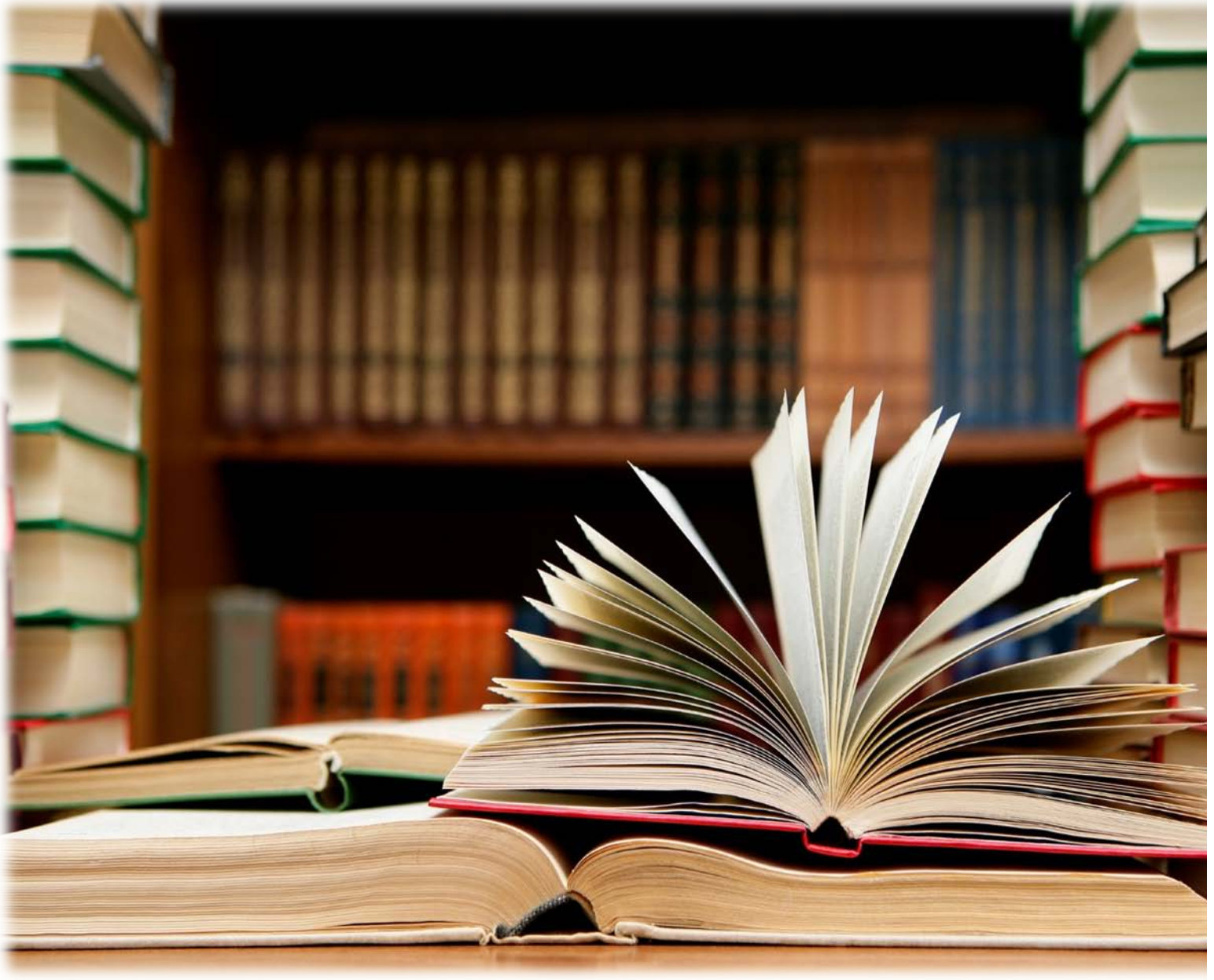


Smoke Alarms Work, But Not Forever

Posing the Challenge of Adopting Multifaceted, Sustained, Interagency Responses to Ensuring the Presence of a Functioning Smoke Alarm



Fire Chief Len Garis and Dr. Joseph Clare

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Executive Summary

1. A case is made for pursuing a comprehensive, whole-of-government commitment to ensuring every dwelling in Canada possesses a present, functioning smoke alarm. Achieving this goal will require a comprehensive, consistent, continuing effort from a range of stakeholders.
2. The three main types of smoke alarms are ionization, photoelectric, and combination alarms. These can be powered in a variety of ways, ranging from batteries through to hard-wired. Regardless of type, smoke alarms should be tested regularly and replaced at least every 10 years.
3. Smoke alarms save lives in the event of residential structure fires. Analysis was undertaken on almost 50,000 fires that occurred in Alberta, British Columbia, and Ontario over a 5-year period (up to October, 2011) involving 663 fatalities. The findings demonstrated that the death rate per 1,000 fires in the absence of a present, functioning smoke alarm was 74% greater than when a functioning smoke alarm was present. These provinces combined represent approximately 62% of the Canadian population. Extrapolating these trends it is estimated that 100% coverage of functioning smoke alarms in residential properties could prevent around 69 deaths per year in Canada: reducing the annual fatalities from residential structure fires by 32%.
4. The risks of fatality in the event of a residential structure fire are unevenly distributed across society. Risks are elevated for households with at least one young child, older adult, or person with disability. In addition, rental units, households in low-income areas, and houses in rural communities also experience elevated risk. BC fire fatality data also indicates increased risk for fires reported by First Nations Bands. Furthermore, because the presence of functioning smoke alarms improves response times to fires, these devices can play a crucial role in preventing deaths when the victims are asleep/under the influence of drugs/alcohol at the time of the fire.
5. Smoke alarms reduce property damage in the event of residential structure fires. Analysis of the 11,000 structure fires from BC revealed that estimated property damage per fire reduced by 19% in the presence of a functioning smoke alarm. Furthermore, fires were smaller in the presence of functioning smoke alarms, with fires significantly more likely to have been contained to the object, area, and room of origin. Without present, functioning smoke alarms, fires extend further and do more damage.
6. The functionality of smoke alarms deteriorates with time and the most common reasons why alarm functionality declines involve access to power. Consequently, installation of smoke alarms forms only part of the solution to this issue. Completely addressing the effectiveness of residential smoke alarms also requires maintenance and ongoing monitoring of effectiveness once installed.
7. A range of successfully implemented strategies demonstrate that it is possible to increase the likelihood of a residential property possessing a present, functioning smoke alarm in the event of a fire. These strategies have varied from involving fire fighters targeting smoke alarm and public education campaigns at high-fire-risk areas of their communities, through to active punitive approaches to enforcing legislation when mandated smoke alarms are not installed. Typically, however, these approaches have suffered from a lack of an unconditional, systematic, ongoing commitment, which means that the positive benefits gained diminish with time. Programs can become victims of their own successes, with funding and effort redirected once the initial impact has been achieved.
8. The key to consolidating the successes of smoke alarm installation campaigns is ensuring their longevity. Smoke alarm presence and functionality should be monitored in a comprehensive, consistent manner. This needs a holistic commitment from all key stakeholders, with strategies that operate in an iterative manner to ensure the problem of presence and functionality of smoke alarms is managed in an ongoing manner. The diverse range of potential approaches for achieving this outcome mean that it is unacceptable not to commit to this approach. The processes and impact of these efforts should be evaluated with time.

The Purpose of this Research

This report explains why a comprehensive, whole-of-government commitment should be pursued to ensure every dwelling in Canada possesses a present, functioning smoke alarm. Initially, three sets of findings with respect to smoke alarms are outlined:

- The presence of functioning smoke alarms saves lives.
- The functionality of smoke alarms deteriorates with time, meaning that they need to be tested on a regular basis.
- It is possible to increase the likelihood of a present, functioning smoke alarm in the event of a fire. However, this third point has the caveat that typical approaches that have positively influenced the presence of functioning smoke alarms have suffered from a lack of an unconditional, systematic, ongoing commitment, meaning that positive impacts typically diminish with time and the problem re-emerges.

With these three findings in mind, the research poses the challenge of ensuring that smoke alarm presence and functionality is monitored in a comprehensive, consistent, ongoing manner, with some potential mechanisms for achieving this outcome proposed. Two key challenges to achieving this objective, along with some potential solutions to these issues are discussed:

1. Making an ongoing commitment to ensuring present, functioning smoke alarms in every residence. A range of strategies exist to meet this challenge, including the use of positive and negative incentives, inter-agency approaches, and leveraging existing resources; and
2. Applying a consistent approach that can be evaluated for impact, taking into account future risk.

Background Information About Smoke Alarms

The three types of smoke alarms are ionization, photoelectric, and combination alarms, and these can be hard-wired, battery powered, portable and powered by electrical outlets, or hard-wired with battery back-up [1]. It is recommended that smoke alarms are placed near sleeping locations, with at least one alarm on every level of a home [1]. Smoke alarms, which do not continue to function forever, “should be installed, maintained, and tested according to the manufacturer’s instructions and should be replaced at least every 10 years” [1: 100]. In addition to this, those alarms that do not use 10-year lithium batteries should have their batteries replaced annually, and smoke alarms generally should be tested on a monthly basis [1].

The Positive Impact of Present and Functioning Smoke Alarms

This section examines the positive impact a present, functioning smoke alarm can have with respect to reducing fire-related fatality and reducing the extent of property damage as a consequence of fire.

Smoke Alarms Reduce Fatality

Data was extracted from reports produced by the Alberta (AB) Emergency Management Agency [2-6], and requests for data were responded to by the British Columbia (BC) Office of the Fire Commissioner and the Ontario (ON) Office of the Fire Marshal. The AB data covered fire incidents that occurred between 2006 and 2009, while the data extracts provided for BC and ON included fire incidents reported over the 5 years between October 2006 and October 2011. As displayed in Table 1, 47,555 residential structure fires were identified through this process. Averaged across the data sets from each province, 36.2% (n = 17,214) of these

residential structure fires had a present, functioning smoke alarm. Overall, this data set included 663 deaths, 75.4% of which resulted from fire incidents in the absence of present, functioning smoke alarms. The average death rate per 1,000 fires without a present, functioning smoke alarm (16.5 deaths per 1,000 fires, for 30,341 residential structure fires) was 74.0% greater than the death rate per 1,000 fires with a present, functioning smoke alarm (9.5 deaths per 1,000)¹. As a result, it can be assumed that the presence of functioning smoke alarms in all cases would have saved 41.4% of the lives that were lost: a total of 203 lives. This would have represented an approximate saving of 42.5 lives per year, reducing the annual rate of residential structure fire deaths from 132.6 per year to 90.1 per year across these three provinces: a 32.1% reduction in annual fatalities. Given that the 2006 Canadian census estimated that AB, BC, and ON represent approximately 61.9% of the national population, assuming these patterns remained constant, 100% coverage of functioning smoke alarms could be expected to prevent around 69 deaths per year in Canada.

TABLE 1. FREQUENCY OF RESIDENTIAL STRUCTURE FIRES, DEATHS, AND DEATH RATE PER 1,000 FIRES BY SMOKE ALARM STATUS, 5-YEARS OF DATA COMBINED FROM AB*, BC, AND ON

Smoke alarm status	Alarm status sub-category	# fires	% fires	# deaths	% deaths	Deaths per 1,000 fires
Present and functioning		17,214	36.2%	163	24.6%	9.5
Not present and functioning	Alarm present, not activated	8,210	17.3%	114	17.2%	13.9
	No alarm	10,549	22.2%	143	21.6%	13.6
	Cannot be determined	11,582	24.4%	243	36.7%	21.0
	<i>Sub-total</i>	<i>30,341</i>	<i>63.8%</i>	<i>500</i>	<i>75.4%</i>	<i>16.5</i>
Total		47,555	100.0%	663	100.0%	13.9

* The AB data was extracted from published reports, from 2006 to 2009 [2-6], while the BC and ON data were provided by the Fire Commissioner and Fire Marshal of those provinces, upon request

These findings regarding the life-saving impact of smoke alarms based on BC data parallel the consistent findings from analysis of the US National Fire Incident Reporting System (NFIRS), which has demonstrated mortality rates in the presence of functioning smoke alarms range between 40-50% lower than for fires in homes without functioning alarms [1]. Furthermore, research undertaken by the National Institute of Standards and Technology (NIST) Fire Research Division also demonstrated that functioning smoke alarms improve response times to fire, thus dramatically reducing the time required to escape [7].

Warda and Ballesteros [1] discuss a range of demographic characteristics that have typically been used to target smoke alarm distribution campaigns to high-fire-risk areas. These are summarized as “communities or households with at least one risk factor, including increased rates of residential fires or fire-related injury/death or low prevalence of smoke alarm use, households with at least one young child or older adult, low-income areas, and high proportion of rental units” [1: 106]. In addition to this, community rurality and persons with disabilities (mental or physical) are also risk factors that have been demonstrate to increase the likelihood of death/injury from fire [1].

There is also an indication from the BC data that there is increased risk of fatality from fire for First Nations Bands, with the 137 residential structure fires reported by First Nations in BC during the period of interest resulting in 5 deaths, at a rate of 36.5 deaths per 1,000 residential structure fires. Compared to the death rate

¹ The death rate per 1,000 fires in the presence of a functioning smoke alarm was significantly lower than the death rate per 1,000 fires in all other smoke alarm status: $Z = -6.14, p < .0001$.

of 15.1 deaths per 1,000 fires for the remainder of BC, the death rate from residential structure fires for BC First Nations bands was 2.4 times greater than for the remainder of the province. None of these deaths occurred in the presence of a functioning smoke alarm.

From a demographic perspective, additional analysis of the available information about fire fatalities in the BC data set revealed the following summary trends:

- Fire fatalities were more likely to have been male (54.7%), and elderly victims were over-represented in the fire fatalities in BC, relative to the percentage they comprise of the whole population: 31.6% of the fire deaths, where the age was known were aged 65 years and over (unknown $n = 34$), compared with 15.0% of the total BC population in 2010 [8].² Both of these demographic characteristic findings are consistent with previous research focused on high-risk demographic characteristics for fire fatality [9].

TABLE 2. CONDITION OF RESIDENTIAL STRUCTURE FIRE FATALITIES, BC DATA, OCT 2006 – OCT 2011

Condition of casualty	Activated smoke alarm			No activated smoke alarm		
	# deaths	% deaths	Avg. Age*	# deaths	% deaths	Avg. Age*
010 - Condition of casualty unknown	12	34.3%	61	62	45.9%	52
011 - Asleep at time of fire	9	25.7%	43	33	24.4%	48
012 - Bedridden or other physical handicap	0	0.0%	na	3	2.2%	61
013 - Impairment alcohol/drugs	5	14.3%	47	21	15.6%	48
014 - Awake, no physical/mental impairment	5	14.3%	79	8	5.9%	70
016 - Too young to react to fire emergency	1	2.9%	1	0	0.0%	na
018 - Child left unattended	2	5.7%	5	1	0.7%	1
019 - Unclassified	1	2.9%	na	7	5.2%	50
Total	35	100.0%	52	135	100.0%	51

* Unknown ages were excluded from this calculation.

- Fire deaths for victims who were under the influence of alcohol/drugs and/or asleep at the time of the fire were more likely without a functioning alarm (see Table 2). After the unknown conditions of the casualties were removed, 21.7% of deaths in the presence of activated smoke alarms occurred when the fatality had been impaired by alcohol/drugs and 39.1% of the time the victims had been asleep. In comparison, when the unknown conditions were removed from the deaths in the absence of an activated smoke alarm, 28.8% of the victims had been impaired and 45.2% had been asleep at the time of the fire. It is reasonable to assume that a functioning alarm would help to alert people who are in these states.
- Fire fatalities were more likely to have not acted to the fire in the absence of a functioning smoke alarm (see Table 3). After the unknown actions of the casualties were removed, 33.3% of deaths in the presence of activated smoke alarms occurred when the fatality had been attempting to escape. 22.2% of the victims suffered a loss of judgement/panic, and 22.2% did not act. In contrast, when the unknown actions were removed, 29.7% of the fatalities in fires where there was no functioning smoke alarm had been attempting to escape, 10.9% suffered a loss of judgement/panic, and 31.3% did not act.

² Importantly, this BCStats report, *Overview of the BC and regional population projections 2011 to 2036* also indicates that this age group is going to increase to 23.7% of the BC population by 2036.

TABLE 3. ACTION OF RESIDENTIAL STRUCTURE FIRE FATALITIES, BC DATA, OCT 2006 – OCT 2011

Action of casualty	Activated smoke alarm			No activated smoke alarm		
	# deaths	% deaths	Avg. Age*	# deaths	% deaths	Avg. Age*
020 - Action of casualty unknown	17	48.6%	56	71	52.6%	51
021 - Injured while attempting escape	6	17.1%	59	19	14.1%	50
022 - Over-exertion, heart attack	0	0.0%	na	2	1.5%	71
023 - Voluntarily enter/remain rescue	1	2.9%	44	3	2.2%	57
024 - Voluntarily enter/remain fire fighting	1	2.9%	18	1	0.7%	64
025 - Voluntarily enter/remain save personal property	0	0.0%	na	1	0.7%	1
026 - Loss of judgement/panic	4	11.4%	55	7	5.2%	47
027 - Received delayed warning	0	0.0%	na	5	3.7%	59
028 - Did not act	4	11.4%	33	20	14.8%	52
029 - Unclassified	2	5.7%	44	6	4.4%	50
Total	35	100.0%	52	135	100.0%	51

* Unknown ages were excluded from this calculation.

- Fire fatalities were more likely to have died as a consequence of smoke inhalation in the absence of a functioning smoke alarm (see Table 4). When unknown causes of death were removed from the calculations, 64.0% of deaths in the presence of a functioning smoke alarm occurred due to smoke inhalation, and 28.0% resulted from burns from fire/flames. In comparison, when the unknown cases were removed, 81.8% of deaths in the absence of a functioning smoke alarm occurred due to smoke inhalation, and 13.0% resulted from burns from fire/flames.³

TABLE 4. CAUSE OF RESIDENTIAL STRUCTURE FIRE FATALITIES, BC DATA, OCT 2006 – OCT 2011

Cause of casualty	Activated smoke alarm			No activated smoke alarm		
	# deaths	% deaths	Avg. Age*	# deaths	% deaths	Avg. Age*
100 - Smoke inhalation	16	45.7%	51	63	46.7%	47
101 - Burns resulting from fire/flames	7	20.0%	46	10	7.4%	60
102 - Burns resulting hot substances	0	0.0%	na	1	0.7%	86
104 - Injury caused by falls	1	2.9%	33	0	0.0%	na
107 - Unclassified	1	2.9%	na	3	2.2%	62
108 - Unknown	10	28.6%	61	58	43.0%	53
Total	35	100.0%	52	135	100.0%	51

* Unknown ages were excluded from this calculation.

Overall, there is suggestion from this pattern of results, that the presence of a functioning smoke alarm could have prevented deaths in fires where the fatality was asleep and/or under the influence of drugs/alcohol at the time.

³ Available data from the Alberta Fire Commissioner indicated that, based on probable causes of death, smoke inhalation accounted for 57% of all fire fatalities in 2009, [2] Alberta Emergency Management Agency, *Alberta Fire Commissioner's Statistical Report, 2009*, Government of Alberta.

Smoke Alarms Reduce Property Damage

Fires in the presence of active smoke alarms suffered an average of \$61,647 damage, compared to \$76,192 damage in the absence of a functioning smoke alarm: an average reduction of \$14,545.⁴ Extrapolated to the 7,695 residential structure fires that did not have functioning alarms, should alarms have been installed at these locations, almost \$112 Million in fire losses could have been prevented. These estimated savings are also likely a conservative under-estimate of the damages covered by insurance companies, given that these figures do not include any estimate of the costs associated with personal injury and life insurance.

Table 5 provides some insight into why fires in the presence of active smoke alarms resulted in less average property damage. As can be seen, fires in the presence of functioning alarms were more likely to be contained, with 42.8% restricted to the object of origin (relative to 29.5% of fires that occurred in the absence of a functioning smoke alarm). At every level of extent of fire spread recorded by post-fire incident reports, fires were more likely to have been contained if there was a functioning smoke alarm on scene. These differences were significant at each level of the extent of fire, with fires in the presence of functioning smoke alarms significantly more likely to have been contained to the object, part of room, and room of origin (all Z 's > 4.6, where critical $Z = 1.96$), and fires in the absence of a present, functioning alarm were significantly more likely to have extended to each level beyond the room of origin (all Z 's > -6.8, where critical $Z = -1.96$).

TABLE 5. FREQUENCY, PERCENTAGE AND CUMULATIVE PERCENTAGE OF RESIDENTIAL STRUCTURE FIRES IN BC BETWEEN OCT 2006 TO OCT 2011 BY EXTENT OF FIRE SPREAD AND SMOKE ALARM STATUS

Extent of fire	Present, functioning alarm			Not present, functioning alarm			Z-score
	# fires	% fires	Cumulative %	# fires	% fires	Cumulative %	
1. Confined to object of origin	1,451	42.8%	42.8%	2,268	29.5%	29.5%	13.7
2. Confined to part of room/area of origin	951	27.9%	70.7%	1,828	23.8%	53.2%	4.6
3. Confined to room of origin	388	11.4%	82.0%	574	7.5%	60.7%	6.3
4. Confined to floor level of origin	174	5.1%	87.1%	481	6.3%	66.9%	-2.4
5. Confined to building of origin	360	10.6%	97.7%	1,922	25.0%	91.9%	-19.9
6. Extended beyond property of origin	55	1.6%	99.4%	460	6.0%	97.9%	-12.6
7. Confined to roof/attic space	22	0.6%	100.0%	162	2.1%	100.0%	-6.8
Total	3,401	100.0%		7,695	100.0%		

The Likelihood of a Present, Functioning Alarm Diminishes with Time

McCormick [10] examined a sample of 20-years of structure fire data from Surrey, BC, and discovered two important trends with respect to smoke alarms. First, the frequency at which smoke alarms were installed in dwellings that experienced residential structure fires increased from fewer than 60% of dwellings in 1988 to almost 81% of dwellings in 2007. Simultaneously, however, the percentage of these residences that possessed a functioning smoke alarm declined from around 60% in 1988 to around 30% in 2007. Further evidence for the importance of maintaining smoke alarms is provided by the experiences of Bremerton Fire Department, Washington, who discovered initial benefits of a smoke alarm installation campaign diminished with time as a

⁴ Independent samples t -test indicated this difference is non-significant, $t = 1.09$, $p = .28$. This reflects the large within-group variation for loss estimates.

result of fires occurring in high turn-over, rental properties where smoke detector functionality had not been monitored [11, Case Study 65, by Jones].

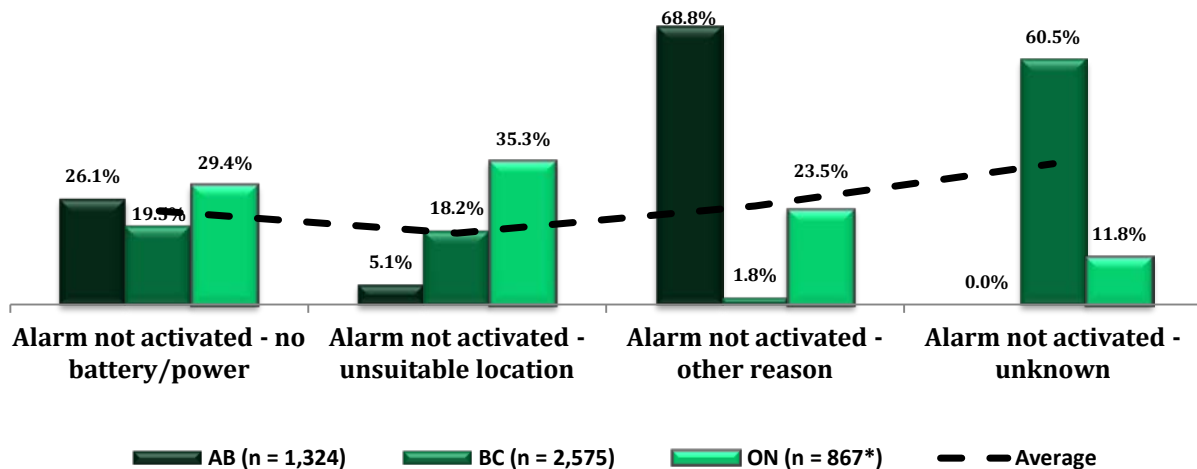
These findings are consistent with a range of other research findings into smoke alarm functionality. For example, a 1993 National Smoke Detector Project Survey found that 20% of installed smoke alarms are non-functioning, and the most commonly identified reason that alarms failed to function were dead/removed batteries and disconnection (often in response to frequent nuisance alarm activation⁵) [1]. It is also important to note here that studies have demonstrated that while 10-year lithium batteries are significantly more likely to be functioning correctly when checked at follow-up after installation, a significant proportion of these alarms were non-functioning 15-months post-installation [12].

Looking once again at the fires from the AB, BC, and ON data sets, in 17.3% of fires a smoke alarm was present but did not activate. Grouping across jurisdictions to enable comparison, the average percentages for the reasons given as to why the alarms did not activate were:

- Power-related (either no battery/dead battery/disconnected, disabled, or off) – 23.1%;
- Unsuitable location – 17.7%;
- Other reason – 24.4%; and
- Unknown – 34.9%.

As can be seen from Figure 1 there was a wide range of these percentages between the three provinces.

FIGURE 1. RELATIVE PERCENTAGES FOR CITED REASONS AS TO WHY SMOKE ALARMS WERE PRESENT AND NON-FUNCTIONING FOR AB, BC, AND ON



* The data analyzed here for ON only included 2010 fires, as per [13]. The fires for AB and BC parallel the data presented in Table 1.

Given the likelihood that alarms will be non-functioning increases with time, it is clear that installation is only part of the issue with respect to the effectiveness of residential smoke alarms. Maintenance and ongoing monitoring of effectiveness is also crucial. An obvious process for reducing the incidence of non-functioning

⁵ Warda and Ballesteros explain that the National Smoke Detector Project recommended the incidence of these nuisance alarms could be reduced by altering the location of alarms and switching alarm types.

alarms involves routine maintenance and replacement of non-functioning alarms and alarms that have reached the end of their 10-year life expectancy [1].

Effective Strategies for Increasing the Likelihood of a Present, Functioning Smoke Alarm

In 2008, an evaluation of 20-years fire data from Surrey Fire Service, BC, was undertaken [10]. This analysis discovered that only 30% of buildings that experienced residential structure fires had functioning smoke alarms. The findings of this research led to the Surrey Fire Service implementing a firefighter-delivered, home visitation program, with a view to simultaneously disseminating fire-prevention education literature and testing smoke alarm functionality in the highest risk areas of the city, with relative risk determined by combining Canadian Census information and with the density distributions of previous fire incidents in the city. At the time of writing this paper, this campaign has been sustained for over 3 years and has reached almost 30,000 of the highest fire-risk addresses in the city, with firefighters disseminating fire-prevention literature, encouraging residents to check smoke alarms, and installing alarms where possible. Evaluation of this initiative [14] demonstrated:

- Rates of fires per 1,000 dwellings reduced in the visited addresses by over 60% relative to controls;
- Smoke alarm activation in the event of a fire increased by almost 170%;
- The frequency at which fires were contained to the object of origin increased by over 250%; and
- The average dollar loss incurred per fire reduced by over 40%.

Overall, as a result of this program, there were fewer residential structure fires, and those that did occur were smaller and residents were alerted more often by functioning smoke alarms. These findings were anticipated, however, given the findings of previous, similar initiatives undertaken in other areas. A sample of previous studies summarized in the TriData collection entitled, “Proving Public Fire Education Works” by Schaenman, Jennings and colleagues [11], include:

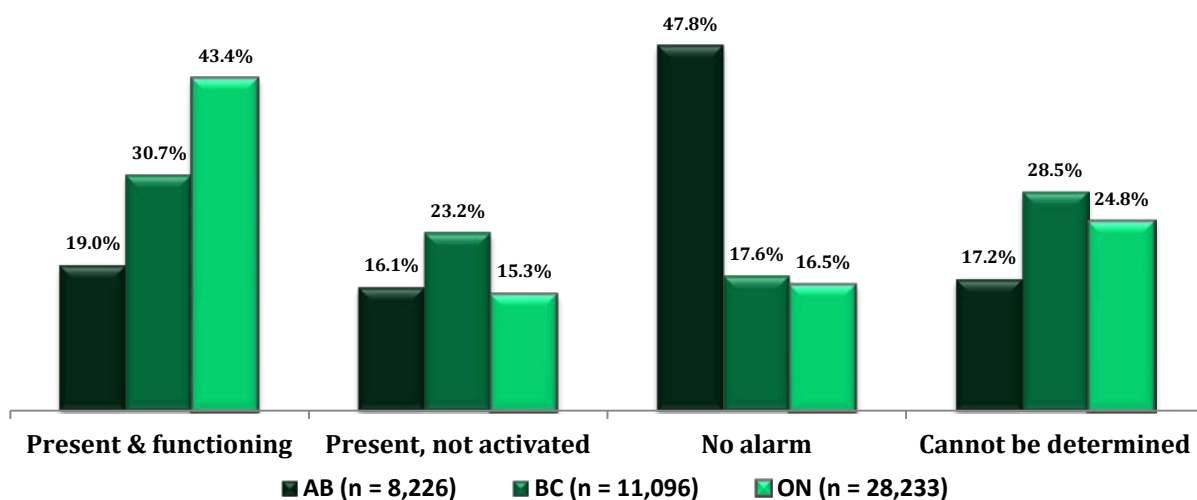
- A door-to-door, smoke alarm give-away and fire-prevention education program was completed in high-fire-risk areas of Portland, Oregon. Although these areas only housed 5% of the population, they experienced 26% of the city’s residential fire deaths. The campaign distributed around 1,000 smoke alarms and reached around 7,000 homes in the target area. No fire deaths were reported in the targeted area for at least two years following the program [11, Case Study 62, by Crawford].
- Following the implementation of legislation to require smoke alarms to be installed in all residential rental properties, a city-funded project in Louisville, Kentucky, that operated throughout the 1980’s, committed to installing smoke alarms in all residential owner-occupier properties. By 1988 this program had reached more than 30,000 dwellings in the city, and evaluation 4-years after the program commenced demonstrated a significant reduction in the average annual fire-related fatalities [11, Case Study 63, by Cummins].
- In the mid-1980’s, Rock Island, Illinois, also committed to delivering a home safety inspection, escape planning, and smoke alarm installation program. Working in partnership with local media outlets, the residents of Rock Island were actively contacting the fire department to participate in this initiative. Fire crews conducted scheduled visits to dwellings in high-risk areas, visiting 14,000 citizens (30% of the population) in 1985-86. This program lasted almost 10 years, during which time smoke alarm usage increased by almost 50% and fire-related fatality declined by 20% [11, Case Study 64, by Deardoff].

- The previously discussed smoke alarm installation program initiated by Bremerton Fire Department, Washington, in the mid-1980's demonstrated initial benefits with respect to per-capita dollar loss associated with fire. However, this program only operated for two years and gains began to diminish following the conclusion of the program [11, Case Study 65, by Jones].
- A combined approach in Montgomery County, Maryland, that involved a combination of mandated smoke alarm installation in single-family dwellings, a strong public education campaign, and enforcement for violations of the smoke alarm legislation, produced a 62% decline in fire fatalities over a 10 year period. Evaluation demonstrated that, following this campaign, Montgomery County had a lower percentage of homes without a functioning detector relative to neighbouring counties.

In addition to this, a Cochrane review undertaken by DiGuseppi and Higgins in 2000 [15] examined four published, non-randomised smoke alarm installation and distribution trials. Two of these campaigns took place in Oklahoma City, and involved targeted interventions focused at the areas experiencing the greatest rates of residential fire. Free smoke alarms and fire-prevention literature were distributed to residents in these areas. Although 6-years post-intervention fire-related injury had declined in the target areas by 81% (compared to 7% in the remainder of the city), a 4-year follow-up revealed that only 46% of the alarms were still installed and functioning [as summarized by 1]. In addition to this, recent research undertaken by Rowland et al. [12] demonstrated that nearly 50% of the smoke alarms installed in local authority housing [in the UK] were non-functional at a 15-month follow-up, with the most common reasons being that the alarm was missing (17.0%), missing a battery (19.4%), or had the battery disconnected (3.7%).

Since March 1, 2006, it has been a legislated requirement for every dwelling in Ontario to possess a working smoke alarm on every storey and outside every sleeping area. AB has equivalent legislation for smoke alarms (*Alberta Fire Code 2006*), which was amended in 2011 with respect to interconnection of alarms in secondary suits. BC implemented equivalently directed legislation on May 1, 2010, requiring smoke alarms be installed outside all sleeping areas in single family, semi-detached, and town homes, whether owner-occupied or rented [16]. However, as can be seen from Figure 2, despite the consistent legislative approach, there is a disparity in the percentage of fires that occurred in AB, BC, and ON that possessed a present and functioning

FIGURE 2. RELATIVE PERCENTAGES OF FIRES BY SMOKE ALARM PRESENCE AND FUNCTIONALITY WITHIN AB, BC, AND ON OVER A FIVE YEAR PERIOD



smoke alarm.⁶ One explanation for this pattern of results may be the compliance and enforcement strategies in effect in ON [17], which enable fire departments to issue fines under the ON *Provincial Offences Act* for failure to comply with the legislation. Further analysis would be required to examine the deterrent effect of these strategies, however, in broad terms the increased compliance in ON is supportive of punitive strategies forming part of a holistic strategy for attaining 100% coverage of functioning smoke alarms.

The combined outcome of this range of approaches, which have been successfully implemented in a diverse set of geographic and socio-economic contexts, is to confirm that it is possible to increase the likelihood of a residential dwelling possessing a functioning smoke alarm. However, the impact and effectiveness of these campaigns diminishes without consistent support to maintain alarm functionality and to monitor the shifting pattern of risk within an area over time.

Summary of Main Findings

Smoke alarms have been demonstrated to save lives, reduce fire-related injury, reduce the spread of fires, and reduce the damage of fires. Canadian data from three provinces has revealed that the rate of fire deaths significantly increases without a functioning smoke alarm. Furthermore, casualty information produced patterns consistent with previous research about high-risk sections of the community, with respect to age and substance use, and also demonstrated some qualitative differences between reasons why victims died in the presence and absence of a functioning smoke alarm. Finally, the spread of fires was significantly reduced in the presence of a functioning smoke alarm.

However, these findings in a general sense are not news, as they mirror patterns demonstrated elsewhere. The additional key contribution of this paper, therefore, is to discuss the other two components to this problem. First, smoke alarm functionality deteriorates with time when left unchecked, and second, it is possible to increase the likelihood of residential properties possessing a functioning smoke alarm in the event of a fire. The key to consolidating the successes of smoke alarm installation campaigns is to ensure their longevity. Support for smoke alarm installation and functionality strategies is often unsustainable, resulting in diminishing positive impacts of programs over time stemming from a loss of funding. In some ways these programs can become victims of their own success, whereby success drops perceived demand, ignoring the findings from the research discussed, previously, about the diminishing effectiveness of smoke alarms with time. With these two sets of findings in mind, it is fundamentally important that sustainable, comprehensive initiatives are launched that aim to ensure functioning smoke alarms are present on every floor of every dwelling in every home across Canada.

To ensure long-term, ongoing change, a holistic governmental commitment is required to adopt an iterative approach to managing smoke alarm functionality, which assumes that this is a problem to be managed, rather than a one-off situation that can be solved, forever. To this end, fire prevention practice should acknowledge Tilley's [18] criticisms of the majority of problem-focused crime-prevention activity, suggesting that unsuccessful initial attempts to address problems are often too quickly and easily abandoned. Instead, Tilley suggests that practitioners should adopt an iterative, cumulative approach to managing problems in a way that parallels disease prevention research. Initially unsuccessful (or not entirely successful) strategies must be evaluated, tweaked, re-launched, and re-examined. It is important to maintain realistic expectations about what will be achieved through each individual implementation of a problem-solving cycle, because this

⁶ Z-comparisons indicated these differences in percentages of present and functioning alarms were significant between the three provinces

process is consistent with the “...application of scientific methods and science rarely comes up with quick fixes. Most initial efforts fail!” [18: 192].

There are a range of strategies that agencies can adopt that would produce increase the coverage of present, functioning smoke alarms in their communities. Some of the examples discussed above incorporated telemarketing, door-to-door deliveries in high-risk areas, and letter drops. There is also the potential to explore the contribution that negative incentives, legislation, and enforcement of violations can make. Moving beyond the fire service working in isolation, it is worth exploring the role that other key stakeholders can play in this process. Examples of these potential partners include service providers who have contact with high-risk members of communities, local media outlets, and the insurance industry. In the face of limited resources, it is possible to commence this process by targeting efforts at the highest-risk areas (individuals and geographic locations) of a community. Regardless of which approaches are adopted, the inability to provide comprehensive coverage from the outset is an insufficient reason to fail to start addressing this issue. Furthermore, regardless of which combination of these strategies is selected, the key is ongoing commitment and development of sustainable strategies that ensure maximum coverage of smoke alarms across the board.

As can be demonstrated by the evaluations of the successful efforts discussed above, it is fundamentally important that these processes are monitored and evaluated in an ongoing manner. Analysis of where the risk is within your communities will help prioritize action, and monitoring the coverage of smoke alarms and the activation in the event of fires, will help provide insight into the longitudinal effectiveness of these efforts. On a fundamental level, evaluation of activity should focus on whether the proposed strategies have been initiated and delivered successfully (process evaluation), and the impact of these activities on the overall problem associated with present and functioning smoke alarms should be measured (impact evaluation) [19].

Committing to 100% Functioning Smoke Alarm Coverage: Posing the Challenge

Given the overall pattern of results presented in this report, it is important to conclude by reemphasizing the following points:

- Smoke alarms reduce the likelihood of death from fire in residential properties – the death rate per 1,000 fires is 74% greater in the absence of a present, functioning smoke alarm.
- Smoke alarms reduce the extent to which fires spread beyond the object of origin, with implications for fire-related damage to property.
- A range of strategies have been demonstrated to increase the likelihood of properties possessing functioning smoke alarms in the event of a fire.
- The impact of these strategies will diminish with time without a sustained, multifaceted, inter-agency commitment to maintaining the focus on present, functioning alarms.

With these points in mind, and given the broad range of potential approaches to maximizing the likelihood of dwellings possessing present, functioning smoke alarms, the authors pose the challenge to those in positions of authority to ensure that smoke alarm presence and functionality is monitored in a comprehensive, consistent, ongoing manner. Every community is capable of taking up this challenge, utilizing a context-specific, appropriate methodology. Given the evidence and strategies available, there are no excuses for failing to address this issue.

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Author Biographical Information

Len Garis is the Fire Chief for the City of Surrey, B.C. and is an Adjunct Professor in the School of Criminology and Criminal Justice at the University of the Fraser Valley and a member of the Institute of Canadian Urban Research Studies, Simon Fraser University. Contact him at LWGaris@surrey.ca.

Dr Joseph Clare, strategic planning analyst for the Surrey Fire Service, is an Associate Professor in the Crime Research Centre, University of Western Australia, and a member of the Institute of Canadian Urban Research Studies, Simon Fraser University. Contact him at jclare@surrey.ca.

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