Life Safety Systems, Fire Department Intervention, and Residential Fire Outcomes

Analysis of 28 Years of BC Fire Incident Reports: 1988-2015

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The Purpose of this Research

This report examines 42,701 residential[1] fire incidents reported to the British Columbia (BC) Office of the Fire Commissioner (OFC) between 1988 and 2015, inclusive (22.4% of the 190,564 fire incidents reported over this time). The high-level purpose of this analysis was to examine the significance of the method of fire control and fire safety systems on the fire outcomes (with respect to damage to properties and fire-related casualties). Building on these patterns, this analysis explores the fire outcomes for the specific subsection of areas within residential properties that experienced a disproportionate number fires and fatalities: the living room, the kitchen, and the bedroom. These room-specific findings are discussed with respect to the potential to enhance residential building fire safety in a targeted manner intended to both increase protection for residents and keep the costs of fire protection relatively low.

Methodology

Accounting for the fact that two versions of the fire reporting manual were used over this time period, all of the available data from the BC OFC was sorted to identify residential structure fires that met the following criteria:

- Retain records with Property Complex (PC) codes relating to "Residential – row, garden, town housing, condominium", "Residential – single detached", or "Residential – duplex, 3-plex, 4-plex";
- Exclude records where the Fire Origin Area (OA codes) could not be determined or where multiple areas of origin were noted; and
- Remove fires that were considered to have occurred in vehicles or outside areas (according to the Sprinkler Protection (SP) field).

The Fire Origin Area was then coded into twenty-four categories. To ensure replicability of this approach, this classification process is outlined in Table 1, below. After sorting in this manner, a total of 42,701 residential structure fires were retained for analysis. These spanned from 1988 to 2015 and resulted in 4,068 fire-related injuries and 512 fire-related deaths. This data forms the basis for the remainder of the analysis discussed in this report.

[1] Defined here as buildings classified as "Residential - row, garden, town housing, condominium", "Residential - single detached", or "Residential - duplex, 3-plex, 4-plex" in the two versions of the fire reporting manual used over this time period.

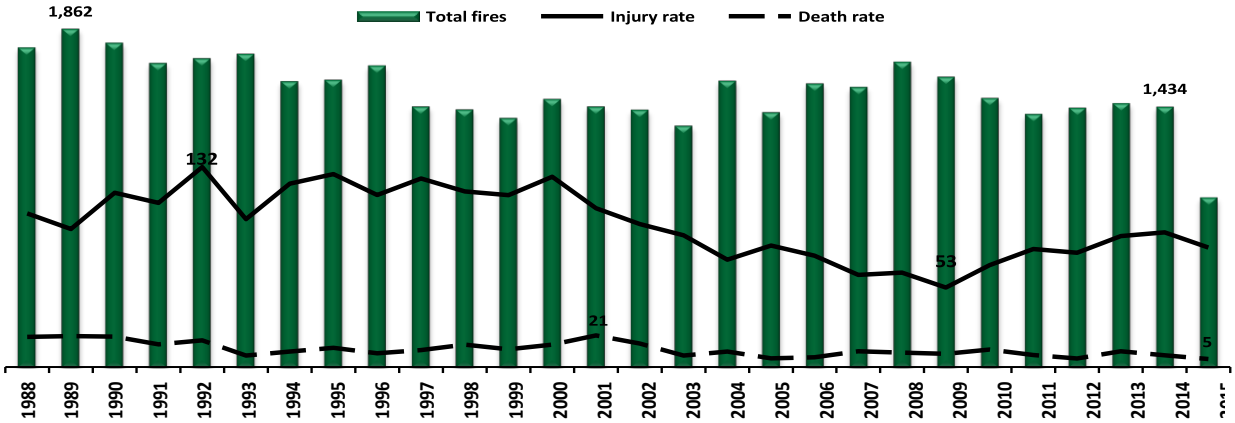
TABLE 1. FIRE ORIGIN AREA CODES USED TO CATEGORIZE RESIDENTIAL FIRES INTO A MEANINGFUL, CONSISTENT ROOM OF ORIGIN

Room of origin after coding OA-codes across the two fire reporting manuals	Pre-2004 codes	2004 and onwards codes
01. Bathroom	OA025	OA2500
02. Bedroom	OA021, OA022	OA2100, OA2200
03. Office	OA026	OA2600
04. Closet	OA042	OA4200
05. Assembly area - other	OA037, OA024, OA018, OA028, OA030, OA035, OA033, OA027, OA034, OA036, OA038, OA015, OA013, OA017, OA019, OA011, OA012, OA016, OA029	OA3700, OA2400, OA1800, OA2800, OA3000, OA3500, OA3300, OA2700, OA3550, OA3400, OA3600, OA3800, OA1500, OA1300, OA1700, OA1900, OA1100, OA1200, OA1600, OA2900, OA3650
06. Laundry room	OA032	OA3200
07. Hallways and means of egress	OA001, OA002, OA003, OA004, OA006, OA009	OA1010, OA1020, OA1030, OA1040, OA1060, OA1090
08. Living room	OA014	OA1400
09. Function area - unclassified	OA039	OA3900
10. Foyer	OA005	OA1050
11. Kitchen	OA031	OA3100
12. Dining area	OA023	OA2300
13. Porch	OA092	OA9200
14. Balcony	OA072	OA7200
15. Storage area	OA094, OA041, OA048, OA043, OA044, OA045, OA049	OA9400, OA4100, OA4800, OA4300, OA4400, OA4500, OA4750, OA4900
16. Garage	OA047, OA093	OA4700, OA9300
17. Outside area - other	OA091, OA099	OA9100, OA9600, OA9900, OA9980
18. Utility and equipment and furnace room	OA061, OA062, OA063, OA064, OA065, OA066, OA067, OA068, OA069	OA6100, OA6200, OA6300, OA6400, OA6700, OA6800, OA6900
19. Trash area	OA046, OA095	OA4600, OA9500
20. Chimney, flue pipe, gas vent	OA057, OA058	OA5800, OA5810
21. Service facilities	OA051, OA052, OA053, OA054, OA055, OA056, OA059	OA5100, OA5200, OA5300, OA5400, OA5500, OA5600, OA5700, OA5900
22. Crawl space	OA071	OA7100
23. Structural area - other	OA073, OA074, OA075, OA076, OA077, OA078, OA079	OA7300, OA7400, OA7500, OA7600, OA7700, OA7800, OA7900
24. All other areas	OA082, OA083, OA084, OA085, OA086, OA089, OA000	OA8200, OA8300, OA8400, OA8500, OA8600, OA8900, OA0000, OA000, OA0008, OA1000, OA2000

Overall Trends: Fires and Casualties

The relative number of these fires across each year and the corresponding death and injury rates are displayed in Figure 1.

FIGURE 1. THE NUMBERS OF FIRES PER YEAR AND THE ANNUAL DEATH AND INJURY RATES (PER 1,000 FIRES), 1988 TO 2015 (PART YEAR)



* Data for fires in 2015 does not include December.

With some year-to-year variation, Figure 1 demonstrates a general decline in the number of these types of residential fires that were reported to the BC OFC, from a high of 1,862 in 1989 to 1,434 in 2014 (a 23.0% reduction for the most recent complete year of data available for analysis). Over the same period of time, the annual rates of fire-related casualties also declined. This is demonstrated in Figure 1 by the differences between highs and lows: with the injury rate (solid black line) dropping from a high of 132 per 1,000 fires in 1992 down to 53 per 1,000 fires in 2009 and the death rate (broken black line) varying between 21 per 1,000 fires in 2001 and 5 per 1,000 fires in 2015. As rates per 100,000 people, these declines are even sharper, given that BC's population increased by almost 50% over this period, from an estimated 3.11 million in 1988 to 4.64 million in 2014 [1].

Presence of Fire Safety Systems and Implications for Casualties

This section examines the overall presence of smoke alarms and sprinkler systems and examines the implications of these fire safety systems for fire-related casualties. This is done in three separate tables. Table 2 looks at the relationship between sprinkler protection in the residential buildings that experienced fires, along with the number of fires and the number and rate of fire-related casualties that resulted from these fires. Table 3 shows similar patterns, but examines the relationship between smoke alarm presence and the frequency of fires and the fire-related casualties that occurred. Finally, Table 4 examines the interaction between these two life safety systems and the corresponding incidence of fire-related casualties.

TABLE 2. FIRES AND FIRE-RELATED CASUALTIES BY SPRINKLER PROTECTION, 1988 TO 2015

Sprinkler protection	Total fires	% fires	Injuries	% injuries	Deaths	% deaths	Injury rate	Death rate
1. Complete sprinkler protection	681	1.6%	47	1.2%	2	0.4%	69.0	2.9
2. Partial sprinkler protection	205	0.5%	17	0.4%	2	0.4%	82.9	9.8
3. No sprinkler protection	40,367	94.5%	3,941	96.9%	498	97.3%	97.6	12.3
5. Sprinkler protection unclassified	131	0.3%	15	0.4%	0	0.0%	114.5	0.0
6. Cannot be determined	1,317	3.1%	48	1.2%	10	2.0%	36.4	7.6
Total	**42,701**	**100.0%**	**4,068**	**100.0%**	**512**	**100.0%**	**95.3**	**12.0**

TABLE 3. NUMBER OF FIRES AND NUMBER/RATE OF FIRE-RELATED CASUALTIES BY SMOKE ALARM STATUS, 1988 TO 2015

Smoke alarm status	Total fires	% fires	Injuries	% injuries	Deaths	% deaths	Injury rate	Death rate
1. Alarm activated	10,665	25.0%	1,189	29.2%	74	14.5%	111.5	6.9
2. Alarm not activated	8,792	20.6%	781	19.2%	102	19.9%	88.8	11.6
3. No smoke alarm installed	12,045	28.2%	1,309	32.2%	190	37.1%	108.7	15.8
4. Cannot be determined / not applicable	11,199	26.2%	789	19.4%	146	28.5%	70.5	13.0
Total	**42,701**	**100.0%**	**4,068**	**100.0%**	**512**	**100.0%**	**95.3**	**12.0**

TABLE 4. NUMBER OF FIRES AND RATE OF FIRE-RELATED CASUALTIES BY SMOKE ALARM STATUS AND SPRINKLER PROTECTION STATUS, 1988 TO 2015

	Complete sprinkler protection			No sprinkler protection		
Smoke alarm status	# Fires	Injury rate	Death rate	# Fires	Injury rate	Death rate
1. Alarm activated	375	77.3	2.7	10,290	112.7	7.1
2. Alarm not activated	126	55.6	0.0	8,666	89.3	11.8
3. No smoke alarm installed	46	43.5	0.0	11,999	108.9	15.8
4. Cannot be determined / not applicable	134	67.2	7.5	11,065	70.5	13.1
Total	**681**	**69.0**	**2.9**	**42,020**	**95.7**	**12.1**

To summarise these results, with respect to life safety systems, the following points are worth emphasizing:

- Very few of the residential properties included in this analysis had complete sprinkler protection (1.6%, Table 2);
- The majority of these residential fires (94.5%, Table 2) occurred in buildings with no sprinkler protection;
- There was a marked reduction in death and injury rates from fires that occurred in those buildings that had complete sprinkler protection (2.9 deaths and 69.0 injuries per 1,000 fires), relative to the buildings with no sprinklers (12.3 and 97.6, respectively, Table 2);
- Relative to the presence of sprinkler protection, a much larger proportion of these houses had present, functioning smoke alarms when the fires occurred (25.0%, Table 3). Consistent with prior research [2] these fires resulted in a relatively lower death rate (6.9 per 1,000 fires) and a relatively higher injury rate

(111.5 per 1,000 fires) compared to 13.7 deaths and 89.9 injuries per 1,000 fires where no working alarm was present;

- The combined fire safety protection of a present, functioning smoke alarm and sprinkler protection was only present for 375 of the fires in the dataset (0.9% of all fires analysed here, Table 4). In comparison, 74.3% of the fires had no present, functioning alarm and were without sprinkler protection.

How Were the Fires Controlled?

This section examines the method of fire control for this set of residential fires with respect to the presence of smoke alarms and sprinkler systems. The interaction between these life safety systems and the response to the control the fire is explored with respect to the fire-related casualties in each case. This is done in four separate tables. Table 5 looks at the overall fire casualty patterns as a function of the method of fire control. Table 6 looks at the relationship between the method of fire control, the number of fires, and the number and rate of fire-related casualties that resulted from these fires with respect to the presence of a working smoke alarm. Table 7 shows similar patterns, but examines the relationship between sprinkler protection, the method of fire control, and the frequency of fires and the fire-related casualties that occurred. Finally, Table 8 examines the interaction between these two life safety systems, the method of fire control, and the corresponding incidence of fire-related casualties.

Table 5 shows that the fire department controlled these residential fires over 51% of the time (Method 04 and 05 combined) and that these fires resulted in over 60% of the injuries and over 82% of the deaths in this dataset. In comparison, the fires that were controlled by sprinkler protection (around 0.6% of the fires, Method 06) accounted for 0.3% of the injuries and 0.2% (1 case) of the deaths.

TABLE 5. NUMBER OF FIRES AND NUMBER/RATE OF FIRE-RELATED CASUALTIES BY METHOD OF FIRE CONTROL, 1988 TO 2015

Method of fire control	Total fires	% fires	Injuries	% injuries	Deaths	% deaths	Injury rate	Death rate
01. Hand held extinguisher	5,327	12.5%	406	10.0%	18	3.5%	76.2	3.4
02. Standpipe and hose systems	1,122	2.6%	84	2.1%	21	4.1%	74.9	18.7
03. Makeshift fire fighting aids	7,350	17.2%	724	17.8%	10	2.0%	98.5	1.4
04. Fire Department - water application	21,298	49.9%	2,422	59.5%	411	80.3%	113.7	19.3
05. Fire Department - other than water	622	1.5%	25	0.6%	9	1.8%	40.2	14.5
06. Sprinkler protection	241	0.6%	14	0.3%	1	0.2%	58.1	4.1
07. Fixed system other than sprinklers	72	0.2%	1	0.0%	1	0.2%	13.9	13.9
08. Burned out	3,698	8.7%	194	4.8%	21	4.1%	52.5	5.7
09. Miscellaneous method of fire control/extinguishment	1,832	4.3%	112	2.8%	3	0.6%	61.1	1.6
10. Cannot be determined	1,139	2.7%	86	2.1%	17	3.3%	75.5	14.9
Total	**42,701**	**100.0%**	**4,068**	**100.0%**	**512**	**100.0%**	**95.3**	**12.0**

Table 6 examines the method of fire control by smoke alarm status and examines the injury and death rates in each case. Looking first at the working smoke alarm fires, it can be seen that the injury rate for fires that were controlled by hand held extinguishers (102.5 per 1,000 fires, Method 01) and makeshift firefighting aids (135.7, Method 03) were elevated relative to the average injury rate overall. This is likely as a result of the

alarm alerting the building resident and then injury resulting from their successful efforts to overcome the fire (36% of the fires in the working smoke alarm group were controlled in this manner). The corresponding reduction in the death rates for both of these methods of fire control (relative to the average) is further support for this theory. When sprinkler systems controlled the fire in the presence of working smoke alarms (129 fires, Method 06) the injury rate was approaching half the overall injury rate for the dataset: 69.8 compared to 111.5, overall. (It should be noted that the death rate of 7.8 for the Method 06 controlled fires was produced by the single death that occurred in the presence of a working alarm and extinguished by a sprinkler system). The fires that had working alarms but still required fire department intervention to control the fire had an elevated injury and death rate relative to the average (Method 04 and 05, combined). In comparison, examination of the fires that occurred in the absence of a working smoke alarm, only 27.6% of these fires were controlled by hand held extinguishers or makeshift aids (Methods 01 and 03) and 54.5% of the fires required the fire department to intervene (compared to 41.8% of the fires in the presence of working smoke alarms, Methods 04 and 05, combined). In all cases, when the fire department was required, the fire-related death rates were well above the average. In the small number of fires with sprinkler protection and no working alarm (n = 112 fires) the fire-related casualties were substantially lower than the average for the dataset overall (44.6 injuries and 0.0 deaths per 1,000 fires).

TABLE 6. NUMBER OF FIRES AND RATE OF FIRE-RELATED CASUALTIES BY METHOD OF FIRE CONTROL AND SMOKE ALARM STATUS, 1988 TO 2015

	Working smoke alarm (1,189 injuries and 74 deaths)			No working smoke alarm (2,879 injuries and 438 deaths)		
Method of fire control	# Fires	Injury rate	Death rate	# Fires	Injury rate	Death rate
01. Hand held extinguisher	1,610	102.5	1.9	3,717	64.8	4.0
02. Standpipe and hose systems	212	103.8	4.7	910	68.1	22.0
03. Makeshift fire fighting aids	2,233	135.7	1.8	5,117	82.3	1.2
04. Fire Department - water application	4,272	128.3	14.0	17,026	110.1	20.6
05. Fire Department - other than water	181	49.7	0.0	441	36.3	20.4
06. Sprinkler protection	129	69.8	7.8	112	44.6	0.0
07. Fixed system other than sprinklers	11	0.0	0.0	61	16.4	16.4
08. Burned out	1,006	67.6	3.0	2,692	46.8	6.7
09. Miscellaneous method of fire control/extinguishment	785	59.9	1.3	1,047	62.1	1.9
10. Cannot be determined	226	79.6	4.4	913	74.5	17.5
Total	**10,665**	**111.5**	**6.9**	**32,036**	**89.9**	**13.7**

Table 7 shows fire related casualties by method of fire control and sprinkler protection status. Looking first at the fires that occurred in the presence of sprinkler protection, it is important to note that there were only 2 deaths in the 681 fires (and as such, death rate fluctuations should be interpreted with caution). Overall, the injury rate (69.0 per 1,000 fires) was lower than the rate in the presence of a working smoke alarm (111.5, Table 6, above). It is also important to note that sprinklers only controlled the fires 26.4% of the time (Method 06) and the fire department was still required to control fires in buildings with complete sprinkler protection 25.1% of the time (Method 04 and 05, combined). In comparison, examination of the fires that occurred in the absence of a sprinkler protection, 52.8% of the fires required the fire department to intervene (Method 04 and 05, combined) and when this was the case the fire-related death rates were well above the average (19.3 per 1,000 fires).

TABLE 7. NUMBER OF FIRES AND RATE OF FIRE-RELATED CASUALTIES BY METHOD OF FIRE CONTROL AND SPRINKLER PROTECTION STATUS, 1988 TO 2015

	Complete sprinkler protection (47 injuries and 2 deaths)			No sprinkler protection (4,021 injuries and 510 deaths)		
Method of fire control	# Fires	Injury rate	Death rate	# Fires	Injury rate	Death rate
01. Hand held extinguisher	78	64.1	0.0	5,249	76.4	3.4
02. Standpipe and hose systems	4	250.0	0.0	1,118	74.2	18.8
03. Makeshift fire fighting aids	91	44.0	0.0	7,259	99.2	1.4
04. Fire Department - water application	154	110.4	0.0	21,144	113.7	19.4
05. Fire Department - other than water	17	117.6	0.0	605	38.0	14.9
06. Sprinkler protection	180	72.2	5.6	61*	16.4	0.0
07. Fixed system other than sprinklers	4	0.0	0.0	68	14.7	14.7
08. Burned out	105	47.6	9.5	3,593	52.6	5.6
09. Miscellaneous method of fire control/extinguishment	36	0.0	0.0	1,796	62.4	1.7
10. Cannot be determined	12	0.0	0.0	1,127	76.3	15.1
Total	**681**	**69.0**	**2.9**	**42,020**	**95.7**	**12.1**

* 61 fires were not classed as having complete sprinkler protection (SP code) but were controlled by sprinklers (EX code) – possibly as a result of partial sprinkler protection and cases where sprinkler protection was 'unclassified'.

Looking at the two extremes of life safety system use, Table 8 shows the ways that the fires were controlled in the presence of sprinklers and smoke alarms versus in the absence of both of these life safety systems. Once again, it needs to be emphasized that there was only 1 death in the 375 fires that had both sprinkler and smoke alarm protection. As expected, overall, there was a much lower injury and death rate for fires with complete life safety protection relative to those with no protection. The fire department was needed to control the fires 22.4% of the time when complete protection was present, as opposed to 54.8% of the time when no life safety systems were in place (Method 04 and 05, combined). Finally, sprinklers still only controlled the fires 29.3% of the time for the complete protection group.

TABLE 8. NUMBER OF FIRES AND RATE OF FIRE-RELATED CASUALTIES BY METHOD OF FIRE CONTROL AND FIRE SAFETY SYSTEM (ALARM AND SPRINKLER) STATUS, 1988 TO 2015

	Complete sprinkler protection & working smoke alarm (29 injuries and 1 death)			No sprinkler protection and no working smoke alarm (2,861 injuries and 437 deaths)		
Method of fire control	# Fires	Injury rate	Death rate	# Fires	Injury rate	Death rate
01. Hand held extinguisher	38	78.9	0.0	3,677	65.0	4.1
02. Standpipe and hose systems	3	333.3	0.0	909	68.2	22.0
03. Makeshift fire fighting aids	47	42.6	0.0	5,073	82.6	1.2
04. Fire Department - water application	72	97.2	0.0	16,944	110.0	20.7
05. Fire Department - other than water	12	166.7	0.0	436	36.7	20.6
06. Sprinkler protection	110	81.8	9.1	42*	23.8	0.0
07. Fixed system other than sprinklers	2	0.0	0.0	59	16.9	16.9
08. Burned out	64	78.1	0.0	2,651	47.5	6.4
09. Miscellaneous method of fire control/extinguishment	23	0.0	0.0	1,034	62.9	1.9
10. Cannot be determined	4	0.0	0.0	905	75.1	17.7
Total	**375**	**77.3**	**2.7**	**31,730**	**90.8**	**13.8**

* 42 fires were not classed as having complete sprinkler protection (SP code) but were controlled by sprinklers (EX code) – possibly as a result of partial sprinkler protection and cases where sprinkler protection was 'unclassified'.

To summarise these points, with respect to how fires were controlled and the interaction with life safety systems, it is clear that:

- Very few fires occurred in residential buildings that had complete sprinkler protection and working smoke alarms. In these fires people were still injured and deaths did still occur. Also, even when sprinkler protection was present, this was not always the system by which the fires were controlled.
- The presence of either life safety system reduced the fire-related death rate relative to the absence of that life safety system.
- The presence of both life safety systems ***still required fire department intervention to control the fires***, but at a much lower rate than for fires with no life safety systems in place.

How Far Did the Fires Spread?

The next section examines the extent of fire spread as a function of life safety system presence. As before, the relative death and injuries are examined with respect to both of these factors. For the 26,847 fires (63.3% of fires) that were contained to the room of origin the death rate was 3.3 per 1,000 fires and the injury rate was 76.3 per 1,000 fires (aggregated data from Table 9). For the fires that extended beyond the room of origin, the death rate increased to 27.2 per 1,000 fires and the injury rate increased to 128.2 per 1,000 fires.

TABLE 9. NUMBER OF FIRES AND NUMBER/RATE OF FIRE-RELATED CASUALTIES BY EXTENT OF FIRE SPREAD, 1988 TO 2015

Extent of fire spread	Total Fires	% fires	Injuries	% injuries	Deaths	% deaths	Injury rate	Death rate
1. Confined to object of origin	10,396	24.5%	395	9.8%	12	2.3%	38.0	1.2
2. Confined to part of room/area of origin	11,931	28.1%	1,086	26.9%	34	6.7%	91.0	2.8
3. Confined to room of origin	4,520	10.7%	568	14.0%	42	8.2%	125.7	9.3
4. Confined to floor level of origin	3,151	7.4%	485	12.0%	70	13.7%	153.9	22.2
5. Confined to building of origin	9,894	23.3%	1,219	30.1%	299	58.5%	123.2	30.2
6. Extended beyond property of origin	1,776	4.2%	279	6.9%	54	10.6%	157.1	30.4
7. Confined to roof/attic space	743	1.8%	12	0.3%	0	0.0%	16.2	0.0
Total	**42,411**	**100.0%**	**4,044**	**100.0%**	**511**	**100.0%**	**95.4**	**12.0**

* Data for fires in pre-2004 excluded 290 fires (24 injuries and 1 death) where extent of fire spread was classified as 'not applicable', 'unclassified' or 'unknown'.

Table 10 shows the extent of fire spread as a function of the presence of a working smoke alarm. This data shows a comparable death rate for fires contained to the room of origin in the presence (3.0 per 1,000 fires) and absence (3.4 per 1,000 fires) of a working alarm. However, 7,913 (74.5% of fires) that occurred in the presence of a working alarm were contained to the room of origin compared to 59.6% of those fires without a working alarm. As expected, the injury rate for fires contained to the room of origin in the presence of a working alarm was higher (93.3 per 1,000 fires) than the rate for fires without a working alarm (69.2). Once again, this is likely as a result of the alarm causing the resident to intervene to control the fire and getting injured while doing so. Fires without working alarms were more likely to extend beyond the room of origin (40.4% compared to 25.5% for fires with working alarms) and the death rate was higher 29.1 per 1,000 fires vs. 18.1).

TABLE 10. NUMBER OF FIRES AND RATE OF FIRE-RELATED CASUALTIES BY EXTENT OF FIRE SPREAD AND SMOKE ALARM STATUS, 1988 TO 2015

	Working smoke alarm (1,180 injuries and 73 deaths)			No working smoke alarm (2,864 injuries and 438 deaths)		
Extent of fire spread	**# Fires**	**Injury rate**	**Death rate**	**# Fires**	**Injury rate**	**Death rate**
1. Confined to object of origin	3,052	45.9	0.7	7,344	34.7	1.4
2. Confined to part of room/area of origin	3,427	119.1	3.5	8,504	79.7	2.6
3. Confined to room of origin	1,434	132.5	7.0	3,086	122.5	10.4
4. Confined to floor level of origin	764	200.3	19.6	2,387	139.1	23.0
5. Confined to building of origin	1,632	147.1	18.4	8,262	118.5	32.6
6. Extended beyond property of origin	229	209.6	17.5	1,547	149.3	32.3
7. Confined to roof/attic space	86	11.6	0.0	657	16.7	0.0
Total	**10,624**	**111.1**	**6.9**	**31,787**	**90.1**	**13.8**

* Data for fires in pre-2004 excluded 290 fires (24 injuries and 1 death) where extent of fire spread was classified as 'not applicable', 'unclassified' or 'unknown'.

Table 11 shows the extent of fire spread as a function of the presence of a sprinkler protection. As with the smoke alarms, this data shows a comparable death rate for fires contained to the room of origin in the presence (3.4 per 1,000 fires) and absence (3.3 per 1,000 fires) of a complete sprinkler protection. In total 87.7% of fires that occurred in the presence of complete sprinkler protection were contained to the room of origin compared to 62.9% of those fires without this life safety system. The injury rate of for fires contained to the room of origin was lower in the presence of sprinkler protection (57.0 per 1,000 fires) than for fires without sprinklers (76.8).

TABLE 11. NUMBER OF FIRES AND RATE OF FIRE-RELATED CASUALTIES BY EXTENT OF FIRE SPREAD AND SPRINKLER PROTECTION STATUS, 1988 TO 2015

	Complete sprinkler protection (47 injuries and 2 deaths)			No sprinkler protection (3,997 injuries and 509 deaths)		
Extent of fire spread	**# Fires**	**Injury rate**	**Death rate**	**# Fires**	**Injury rate**	**Death rate**
1. Confined to object of origin	294	40.8	3.4	10,102	37.9	1.1
2. Confined to part of room/area of origin	234	59.8	4.3	11,697	91.6	2.8
3. Confined to room of origin	69	115.9	0.0	4,451	125.8	9.4
4. Confined to floor level of origin	17	352.9	0.0	3,134	152.8	22.3
5. Confined to building of origin	48	145.8	0.0	9,846	123.1	30.4
6. Extended beyond property of origin	12	0.0	0.0	1,764	158.2	30.6
7. Confined to roof/attic space	7	0.0	0.0	736	16.3	0.0
Total	**681**	**69.0**	**2.9**	**41,730**	**95.8**	**12.2**

* Data for fires in pre-2004 excluded 290 fires (24 injuries and 1 death) where there was no sprinkler protection and the extent of fire spread was classified as 'not applicable', 'unclassified' or 'unknown'.

Finally, Table 12 shows the extent of fire spread as a function of the complete coverage of the two life safety systems versus the complete absence of either system. The fires with complete life safety protection (n = 375) were contained to the room of origin 92.0% of the time, with a death rate of 2.7 per 1,000 fires (1 fatality) and an injury rate of 77.3 per 1,000 fires (29 injuries). In comparison, fires without either of these fire protection systems in place were only contained to the room of origin 59.3% of the time and had a death rate of 13.9 per 1,000 fires.

TABLE 12. NUMBER OF FIRES AND RATE OF FIRE-RELATED CASUALTIES BY EXTENT OF FIRE SPREAD AND FIRE SAFETY SYSTEM (ALARM AND SPRINKLER) STATUS, 1988 TO 2015

	Complete sprinkler protection & working smoke alarm (29 injuries and 1 death)			No sprinkler protection and no working smoke alarm (2,846 injuries and 437 deaths)		
Extent of fire spread	**# Fires**	**Injury rate**	**Death rate**	**# Fires**	**Injury rate**	**Death rate**
1. Confined to object of origin	166	54.2	0.0	7,216	34.9	1.2
2. Confined to part of room/area of origin	131	76.3	7.6	8,401	80.2	2.6
3. Confined to room of origin	48	166.7	0.0	3,065	123.3	10.4
4. Confined to floor level of origin	5	400.0	0.0	2,375	138.1	23.2
5. Confined to building of origin	16	0.0	0.0	8,230	118.1	32.7
6. Extended beyond property of origin	6	0.0	0.0	1,541	149.9	32.4
7. Confined to roof/attic space	3	0.0	0.0	653	16.8	0.0
Total	**375**	**77.3**	**2.7**	**31,481**	**92.4**	**13.9**

* Data for fires in pre-2004 excluded 249 fires (15 injuries and 0 deaths) where there was no sprinkler protection or working smoke alarm and the extent of fire spread was classified as 'not applicable', 'unclassified' or 'unknown'.

Table 13 summarizes the findings from this section. This table presents the relative trends as a function of the combination of life safety systems that were in place for each residential fire. Table 13 also provides 95% confidence intervals for the estimates of death rates, fire department intervention, and the extent of fire spread for each of these combinations of life safety systems.

TABLE 13. FIRES, FIRE-RELATED CASUALTIES, FIRE DEPARTMENT INVOLVEMENT, AND EXTENT OF FIRE SPREAD BY COMBINATIONS OF LIFE SAFETY SYSTEMS: ALL RESIDENTIAL FIRES, 1988 TO 2015

Smoke alarm	Sprinkler	Fires (% total)	Injuries	Injury rate	Deaths (% total)	Death rate (95% CI)		% Fire department extinguish (95% CI)		% Beyond room of origin (95% CI)	
Yes	Yes	375 (0.9%)	29	77.3	1 (0.2%)	2.7	(−2.6, 7.9)	22.4%	(20.2%, 24.6%)	8.0%	(6.6%, 9.4%)
No	Yes	306 (0.7%)	18	58.8	1 (0.2%)	3.3	(−3.1, 9.7)	28.4%	(25.9%, 31.0%)	17.6%	(15.5%, 19.8%)
Yes	No	10,290 (24.1%)	1,160	112.7	73 (14.3%)	7.1	(5.5, 8.7)	42.5%	(42.0%, 42.9%)	26.1%	(25.6%, 26.5%)
No	No	31,730 (74.3%)	2,861	90.2	437 (85.4%)	13.8	(12.5, 15.1)	54.8%	(54.5%, 55.1%)	40.3%	(40.1%, 40.6%)
Total		***42,701 (100.0%)***	***4,068***	***95.3***	***512 (100.0%)***	***12.0***	***(11.0, 13.0)***	***51.2%***	***(50.9%, 51.4%)***	***36.4%***	(36.2%, 36.6%)

The main findings from Table 13 include:

- Almost three-quarters of these residential fires had no present, functioning life-safety systems and these fires resulted in 85.4% of the deaths in this sample.
- Relative to fires with no life safety systems in place, fires with either a working smoke alarm or complete sprinkler protection are much less likely to result in a death, less likely to require fire department intervention, and less likely to extend beyond the room of origin.
- The compound effect of both sprinkler protection and a working smoke alarm resulted in only 1 death, required the least amount of fire department intervention, and the fires did not extend beyond the room of origin 92% of the time.

Room-Specific Findings

This section examines the fire outcomes for the specific subsection of areas within residential properties that experienced a disproportionate number fires and fatalities. This forms the basis of some discussion as to how these room-specific findings could contribute to enhancing residential building fire safety in a targeted manner that would increase protection for residents and keep the costs of fire protection relatively low. Table 14 shows that the living room (11.9% of fires, 15.9% of injuries, and 41.4% of deaths), the kitchen (26.0% of fires, 33.1% of injuries, and 13.7% of deaths), and the bedrooms (10.8% of fires, 17.5% of injuries, and 20.7% of deaths) are the rooms in which 48.7% of the residential fires examined in this dataset originated accounting for 66.5% of the injuries and 75.8% of the deaths.

TABLE 14. AREA OF FIRE ORIGIN (GROUPED AS PER TABLE 1), 1988 TO 2015

Area of origin (grouped)!	Total fires	% total fires	Injuries	% injuries	Deaths	% deaths
01. Bathroom	811	1.9%	66	1.6%	6	1.2%
02. Bedroom	4,601	10.8%	713	17.5%	106	20.7%
03. Office	88	0.2%	5	0.1%	1	0.2%
04. Closet	324	0.8%	32	0.8%	6	1.2%
05. Assembly area - other	239	0.6%	22	0.5%	2	0.4%
06. Laundry room	1,733	4.1%	142	3.5%	7	1.4%
07. Hallways and means of egress	1,030	2.4%	97	2.4%	16	3.1%
08. Living room	5,090	11.9%	647	15.9%	212	41.4%
09. Function area - unclassified	353	0.8%	41	1.0%	6	1.2%
10. Foyer	406	1.0%	42	1.0%	5	1.0%
11. Kitchen	11,103	26.0%	1,347	33.1%	70	13.7%
12. Dining area	277	0.6%	27	0.7%	10	2.0%
13. Porch	1,084	2.5%	81	2.0%	0	0.0%
14. Balcony	1,111	2.6%	80	2.0%	11	2.1%
15. Storage area	1,212	2.8%	105	2.6%	7	1.4%
16. Garage	2,194	5.1%	182	4.5%	5	1.0%
17. Outside area - other	1,392	3.3%	43	1.1%	1	0.2%
18. Utility and equipment and furnace room	1,431	3.4%	131	3.2%	18	3.5%
19. Trash area	191	0.4%	6	0.1%	1	0.2%
20. Chimney, flue pipe, gas vent	2,503	5.9%	25	0.6%	0	0.0%
21. Service facilities	149	0.3%	10	0.2%	0	0.0%
22. Crawl space	537	1.3%	36	0.9%	6	1.2%
23. Structural area - other	4,722	11.1%	180	4.4%	16	3.1%
24. All other areas	120	0.3%	8	0.2%	0	0.0%
Total	**42,701**	**100.0%**	**4,068**	**100.0%**	**512**	**100.0%**

Living Room

Table 15 looks in more detail at the living room fires (11.9% of all fires analysed resulting in 15.9% of injuries and 41.4% of deaths). The main findings are as follows:

- The overall death rate for fires that commence in living rooms (41.7 per 1,000 fires) is 3.5 times greater than the death rate for the total sample of residential fires (12.0 per 1,000 fires – see Table 13, above). It should also be noted that relative to the full sample of fires, when the fire originates in the living room they are more likely to require fire department intervention (59.9% compared to 51.2% overall) and extend beyond the room of origin (43.7% compared to 36.4% overall).
- Approximately one-quarter of the living room fires had at least one fire safety system in place. In 97.3% of these cases, this was a working smoke alarm but no sprinkler protection.
- The small number of fires with sprinkler systems means that conclusions about these life safety devices and the fire outcomes should be made with caution (with the confidence intervals clearly demonstrating this point). However, relative to fires with no life safety systems, it seems reasonable to conclude that fires that commence in living rooms with at least a working smoke alarm or sprinkler protection have a reduced death rate (28.9 per 1,000 with a 95% confidence interval ranging from 19.6 to 38.2), were less likely to require the fire department to intervene (51.5% of the time, 95% confidence interval 50.1% to 52.9%), and were less likely to have extended beyond the room of origin (31.3% of the time, 95% confidence interval 30.0% to 32.6%).

TABLE 15. FIRES, FIRE-RELATED CASUALTIES, FIRE DEPARTMENT INVOLVEMENT, AND EXTENT OF FIRE SPREAD BY COMBINATIONS OF LIFE SAFETY SYSTEMS: FIRES IN LIVING ROOMS, 1988 TO 2015

Smoke alarm	Sprinkler	Fires (% total)	Injuries	Injury rate	Deaths (% total)	Death rate (95% CI)	% Fire department extinguish (95% CI)	% Beyond room of origin (95% CI)
Yes	Yes	21 (0.4%)	3	142.9	0 (0.0%)	0.0 (0.0, 0.0)	23.8% (14.5%, 33.1%)	14.3% (6.6%, 21.9%)
No	Yes	14 (0.3%)	7	500.0	0 (0.0%)	0.0 (0.0, 0.0)	42.9% (29.6%, 56.1%)	35.7% (22.9%, 48.5%)
Yes	No	1,247 (24.5%)	155	124.3	37 (17.5%)	29.7 (20.1, 39.2)	52.0% (50.6%, 53.5%)	31.5% (30.2%, 32.8%)
No	No	3,808 (74.8%)	482	126.6	175 (82.5%)	46.0 (39.1, 52.8)	62.8% (62.0%, 63.5%)	47.9% (47.1%, 48.7%)
Total		***5,090 (100.0%)***	***647***	***127.1***	***212 (100.0%)***	***41.7 (36.0, 47.3)***	***59.9% (59.2%, 60.6%)***	***43.7%*** (43.0%, 44.4%)

Kitchen

Table 16 looks in more detail at the kitchen fires (26.0% of fires, 33.1% of injuries, and 13.7% of deaths). The main findings are as follows:

- The overall death rate for fires that commence in kitchens (6.3 per 1,000 fires) is 0.5 times less than the death rate for the total sample of residential fires (12.0 per 1,000 fires – see Table 13, above). It should also be noted that relative to the full sample of fires, when the fire originates in the kitchen they are less likely to require fire department intervention (27.5% compared to 51.2% overall) and extend beyond the room of origin (20.0% compared to 36.4% overall).

- Approximately 40% of the living room fires had at least one fire safety system in place. In 93.0% of these cases, this was a working smoke alarm but no sprinkler protection.
- The small number of fires with sprinkler systems means that conclusions about these life safety devices and the fire outcomes should be made with caution (with the confidence intervals clearly demonstrating this point). However, relative to fires with no life safety systems, it seems reasonable to conclude that fires that commence in kitchens with at least a working smoke alarm or sprinkler protection have a reduced death rate (1.8 per 1,000 with a 95% confidence interval ranging from 0.6 to 3.1), were less likely to require the fire department to intervene (19.8% of the time, 95% confidence interval 19.2% to 20.4%), and were less likely to have extended beyond the room of origin (10.6% of the time, 95% confidence interval 10.1% to 11.1%).

TABLE 16. FIRES, FIRE-RELATED CASUALTIES, FIRE DEPARTMENT INVOLVEMENT, AND EXTENT OF FIRE SPREAD BY COMBINATIONS OF LIFE SAFETY SYSTEMS: FIRES IN KITCHENS, 1988 TO 2015

Smoke alarm	Sprinkler	Fires (% total)	Injuries	Injury rate	Deaths (% total)	Death rate (95% CI)	% Fire department extinguish (95% CI)	% Beyond room of origin (95% CI)
Yes	Yes	201 (1.8%)	15	74.6	0 (0.0%)	0.0 (0.0, 0.0)	9.5% (7.4%, 11.5%)	0.5% (0.0%, 1.0%)
No	Yes	108 (1.0%)	2	18.5	1 (1.4%)	9.3 (–8.9, 27.4)	9.3% (6.5%, 12.0%)	3.7% (1.9%, 5.5%)
Yes	No	4,105 (37.0%)	506	123.3	7 (10.0%)	1.7 (0.4, 3.0)	20.6% (20.0%, 21.2%)	11.3% (10.8%, 11.8%)
No	No	6,689 (60.2%)	824	123.2	62 (88.6%)	9.3 (7.0, 11.6)	32.1% (31.6%, 32.7%)	22.0% (21.5%, 22.5%)
Total		***11,103 (100.0%)***	***1,347***	***121.3***	***70 (100.0%)***	***6.3 (4.8, 7.8)***	***27.5% (27.0%, 27.9%)***	***20.0%*** (19.6%, 20.4%)

Bedroom

Table 17 looks in more detail at the bedroom fires (10.8% of fires, 17.5% of injuries, and 20.7% of deaths). The main findings are outlined below the table:

TABLE 17. FIRES, FIRE-RELATED CASUALTIES, FIRE DEPARTMENT INVOLVEMENT, AND EXTENT OF FIRE SPREAD BY COMBINATIONS OF LIFE SAFETY SYSTEMS: FIRES IN BEDROOMS, 1988 TO 2015

Smoke alarm	Sprinkler	Fires (% total)	Injuries	Injury rate	Deaths (% total)	Death rate (95% CI)	% Fire department extinguish (95% CI)	% Beyond room of origin (95% CI)
Yes	Yes	35 (0.8%)	3	85.7	1 (0.9%)	28.6 (–27.4, 84.6)	25.7% (18.3%, 33.1%)	0.0% (0.0%, 0.0%)
No	Yes	23 (0.5%)	4	173.9	0 (0.0%)	0.0 (0.0, 0.0)	26.1% (16.9%, 35.2%)	21.7% (13.1%, 30.3%)
Yes	No	1,241 (27.0%)	211	170.0	13 (12.3%)	10.5 (4.8, 16.2)	60.0% (58.6%, 61.4%)	29.8% (28.5%, 31.1%)
No	No	3,302 (71.8%)	495	149.9	92 (86.8%)	27.9 (22.2, 33.6)	68.2% (67.4%, 69.0%)	42.8% (42.0%, 43.7%)
Total		***4,601 (100.0%)***	***713***	***155.0***	***106 (100.0%)***	***23.0 (18.7, 27.4)***	***66.3% (65.6%, 67.0%)***	***48.3%*** (47.6%, 49.1%)

- The overall death rate for fires that commence in bedrooms (23.0 per 1,000 fires) is 1.9 times greater than the death rate for the total sample of residential fires (12.0 per 1,000 fires – see Table 13, above). It should also be noted that relative to the full sample of fires, when the fire originates in bedrooms they are more likely to require fire department intervention (66.3% compared to 51.2% overall) and extend beyond the room of origin (48.3% compared to 36.4% overall).
- Approximately 28% of the living room fires had at least one fire safety system in place. In 95.5% of these cases, this was a working smoke alarm but no sprinkler protection.
- The small number of fires with sprinkler systems means that conclusions about these life safety devices and the fire outcomes should be made with caution (with the confidence intervals clearly demonstrating this point). However, relative to fires with no life safety systems, it seems reasonable to conclude that fires that commence in bedrooms with at least a working smoke alarm or sprinkler protection have a reduced death rate (10.8 per 1,000 with a 95% confidence interval ranging from 5.1 to 16.4), were less likely to require the fire department to intervene (58.5% of the time, 95% confidence interval 57.1% to 59.9%), and were less likely to have extended beyond the room of origin (28.9% of the time, 95% confidence interval 27.6% to 30.1%).

Discussion: Can Fire Safety be Enhanced in a Targeted, Cost-Effective Manner?

Overall, these findings demonstrate the following:

- The number and rate (per 100,000 population in BC) of residential structure fires has declined between 1988 and 2015. The death and injury rate per 1,000 fires has also reduced over this period of time.
- Almost three-quarters of these residential fires had no present, functioning life-safety systems and these fires resulted in over 85% of the deaths in this sample.
- When either a working smoke alarm or complete sprinkler protection were present the residential fires were much less likely to result in death, less likely to require fire department intervention to control the fire, and were contained to the room of origin more often (relative to fires with no life safety systems in place).
- For the 375 residential structure fires (less than 1% of the sample) that occurred in the presence of a working smoke alarm and complete sprinkler protection there was 1 death, the fires only required fire department intervention to control them 22% of the time, and the fires only extend beyond the room of origin 8% of the time.
- Forty-nine per cent of these fires originated in three main areas within residential buildings. These fires caused over two-thirds of the injuries and over three-quarters of the deaths. These rooms were the living room, the kitchen, and the bedrooms.
- Living room fires (12% of fires and 41% of deaths) had a death rate that was 3.5 times greater than the sample overall. Relative to the whole sample, these fires were more likely to require fire department intervention to control them and spread further throughout the house. Relative to fires with no life safety systems it can cautiously be concluded that living room fires that occur in the presence of at least one life safety system have a reduced death rate, place reduced demands on fire services to control the fires, and were more likely to be contained to the room of origin within the building.
- Kitchen fires (26% of fires and 14% of deaths) had a death rate that was 0.5 times less than the sample overall. Relative to the whole sample, these fires were less likely to require fire department intervention to control them and were more likely to be contained to the room of origin. Relative to fires with no life

safety systems it can cautiously be concluded that living room fires that occur in the presence of at least one life safety system have a reduced death rate, place reduced demands on fire services to control the fires, and were more likely to be contained to the room of origin within the building.

- Bedroom fires (11% of fires and 21% of deaths) had a death rate that was 1.9 times greater than the sample overall. Relative to the whole sample, these fires were more likely to require fire department intervention to control them and spread further throughout the house. Relative to fires with no life safety systems it can cautiously be concluded that living room fires that occur in the presence of at least one life safety system have a reduced death rate, place reduced demands on fire services to control the fires, and were more likely to be contained to the room of origin within the building.

Given the disproportionately large number of fires and fatalities that occur in these three room types, the viability of focusing prevention efforts in these locations in the first instance should be explored. This research has demonstrated that, for the residential fires analysed here, fires that commence in living rooms and bedrooms have elevated death rates relative to the overall patterns. This research also shows that historically, the presence of at least one life safety system (out of sprinklers and working smoke alarms) has reduced the likelihood that fires will result in the loss of life, the extent to which the fires spread throughout residential buildings, and the demands placed on fire services to extinguish the fires. It seems plausible that these patterns could provide a starting point for targeted interventions designed to reduce the loss of life, limit the damaged caused by residential fires, and limit the costs of installing fire safety devices in residential buildings. Further research is required to determine the extent to which these findings extrapolate to different contexts and any targeted interventions should be evaluated in an ongoing manner to ensure effectiveness.

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