

Structure Fires in British Columbia:

Exploring Variations in Outcomes as a Function of Building Height
and Life Safety Systems



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Executive Summary

- This report examines 31,582 structure fires that occurred in British Columbia (BC) over a thirteen year period, exploring variations in outcomes as a function of building height and life safety systems.
- Data was initially examined to determine the relationship between fire frequency and building height. This analysis demonstrated that at the building level, the annual rate of fires per building seems much higher for taller buildings (relative to buildings at 4 storeys or below). However, estimations about the number of residential units within these taller buildings indicate that the frequency of fire service response per unit is much similar to lower structures. The message from this is that the relative risk presented by taller buildings needs to be considered with height and residential units as parameters, rather than equating risk to frequency of calls to a single street address.
- With respect to life safety systems across the structure fires in this sample:
 - (a) Buildings with present, functioning smoke alarms and complete sprinkler protection resulted in relatively low rates of fire casualties, required less fire department intervention to control fires, and were largely contained to the room of origin. This remained true across all building heights examined.
 - (b) Conversely, fires that occurred in the absence of smoke alarms and sprinkler protection resulted in high rates of fire-related death, frequently required fire department intervention to control fires, and were much more likely to extend beyond the room of origin. This remained true across all building heights examined.
- As fires originated higher in buildings, the extent of fire spread and the demand on fire departments to control fires decreased whilst the presence of fire safety systems increased. There was also no indication that the fire-related casualties increase with building height.
- A survey of fire departments asking about the fire service policy/practice about response to fires (with respect to first-in attack forces) revealed no clear differences in attack forces that were related to building safety systems (with respect to sprinkler protection) and little variation relating to building height.
- Moving forward, the authors would encourage the fire service to continue to work to ensure as complete coverage of fire life safety systems (alarms and/or sprinkler systems) as possible, and to continue to utilise the available information about historical fire outcomes to shape their policy and practice with respect to emergency response.

The Purpose of this Research

This report examines structure fires in British Columbia (BC) that occurred over a thirteen year period to explore variations in outcomes as a function of building height and life safety systems. The study outlines the data definitions that were used to identify the relevant subset of fires that occurred in the province during this time period. This subset is then analysed to consider:

- The frequency of fires as function of building height;
- The level of fire origin within buildings and the significance of this factor on fire outcomes;
- The relationship between fire life safety systems and fire outcomes within buildings grouped by height; and
- Variations in fire service responses to structure fires as a function of height and life safety system presence.

The main results are discussed with particular relevance to the importance of continuing to ensure all structures in BC have working life safety systems in place.

Data Sets

The first data included in this analysis was provided by the British Columbia Office of the Fire Commissioner (BCOFC) and represents all fire incidents reported in BC between January 2006 and August 2018. ($n = 91,153$ fire incidents). The relevant subset of this data ($n = 31,582$ fires, 35%) was identified according to the following inclusion/exclusion criteria:

- Incident type: retained only structure fires;
- Building height: excluded 'not applicable' and 'cannot be determined' cases;
- Level of fire origin: excluded fires coded as having originated in "crawl space, under structure", "roof level (including concealed roof space, attic)", "exposure fire", and "cannot be determined".

A special data request was also made from BC Assessment (BCA) to find out about the frequency of buildings as a function of height across the province. BCA made a range of data available for this research. Having reviewed the figures and compared with internal Surrey data, the researchers made the decision to use 'verified' BCA data, representing data maintained and reviewed by BCA as part of an annual assessment cycle. To account for growth in building numbers over time and to best-align with the fire data available for analysis, the average number of properties was calculated for 2013 to 2019.

Fire Frequency and Outcome as a Function of Building Height

This section examines the relationship between building height and the frequency and outcome of structure fires. Table 1 shows the frequency of fires by grouped building height, including the relative frequency of fire-related casualties. This table demonstrates that the majority of fires (92.5%) occur in buildings between 1 and 4 storeys in height. These fires also result in 94% of injuries and 97% of deaths. The confidence intervals for the injury and death rates provide a range within which the true rate is expected to fall. This shows that taller buildings are no more likely to result in deaths from fire than 1 to 4 storey buildings are.

TABLE 1. FIRE FREQUENCY AND FIRE RELATED CASUALTY (95% CONFIDENCE INTERVALS) BY GROUPED BUILDING HEIGHT

Building Height	# Fires	# Injuries	Injury Rate per 1,000 Fires (95% CI low-high)	# Deaths	Death Rate per 1,000 Fires (95% CI low-high)
01 to 04 storeys	29,221	2,051	70.2 (67.2, 73.2)	263	9.0 (7.9, 10.1)
05 to 06 storeys	636	22	34.6 (20.1, 49.0)	1	1.6 (-1.5, 4.7)
07 to 12 storeys	852	41	48.1 (33.4, 62.9)	2	2.3 (-0.9, 5.6)
13 storeys and over	873	66	75.6 (57.4, 93.8)	6	6.9 (1.4, 12.4)
Total	31,582	2,180	69.0 (66.1, 71.9)	272	8.6 (7.6, 9.6)

To control for the varying number of residential units within buildings of different heights, Table 2 attempts to estimate the frequency of fires per building by height. This analysis incorporates the BCA data to produce annual frequency at which fires occurred within the total building stock at each height grouping. As a proxy, it was assumed that 1 and 2 storey buildings contained a single residential unit. For taller buildings it was assumed that each residential floor contains 8 units. Based on the average number of buildings at each floor height (BCA data), Table 2 shows the estimated number of residential units within buildings from a range of different heights. The BCA data shows that this group of buildings between 1 and 4 storeys in height account for almost the entire building stock in BC (99.8%). As a percentage of fires per building stock height (per year), looking at the number of units per building, it is clear that the greatest frequency of fire occurs for units in 2 storey buildings (0.33% of all units in 2 storey buildings experiencing a fire, per year), followed by units in 3 storey (0.16%) and 4 storey (0.16%) buildings. In comparison, according to the parameter estimates being used here, only 0.04% of units in 13 storey and higher buildings experience a fire, per year. In contrast, you can see there is a much higher frequency of fires as a percentage of building stock for the taller buildings: 4.82% of 5-6 storey properties, per year, 7.96% of 7-12 storey properties, and 7.49% of 13 storey and over properties.

Whilst these figures are estimates, the point is to demonstrate that the relative risk presented by these buildings needs to be considered with the height and residential units as parameters (as opposed to simply equating risk to frequency of repeat calls to single street addresses). Using the building as the denominator for service demand masks the influence of the number of residential units on each floor. Based on what is known about the non-random nature of emergency first responder problems [1,2] it would be worth exploring the extent to which the fires in all buildings

represent chronic repeat locations, as it may be possible to make some targeted situational alterations to reduce the likelihood of future fire events.

TABLE 2: ESTIMATED FIRE FREQUENCY PER UNIT AND BUILDING, BY BUILDING HEIGHT

Building Height	Number of Fires	Number of Buildings	Estimated Number of Units (@ 8 per floor)	% of Fires per Unit per Year	% of Buildings with a Fire per Year
1 storey	10,387	845,355	845,355	0.09%	0.09%
2 storey	12,857	295,972	295,972	0.33%	0.33%
3 storey	4,061	8,025	192,600	0.16%	3.89%
4 storey	1,916	2,829	90,528	0.16%	5.21%
5 to 6 storeys	636	1,016	43,720	0.11%	4.82%
7 to 12 storeys	852	823	58,376	0.11%	7.96%
13 storeys and over	873	896	150,736	0.04%	7.49%

Fire by Building Height and Level of Fire Origin

Table 3 provides another lens for understanding fires at buildings of different heights. This table shows the relationship between grouped building height and where the fire commenced within the building (level of fire origin, grouped). The percentage values under each fire count represent the percentage of all fires each cell contributes (e.g., $n = 2,740$ fires commenced in the basement of 1-4 storey buildings, which represents 9% of the total 31,582 fires being analysed here). Some highlights from the top half of Table 3 include:

- Influenced by the heights of the majority of homes, 94% of fires in 1-4 storey buildings originated on the second storey or below;
- 53% of fires in 5-6 storey buildings commenced on the third storey or higher;
- 53% of fires in 7-12 storey buildings commenced on the fourth storey or higher;
- For the tallest buildings, 35% of fires commenced at 4-12 storeys, and 30% commenced at 13 or more storeys.

The lower half of Table 3 provides additional context about the relative rates of fire protection, extent of fire spread, fire department involvement in controlling fires, and fire-related casualties as a function of building height and level of fire origin. Some highlights from the bottom half of Table 3 include:

- The level of fire origin increases, the percentage of fires that occurred in the presence of working smoke alarms and complete sprinkler protection also increases. Fires that occurred on the ground floor had working smoke alarms 27% of the time and complete sprinkler protection 11% of the time. In comparison, fires that commenced on the thirteenth floor or higher had working smoke alarms 71% of the time and complete sprinkler protection 67% of the time.
- In accordance with this increase in fire safety system presence, as fires originate higher in buildings, the extent of fire spread also reduces. Two-thirds of fires commencing on the first

floor are contained to the room of origin, compared to 96% of fires that commence on the thirteenth floor or higher.

- By extension, the likelihood of the fire department being required to control the fire declined with building height. For fires that commence on the first floor, 48% required fire department intervention to control, compared to 16% of fires that commenced on the thirteenth floor or higher.
- Finally, there is no indication that the fire-related casualties increase with building height. The 95% confidence intervals are included here to account for the variation in number of fires and casualties at each grouped building height. Despite the wider confidence intervals around the casualties from fires that originate higher in buildings, for the most part injuries and deaths are less frequent from fires that commence on the third storey and higher.

TABLE 3: FIRES BY BUILDING HEIGHT AND LEVEL OF FIRE ORIGIN: INCLUDING FIRE PROTECTION, EXTENT OF FIRE SPREAD, FIRE CONTROL, AND RATE OF FIRE RELATED CASUALTY

Building Height	Level of Fire Origin						Total
	Basement	Ground Floor	2nd Storey	3rd Storey	4th to 12th Storeys	13 and over Storeys	
01 to 04 storeys (n)	2,740	19,186	5,622	1,318	351	4	29,221
(% row)	9%	66%	19%	5%	1%	0%	100%
05 to 06 storeys (n)	37	134	126	122	216	1	636
(% row)	6%	21%	20%	19%	34%	0%	100%
07 to 12 storeys (n)	52	146	116	89	441	8	852
(% row)	6%	17%	14%	10%	52%	1%	100%
13 storeys and over (n)	56	123	66	57	309	262	873
(% row)	6%	14%	8%	7%	35%	30%	100%
Total (n fires)	2,885	19,589	5,930	1,586	1,317	275	31,582
(Row %)	9%	62%	19%	5%	4%	1%	100%
% Working smoke alarms	34%	27%	42%	56%	67%	71%	34%
% Complete sprinkler protection	10%	11%	16%	35%	52%	67%	15%
% Contained within the room of origin	71%	66%	79%	88%	93%	96%	71%
% Controlled by the fire department	46%	48%	37%	25%	18%	16%	43%
Injury rate per 1,000 fires (95% CI - low, high)	77.3 (67.2, 87.4)	61.6 (58.1, 65.0)	83.5 (76.1, 90.8)	91.4 (76.5, 106.3)	75.2 (60.4, 90.0)	43.6 (18.9, 68.3)	69.0 (66.1, 71.9)
Injury totals	223	1,206	495	145	99	12	2,180
Death rate per 1,000 fires (95% CI - low, high)	6.6 (3.6, 9.5)	9.6 (8.3, 11.0)	8.4 (6.1, 10.8)	4.4 (1.1, 7.7)	4.6 (0.9, 8.2)	3.6 (-3.5, 10.8)	8.6 (7.6, 9.6)
Deaths totals	19	189	50	7	6	1	272

Fire Outcomes by Building Height and Combinations of Fire Protection

This section examines the relative frequency of fire protection within each group of building heights. First, Table 4 looks at the fire outcomes for fires that occurred in 1-4 storey buildings. Throughout this section, smoke alarm status in this table represented those fires that had an alarm activated ('yes') or no smoke alarm installed ('no'). Similarly, throughout this section, sprinkler status represented those fires that had complete sprinkler protection ('yes') or no sprinkler protection ('no'). According to this classification process, the 'other' category fires shown in these tables were neither 'yes' or 'no' for smoke alarm nor for sprinkler protection. Where appropriate, 95% confidence intervals are included to show the estimated range around each rate and percentage. With a focus on the presence/absence of fire safety systems, relative to the base case (no smoke alarm and no sprinkler protection), the following trends can be seen:

- Injury rates are significantly higher in the presence of a working smoke alarm and no sprinkler protection – likely because residents attempted to control the fires themselves when the alarms activated;
- Death rates are significantly lower whenever the fires occurred in the presence of sprinkler protection;
- The presence of smoke alarms and/or sprinkler protection significantly reduced the dependence on the fire department to control the fires; and
- The presence of smoke alarms and/or sprinkler protection significantly reduced the extent to which fires spread beyond the room of origin.

TABLE 4: 1 TO 4 STOREY BUILDING FIRE OUTCOMES AS A FUNCTION OF FIRE PROTECTION SYSTEMS

Smoke Alarm	Sprinkler	Fires (% total)	Injuries (% total)	Injury Rate (95% CI)	Deaths (% total)	Death Rate (95% CI)	% Fire department Extinguish (95% CI)	% Beyond Room of Origin (95% CI)
Yes	Yes	1,711 (6%)	102 (5%)	59.6 (49.6, 73.1)	2 (1%)	1.2 (-0.5, 2.8)	21.2% (20.2%, 22.1%)	7.9% (7.2%, 8.5%)
No	Yes	577 (2%)	12 (1%)	20.8 (9.0, 32.6)	1 (< 1%)	1.7 (-1.7, 5.1)	30.0% (28.1%, 31.9%)	15.9% (14.4%, 17.5%)
Yes	No	6,223 (21%)	654 (32%)	105.1 (97.0, 113.1)	45 (17%)	7.2 (5.1, 9.3)	46.1% (45.5%, 46.8%)	24.2% (23.7%, 24.7%)
No	No	5,690 (19%)	323 (16%)	56.8 (50.6, 63.0)	55 (21%)	9.7 (7.1, 12.2)	69.0% (68.3%, 69.6%)	51.9% (51.3%, 52.6%)
Other	Other	15,020 (51%)	960 (47%)	63.9 (59.9, 68.0)	160 (61%)	10.7 (9.0, 12.3)	38.1% (37.7%, 38.5%)	27.9% (27.6%, 28.3%)
All 1 to 4 storey fires		29,221 (100%)	2,051 (100%)	70.2 (67.2, 73.2)	263 (100%)	9.0 (7.9, 10.1)	44.7% (44.4%, 45.0%)	30.4% (30.1%, 30.7%)

NB: 'Other' status here indicates fires for which the smoke alarm status with neither activated/not present and the sprinkler system was neither complete/none.

Table 5 looks at the fire outcomes for fires that occurred in 5-6 storey buildings, using the same definitions for smoke alarm presence and sprinkler protection as outlined, above. With a focus on

the presence/absence of fire safety systems, relative to the base case (no smoke alarm and no sprinkler protection), the following trends can be seen:

- Injury rates are higher in the presence of a working smoke alarm – likely because residents attempted to control the fires themselves when the alarms activated;
- The death that occurred in a 5-6 storey building was not included in this subset;
- The presence of smoke alarms and/or sprinkler protection significantly reduced the dependence on the fire department to control the fires; and,
- The presence of smoke alarms significantly reduced the extent to which fires spread beyond the room of origin.

TABLE 5: 5 TO 6 STOREY BUILDING FIRE OUTCOMES AS A FUNCTION OF FIRE PROTECTION SYSTEMS

Smoke Alarm	Sprinkler	Fires (% total)	Injuries (% total)	Injury Rate (95% CI)	Deaths (% total)	Death Rate (95% CI)	% Fire Department Extinguish (95% CI)	% Beyond Room of Origin (95% CI)
Yes	Yes	206 (32%)	12 (55%)	58.3 (25.3, 91.2)	0 (0%)	0.0 (0.0, 0.0)	13.6% (11.2%, 16.0%)	4.4% (2.9%, 5.8%)
No	Yes	19 (3%)	0 (0%)	0 (0.0, 0.0)	0 (0%)	0.0 (0.0, 0.0)	42.1% (30.8%, 53.4%)	21.1% (11.7%, 30.4%)
Yes	No	36 (6%)	3 (14%)	83.3 (-11.0, 177.6)	0 (0%)	0.0 (0.0, 0.0)	19.4% (12.8%, 26.0%)	8.3% (3.7%, 12.9%)
No	No	20 (3%)	0 (0%)	0.0 (0.0, 0.0)	0 (0%)	0.0 (0.0, 0.0)	70.0% (59.8%, 80.2%)	35.0% (24.3%, 45.7%)
Other	Other	355 (56%)	7 (32%)	19.7 (5.1, 34.3)	1 (100%)	2.8 (-2.7, 8.3)	32.7% (30.2%, 35.2%)	11.8% (10.1%, 13.5%)
All 5 to 6 storey fires		636 (100%)	22 (100%)	34.6 (20.1, 49.0)	1 (100%)	1.6 (-1.5, 4.7)	18.2% (16.7%, 19.8%)	6.6% (5.6%, 7.6%)

NB: 'Other' status here indicates fires for which the smoke alarm status with neither activated/not present and the sprinkler system was neither complete/none.

Table 6 looks at the fire outcomes for fires that occurred in 7-12 storey buildings, using the same definitions for smoke alarm presence and sprinkler protection as outlined, above. With a focus on the presence/absence of fire safety systems, relative to the base case (no smoke alarm and no sprinkler protection), the following trends can be seen:

- Injury rates are higher in the presence of a working smoke alarm – likely because residents attempted to control the fires themselves when the alarms activated;
- The presence of smoke alarms and sprinkler protection significantly reduced the dependence on the fire department to control the fires; and
- The presence of smoke alarms and/or sprinkler protection significantly reduced the extent to which fires spread beyond the room of origin.

TABLE 6: 7 TO 12 STOREY BUILDING FIRE OUTCOMES AS A FUNCTION OF FIRE PROTECTION SYSTEMS

Smoke Alarm	Sprinkler	Fires (% total)	Injuries (% total)	Injury Rate (95% CI)	Deaths (% total)	Death Rate (95% CI)	% Fire Department Extinguish (95% CI)	% Beyond Room of Origin (95% CI)
Yes	Yes	309 (36%)	10 (24%)	32.4 (12.3, 52.4)	0 (0%)	0.0 (0.0, 0.0)	14.9% (12.9%, 16.2%)	3.9% (2.8%, 5.0%)
No	Yes	42 (5%)	0 (0%)	0.0 (0.0, 0.0)	0 (0%)	0.0 (0.0, 0.0)	61.9% (54.4%, 69.4%)	35.7% (28.3%, 43.1%)
Yes	No	57 (7%)	10 (24%)	175.4 (66.7, 284.2)	0 (0%)	0.0 (0.0, 0.0)	28.1% (22.1%, 34.0%)	8.8% (5.0%, 12.5%)
No	No	12 (1%)	1 (2%)	83.3 (-80.0, 246.7)	0 (0%)	0.0 (0.0, 0.0)	58.3% (44.1%, 72.6%)	66.7% (53.1%, 80.3%)
Other	Other	432 (51%)	20 (49%)	46.3 (26.0, 66.6)	2 (100%)	4.6 (-1.8, 11.0)	39.4% (37.0%, 41.7%)	16.0% (14.2%, 17.7%)
All 7 to 12 storey fires		852 (100%)	41 (100%)	48.1 (33.4, 62.9)	2 (100%)	2.3 (-0.9, 5.6)	20.0% (18.6%, 21.3%)	8.1% (7.2%, 9.0%)

NB: 'Other' status here indicates fires for which the smoke alarm status with neither activated/not present and the sprinkler system was neither complete/none.

Table 7 looks at the fire outcomes for fires that occurred in 13 storey and over buildings, using the same definitions for smoke alarm presence and sprinkler protection as outlined, above. With a focus on the presence/absence of fire safety systems, relative to the base case (no smoke alarm and no sprinkler protection), the following trends can be seen:

- Injury rates are higher in the presence of a working smoke alarm – likely because residents attempted to control the fires themselves when the alarms activated;
- The presence of smoke alarms and sprinkler protection significantly reduced the dependence on the fire department to control the fires; and
- The presence of smoke alarms significantly reduced the extent to which fires spread beyond the room of origin.

TABLE 7: 13 STOREYS AND OVER BUILDING FIRE OUTCOMES AS A FUNCTION OF FIRE PROTECTION SYSTEMS

Smoke Alarm	Sprinkler	Fires (% total)	Injuries (% Total)	Injury Rate (95% CI)	Deaths (% total)	Death Rate (95% CI)	% Fire Department Extinguish (95% CI)	% Beyond Room of Origin (95% CI)
Yes	Yes	340 (39%)	23 (35%)	67.6 (40.0, 95.3)	1 (17%)	2.9 (-2.8, 8.7)	12.4% (10.6%, 14.1%)	2.9% (2.0%, 3.9%)
No	Yes	24 (3%)	0 (0%)	0.0 (0.0, 0.0)	0 (0%)	0.0 (0.0, 0.0)	66.7% (57.0%, 76.3%)	37.5% (27.6%, 47.4%)
Yes	No	64 (7%)	14 (21%)	218.8 (104.2, 333.3)	2 (33%)	31.3 (-12.1, 74.6)	39.1% (33.0%, 45.2%)	10.9% (7.0%, 14.8%)
No	No	15 (2%)	0 (0%)	0.0 (0.0, 0.0)	0 (0%)	0.0 (0.0, 0.0)	60.0% (47.4%, 72.6%)	40.0% (27.4%, 52.6%)
Other	Other	430 (49%)	29 (44%)	67.4 (42.9, 92.0)	3 (50%)	7.0 (-0.9, 14.9)	38.4% (36.0%, 40.7%)	10.2% (8.8%, 11.7%)
All 13 storey and over fires		873 (100%)	66 (100%)	75.6 (57.4, 93.8)	6 (100%)	6.9 (1.4, 12.4)	18.9% (17.6%, 20.2%)	5.0% (4.3%, 5.8%)

NB: 'Other' status here indicates fires for which the smoke alarm status with neither activated/not present and the sprinkler system was neither complete/none.

Fire Service Response as a Function of Building Height and Sprinkler Protection

Surrey Fire Service initiated a self-report survey of fire departments in BC to ask about their typical response to fires as a function of building height and sprinkler status. Twenty-five fire departments responded. These responses were analysed to look for variations in first-in attack force response as a function of building height and sprinkler presence. The main findings of this survey are:

- For the larger departments, the first-in response included an average:
 - 15 fire fighters (min = 9 fire fighters, max = 27 fire fighters);
 - 3 engines (min = 2, max = 4);
 - 1 ladder (min = 0, max = 2); and
 - 1 rescue (min = 0, max = 1).
- Across all departments that provided this information there was no policy difference relating to the size or compilation of first-in attack force response to first alarms as a function of sprinkler protection; and
- There was almost no variation in policy relating to the size or compilation of first-in attack force response as a function of building height, with the exception that some departments do send larger first-in teams for very tall buildings (with the same larger team sent regardless of building sprinkler protection).

Summary and Discussion of Main Findings

This retrospective analysis of fires reported to the BCOFC demonstrates patterns that are largely consistent with previous research done by the authors, including:

- Buildings with present, functioning smoke alarms and complete sprinkler protection result in relatively low rates of fire casualties, require less fire department intervention to control fires, and are largely contained to the room of origin. This remains true across all building heights considered here.
- Conversely, fires that occur in the absence of smoke alarms and sprinkler protection result in high rates of fire-related death, frequently require fire department intervention to control fires, and are much more likely to extend beyond the room of origin. This also remains true across all building heights considered here.

In addition to this, the results presented here provide additional context about the patterns of fire safety system protection and fire outcome as a function of where fires occurred within buildings of varying heights. This demonstrated that, as fires originated higher in buildings, the extent of fire spread and the demand on fire departments to control fires decreased whilst the presence of fire safety systems increased. There was also no indication that the fire-related casualties increase with building height.

Finally, it does not seem that the fire service policy/practice about response to fires (with respect to first-in attack forces) are influenced by these findings. The industry survey did not reveal any clear differences in attack forces that were related to building safety systems (with respect to sprinkler protection) and little variation relating to building height.

Moving forward, the authors would encourage the fire service to continue to work to ensure as complete coverage of fire life safety systems (alarms and/or sprinkler systems) as possible, and to continue to utilise the available information about historical fire outcomes to shape their policy and practice with respect to emergency response.

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