATIONS, FIRES, DEATHS, AND INJURIES BY BROAD REPORTING AREA

Broad Reporting Area	# Reporting Locations	# Fires	% Fires	# Deaths	# Injuries
Municipal Areas	85	1,923	99.0%	29	199
Non-Municipal, fire protection	8	10	0.5%	1	1
Non-Municipal, no fire protection	3	3	0.2%	0	0
First Nations Band - grouped	5	6	0.3%	0	0
Total	101	1,942	100.0%	30	200

Origin of Fires by Sprinkler Protection Status

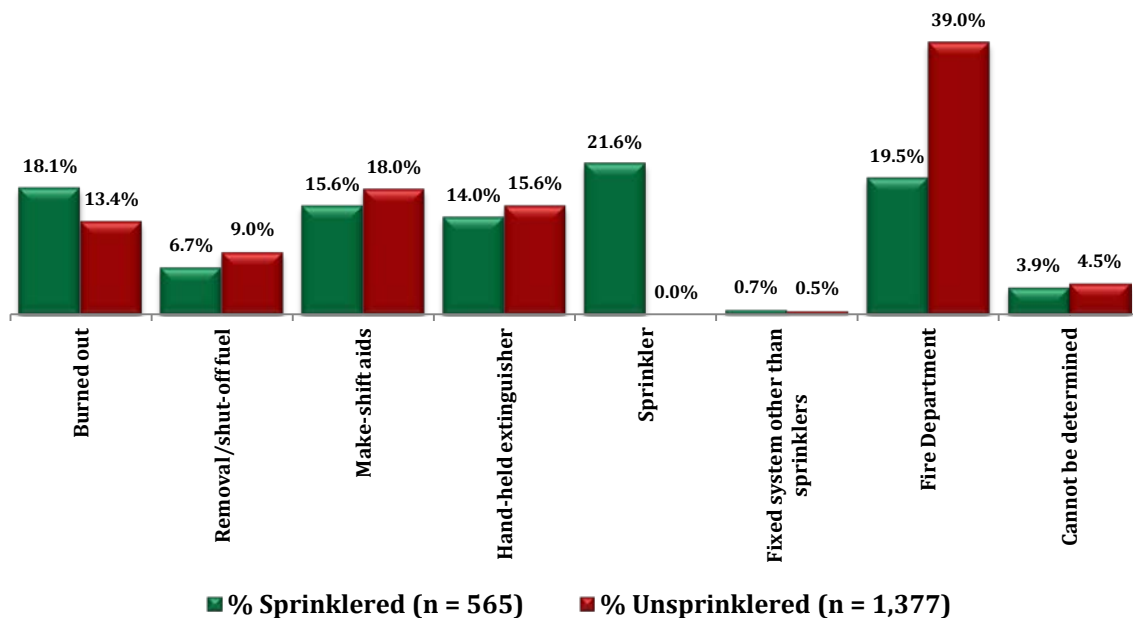
The relative percentages of the fires by area of origin within the sprinklered and unsprinklered groups were examined to determine how similar the fires within each of these categories were in order to provide a better understanding of whether differences in fire spread, method of extinguishment, and injury/death could be attributed to the presence/absence of sprinklers. Overall, there was a relatively equivalent distribution of fires within each group across these areas of origin, with the most frequent source “Assembly, family, sales area – kitchen, cooking area” (43.2% of fires in sprinklered buildings and 38.6% of fires in unsprinklered buildings). This analysis did not reveal any meaningful differences with respect to the area of origin of the fires as a function of sprinkler protection status that would prevent differences in the fire outcomes being attributed to the involvement of the sprinklers.

Method of Fire Control by Sprinkler Protection Status

A broad range of methods was employed to control this set of fires and the relative frequency of each of these as a function of the sprinkler protection status of the building (see Figure 1). 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 sprinklered buildings. It is important to note that this does not reflect a failure of the sprinkler system as there are a range of broad types of fire control mechanisms, including 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 the sprinkler system was only used to control fires in sprinklered buildings in 21.6% of fires (n = 122 cases). As demonstrated by Figure 1, there was an equivalent dependence on all other broad methods of controlling the fires, regardless of sprinkler protection status, with the exception of the involvement of the Fire Department, which was

required 19.5% more frequently for fires in unsprinklered buildings.⁵ In addition to this, when the Fire Department was required to control fires, a greater amount of resources were also required in unsprinklered buildings, with multiple hose lines required in 14.4% (n = 198 cases). This compares with only 3.9% (n = 22 cases) where multiple hose lines were recorded as having been required to control fires in sprinklered buildings.⁶ Overall, therefore, fires in sprinklered buildings required Fire Department intervention less frequently and less significantly.

FIGURE 1: WITHIN-GROUP PERCENTAGES OF BROADLY GROUPED METHODS OF FIRE CONTROL BY SPRINKLER PROTECTION STATUS



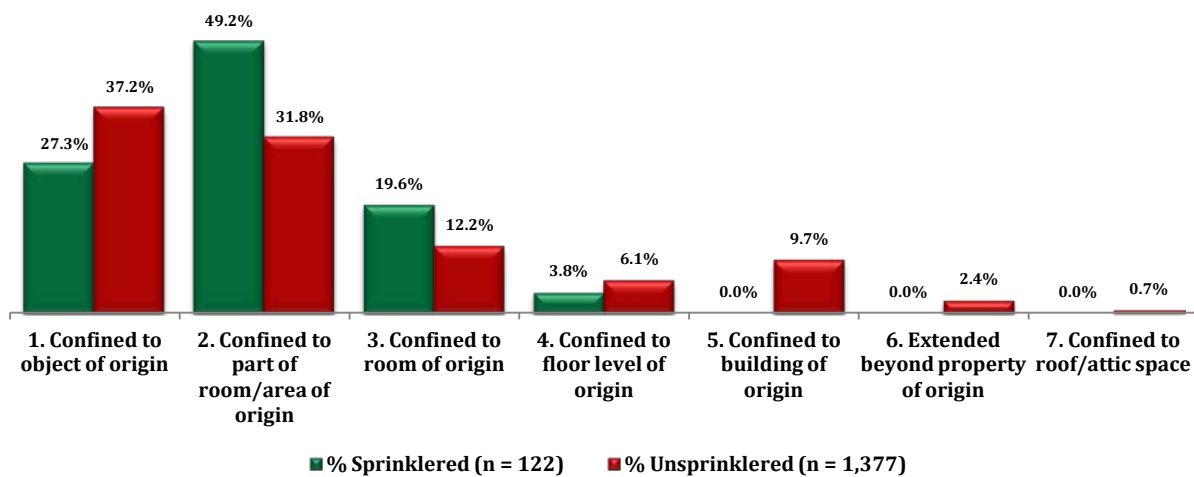
Spread of Fires by Sprinkler Protection Status

The extent to which the 21.6% of fires that occurred in sprinklered buildings and were controlled by the sprinkler protection systems extended from the object of origin relative to the spread of the fires in the unsprinklered buildings is presented in Figure 2. Overall, when the sprinkler systems were present and responsible for controlling the fire, the fires never extended beyond the floor of origin and only very rarely (3.8%) were not contained to the room of origin. In comparison, 18.8% of the fires (n = 259) in unsprinklered buildings extended beyond the room of origin, and 12.7% extended beyond the floor of origin.

⁵ Z-tests revealed non-significant differences in these proportions for all broad categories, with the exception of 'Burned-out' ($Z = -1.74$), where the sprinklered buildings were significantly more likely to have burned out, and the role of the Fire Department in unsprinklered buildings ($Z = 9.20$).

⁶ The frequency of multiple hose line utilization was significantly higher for unsprinklered buildings, $Z = 8.40$, $p < .001$.

FIGURE 2: PERCENTAGE (AND CUMULATIVE PERCENTAGE) OF EXTENT OF FIRE SPREAD BY SPRINKLER PROTECTION STATUS



Of the remaining 443 fires in sprinklered buildings extinguished by means other than the sprinkler system, 3.5% of the fires (n = 20) were recorded as having extended beyond the floor of origin. Of these, 16 were coded as having been confined to the building of origin, and 4 were coded as having extended beyond the property of origin. More specifically, five of these incidents, all coded as having been confined to the building of origin, were fires that had been responded to by the Surrey Fire Service.⁷ Of note:

- Three of the records reflected a common incident that involved three apartments in a single building. The area of origin in this case was a kitchen stove top, and the sprinkler head in this unit deployed and extinguished the fire. The reason the fire extended was because the kitchen fume hood vented into an unsprinklered attic space that also had no fire stops, causing the fire to extend to the adjoining suite. The third suite was located underneath the room of origin and suffered water damage only as a consequence of water from the sprinkler head deployed in the floor above.
- One of the records involved a fire that originated in a barbecue that was located on an unsprinklered exterior balcony. The fire spread into the suite, whereby the sprinkler system did activate, resulting in a large amount of water damage.
- One of the records involved a smouldering mattress fire that caused extensive smoke damage, but never produced enough heat to cause the sprinkler system to activate. The damage was the result of smoke.

It was not possible to undertake equivalent additional analysis for the remaining 15 fire incidents. However, from an examination of the information included in the post-fire incident data, it does not appear that these fires represented a failure of a functioning sprinkler system to contain the spread of a structure fire. Some summary findings from these fire reports are:

- Three people were injured (two of which occurred in a single fire incident) and there were no fatalities.
- The area of origin was listed as either “Outside area – open area”, “Outside area – court, patio, terrace”, “Structural area – exterior balcony”, or “Structural area – exterior wall” in nine of the 15 fires.
- The total dollar loss incurred was equal to or less than \$15,000 in seven of the cases, and was \$0 in four of the cases.

⁷ These were incidents #192261, #194855, #200286, #200287, and #200288.

Injury and Death by Sprinkler Protection Status

Given the relative reductions in average dollar damage and reduced spread of fire in sprinkler protected buildings, it is important to consider how these safety systems influence injury and death in the event of fire. As discussed previously, while fires in sprinklered buildings accounted for 29.1% of the total fires, they only resulted in 3.4% of the deaths and 14.3% of the injuries in this data set. It is unsurprising, therefore, that the rate of injuries per 1,000 fires was higher in unsprinklered buildings (127.1 injuries per 1,000 fires) compared to sprinklered buildings (44.2 injuries per 1,000 fires). In effect, the odds of being injured in a fire increased by 2.9 without sprinkler protection.⁸ Furthermore, fires in unsprinklered buildings were also significantly more likely to result in a fatality (21.1 deaths per 1,000 fires) compared to sprinklered protected buildings (1.8 deaths per 1,000 fires), meaning that the odds of dying in a fire increased by a factor of 11.9 if the building was unsprinklered (significant difference in rate ratios, $Z = 2.43$, $p < .01$).⁹

TABLE 3: NUMBER OF FIRES, INJURIES, AND DEATH BY FIRE DEPARTMENT TYPE AND SPRINKLER PROTECTION STATUS

Fire Department Type	Sprinkler Protection Status	# Fires	% Fires	Injury	Death
Career fire department only	Sprinklered	355	18.3%	18	1
	Unsprinklered	663	34.1%	90	13
	<i>Sub-total</i>	<i>1,018</i>	<i>52.4%</i>	<i>108</i>	<i>14</i>
Composite - career and volunteer/paid-on-call fire department	Sprinklered	206	10.6%	7	0
	Unsprinklered	656	33.8%	80	8
	<i>Sub-total</i>	<i>862</i>	<i>44.4%</i>	<i>87</i>	<i>8</i>
Volunteer/paid-on-call fire department only	Sprinklered	3	0.2%	0	0
	Unsprinklered	55	2.8%	5	8
	<i>Sub-total</i>	<i>58</i>	<i>3.0%</i>	<i>5</i>	<i>8</i>
Fire service - unclassified	Sprinklered	1	0.1%	0	0
	Unsprinklered	1	0.1%	0	0
	<i>Sub-total</i>	<i>2</i>	<i>0.1%</i>	<i>0</i>	<i>0</i>
No fire service	Sprinklered	0	0.0%	0	0
	Unsprinklered	2	0.1%	0	0
	<i>Sub-total</i>	<i>2</i>	<i>0.1%</i>	<i>0</i>	<i>0</i>
Total		1,942	100.0%	200	30

⁸ Comparison of rate ratios indicated this difference is significant, $Z = 4.93$, $p < .01$

⁹ It is unclear from the information available about the fire incident that incurred a death in a sprinklered building 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 part area of 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, as this is currently how the incident was recorded in the database.

Fire Department Type and Sprinkler Protection Status

Given the potential variations in Fire Department resources as a function of being in a rural area and remoteness, it is important to examine whether there were any indications that the overall findings for improved fire control and life safety are observed for sprinkler protected buildings across all areas in British Columbia. Using Fire Department type as a proxy indicator for being in a rural area, the relative numbers of fires responded to by Fire Department type as a function of sprinkler status of the buildings along with the deaths and injuries that resulted from these fires was analysed (see Table 3).

Consistent with the finding discussed earlier that 99.0% of the fires occurred in municipal areas of the province, 96.8% of the fires were responded to by career or composite departments (see Table 3). Interestingly, for those Fire Department types that responded to 58 or more fires, the relative proportion of fires in sprinkler protected building was 34.9% for career departments, 23.9% for composite departments, and only 5.2% for volunteer/paid-on-call departments. Despite the reduced frequency of sprinkler protection in the more remote areas, examination of the extent of fire spread for fires responded to by volunteer/paid-on-call departments was consistent with the overall pattern already discussed. As demonstrated in Table 4, the three fires that occurred in sprinklered buildings within this volunteer/paid-on-call sample were all confined to the room of origin. In contrast, the remaining 55 fires spread beyond the room of origin 27.3% of the time, and beyond the floor of origin 23.6% of the time. Furthermore, the one fire in a building with sprinkler protection that was responded to by the unclassified fire service was also contained to the room of origin. Overall, therefore, regardless of the rurality of the building, sprinkler systems were equally effective at containing the spread of fire.

TABLE 4: NUMBER OF FIRES CONTROLLED BY VOLUNTEER/PAID-ON-CALL FIRE DEPARTMENTS BY EXTENT OF FIRE SPREAD AND SPRINKLER PROTECTION STATUS

Extent of Fire	Sprinklered		Unsprinklered	
	# Fires	% Fires	# Fires	% Fires
1. Confined to object of origin	2	66.7%	16	29.1%
2. Confined to part of room/area of origin	0	0.0%	17	30.9%
3. Confined to room of origin	1	33.3%	7	12.7%
4. Confined to floor level of origin	0	0.0%	2	3.6%
5. Confined to building of origin	0	0.0%	9	16.4%
6. Extended beyond property of origin	0	0.0%	4	7.3%
Total	3	100.0%	55	100.0%

Summary and Conclusions

In summary, the findings of this analysis revealed that:

- The areas of origin for the fires in sprinklered and unsprinklered buildings were highly comparable, most frequently originating from kitchen/cooking areas.
- The sprinkler protection systems in sprinklered buildings extinguished 21.6% of the fire cases analysed, and required involvement of the Fire Department significantly less frequently and to a lesser extent than in unsprinklered buildings.
- When sprinkler systems were responsible for controlling the fire, these fires never extended beyond the floor of origin, and were contained to the room of origin 96.2% of the time.

- Death and injury were significantly less frequent in sprinklered buildings.
- There was no indication of a rural/urban distinction in the performance of sprinkler systems, as fires in sprinklered buildings responded to by volunteer/paid-on-call and unclassified fire services were contained to the room of origin 100% of the time.

Overall, fires in sprinklered buildings were less likely to result in extensive resourcing consumption from Fire Departments, resulted in less damage (average cost, and spread of fire), and were less likely to result in injury and death. Furthermore, the few cases of fires in sprinklered buildings in areas not protected by career or composite Fire Departments indicated that sprinklers remained equally effective, regardless of Fire Department type and the rurality of the buildings. These results are significant when placed in the context of the amendments made to the BC Building Code (BCBC).

Provisions were made to the BCBC enacted by Ministerial Order in January 2009, and came into effect in April 2009 (Office of Housing and Construction Standards). Essentially, these provisions allowed for mid-rise wood-frame residential buildings of up to 6 stories in height. The amendments to the BCBC involved alterations to *Related Undertakings* involving sprinklering (to be NFPA 13 compliant), energy efficiency, occupancy, local government, and education/training. In addition, there were a range of specific new code provisions concerned with building height, combustibility of cladding, earthquake load and effects, configuration of timber shear wall systems, fire doors in public corridors, and issues focused on shrinkage of wood in structural designs.

Based on the findings of this research, given that all of the buildings constructed under the amended legislation will have sprinkler protection to ensure compliance with NFPA 13, which is a higher NFPA standard than previously required, as well as being constructed with a range of other in-built fire-protection systems, it seems reasonable to assume that these new structures should pose a reduced risk relative to the sample analysed within this research note. Furthermore, to alleviate alternative concerns about the potential inability of some smaller rural/remote communities to meet the same standards/frequency of fire safety inspections as the larger, career-based departments in the metropolitan area, research undertaken by McCormick (2009; 2011) suggested that there was no relationship between the frequency of building inspection and fire spread, injury, and death. These findings were based on an examination of the significance of the timing of fire safety inspections for incidents of fire and injury/death that occurred at 265 inspectable residential properties between 1998 and 2003. McCormick (2009; 2011) categorized these fire incidents occurring in properties that had been inspected less than or equal to one year prior to the fire (n = 212 incidents) and properties for which the most recent inspection was more than 1 year before the fire incident (n = 53 incidents). McCormick's analysis returned non-significant results in all of these cases suggesting that there was no significant overall relationship between the frequencies of the fires within each of these categories as a function of the time since last inspection.

The additional insight that these findings provide into how well the system functioned in the event of fire incidents indicate that there should be continued movement towards a "systems approach" to managing risk in these settings, with an emphasis on re-evaluating the risk posed by existing wood-frame constructions that do not have sprinkler protection and addressing problems with the system comprised of fire suppression, fire, buildings codes, and enforcement, and public education/human factors (Manitou Incorporated, 2008).

References

- Surrey Fire Service, *Surrey Fire Service Construction Fire Safety Plan Bulletin*, 2011, Surrey Fire Service: Surrey. p. 8.
- Office of Housing and Constuction Standards. *Mid-rise wood frame | Building Provisions*. [cited 2011 3 November]; Available from: http://www.housing.gov.bc.ca/building/wood_frame/6storey_form.htm.
- A.V. McCormick, *Residential Fires in Surrey, B.C.: 1988-2007*, 2009, University of the Fraser Valley: Abbotsford. p. 72.
- A.V. McCormick, *Residential Inspections and Fire Outcomes*, 2011, University of the Fraser Valley: Abbotsford. p. 5.
- Manitou Incorporated, *Surrey Fire Service High-Rise Fire Service Study, City of Surrey, British Columbia*, 2008. p. 47.

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