Fire Protection System(s) Performance in the Residential Building Environment:

Examining the Relationship between Civilian and Firefighter Injuries: A Retrospective Evaluation of Residential and Residential Apartment Fires, 2005 to 2015

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Executive Summary

This paper summarizes the findings from an analysis of the fire protection performance of sprinkler systems and smoke alarms in residential and multi-level residential buildings in the Provinces of British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and New Brunswick between 2005 and 2015 inclusive. The primary focus is on the relationship between the presence of protective devices, civilian and firefighter causalities, and fire containment in residential buildings.

In all, 439,256 fire incidents are analyzed with a focus on key characteristics of structural fire incidents (e.g., fire spread and fire department intervention) as well as fire-related casualties (i.e., deaths and persons injured) resulting from those incidents. A total of, 1,736 fire-related deaths (10 among firefighters) and 12,682 persons injured (3,308 among firefighters) were reported over the ten years under review.

A total of 129,901 fire incidents classified as "residential use" were examined by overall frequencies of fires, injuries, deaths, frequency the fire department was reported to have extinguished the fire, and the frequency the fire spread beyond the room of origin by the fire protection systems performance. There were 1,418 fire-related deaths (2 were firefighters) and 8,919 persons injured were reported over the period (1,956 were firefighters). Almost two-thirds of these residential fires had no functioning life safety system present (that is, sprinkler system or smoke alarm), and these fires resulted in 78% of the deaths.

Death and injuries were significantly less frequent in residential buildings that had sprinklers and a smoke alarm. The odds of a death in a residential building without sprinklers and no smoke alarm was 4.3 times greater than for fires in buildings with sprinklers and smoke alarm, with death rates of 2.9 per 1,000 fires in buildings with sprinklers and smoke alarm compared to 12.6 deaths per 1,000 fires in those without sprinklers and with no smoke alarm. Almost half of these residential fires had no present functioning life safety system and these fires resulted in 58.5% of the deaths. Also, fires in sprinklered residential buildings with smoke detection required far fewer departmental interventions and were contained to the room of origin 93.9% of the time.

A total of 38,453 fire incidents in structures classified as "residential apartment use," a subset of residential fires, were also examined by overall frequencies of fires, injuries, deaths, how often a fire department extinguished the fire, and the fire spread beyond the room of origin by the fire protection systems performance. When fire incidents occurred in these structures, the outcome was less serious than in other residential structures. For example, in apartments, there were 357 fire-related deaths (there were no firefighter deaths) and 3,799 persons injured were reported over 10 years (662 were firefighters).

Again, death and injuries were notably less frequent in apartment buildings that had sprinklers and a smoke alarm. The odds of a death in a residential building fire where neither smoke alarms or sprinklers were present was 3.2 times greater than for fires in buildings with

sprinklers and smoke alarms. Furthermore, death rates were 3.3 per 1,000 fires in buildings with sprinkler and smoke alarms compared with 10.6 deaths per 1,000 fires in buildings without sprinklers or smoke alarms. Fires in sprinklered residential apartment buildings with smoke detection were contained to the room of origin 93.5 % of the time, and only required fire department intervention to extinguish the fire in 35.5 % of the incidents as opposed to close to half of the fires in buildings without alarms or sprinklers.

The retrospective research in this study and in the referenced research was not able to establish a benefit from the additional provisions in the Ontario Building Code that will improve the safety of civilians, firefighters or buildings to warrant these provisions. Clearly fire spread in like buildings to midrise (n=38,453) over a 10-year span was contained to the room of origin 93.5% of the time and seldom progressed beyond the floor of origin. It was not possible to find an incident where a floor or building collapsed in a fully sprinklered building. Finally, since such a large portion of the fires rarely spread beyond the room of origin and even less beyond the floor of origin, in reference to this we believe that fire-resistance rated exit stair shafts made of combustible construction are unlikely to become a factor for concern.

Purpose

This study examines the performance of fire safety systems—specifically, smoke alarms and sprinkler systems—in residential and multi-level residential buildings in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and New Brunswick between 2005 and 2015 inclusive. Remaining other provinces did not participate in the NFID data submissions.

Of primary interest is the performance of fire safety systems in the residential apartment building environment. Our intent is to identify how those systems performed and then relate the performance to that of mid-rise building, specifically being attentive to;

- fire spread into exit stair shafts using combustible construction,
- fire spread into elevator shafts,
- Integrity of stair shaft and the potential of floor collapse.

While historical patterns are informative in themselves, they can also provide some guidance as to what we might observe going forward. By focusing on fire incidents in past and current structures we may gain insights into potential vulnerabilities in future structures, including midrise wood-frame construction. Debate continues in some jurisdictions as to the relative fire-risks posed by mid-rise structures using combustible construction.

Specifically, provisions made to the *British Columbia Building Code* (BCBC) in January 2009 and in the *National Building Code of Canada* (2015) allowed for mid-rise, residential buildings of up to 6 stories in height be built using combustible construction. These provisions were adopted mostly across Canada with exception of the Provinces of Ontario and Quebec. These two provincial fire services have expressed safety concerns should a fire advance that would create

additional risks due to potential collapse and or/endangering civilian evacuation and advancing fire service operations.

Identifying Relevant Cases for Analyses

The data presented in this study were obtained from the National Fire Incident Information Data Base (NFID) assembled by Statistics Canada on behalf of the Canadian Association of Fire Chiefs and the Canadian Association of Fire Commissioners and Fire Marshalls.

The NFID database contains information on 439,256 fire incidents. Among those are 205,332 structure fire incidents where we can examine some key characteristics of those incidents (such as, fire spread and fire department intervention) as well as fire-related casualties (that is, deaths and persons injured) resulting from incidents. In total, 1,733 fire-related deaths (10 were firefighters) and 12,503 persons injured (1,956 were firefighters) were reported in structural fires over the ten-year period covered by the data.

There were three considerations used to identify the relevant cases for this analysis. First, the overall set of 205,332 structure fire incidents was sorted to select only those incidents involving a property classified as "Residential Use" then a sub-set of an "Apartment, Tenement, Flat, Townhouse, or Condominium" was identified. Strictly commercial and other structures were excluded. Second, selection was based on the presence and functionality of fire protection systems across buildings—specifically, sprinkler systems and smoke alarms. In some cases, the presence or operation of those mechanisms at the time of the fire may have been coded as blank or unknown. Those incidents were filtered with the assumption they did not function at the time of the incident. Third, 507 incidents were omitted from the casualty information because there was missing information.

From this screening process involving properties classified as "Residential Use," 129,910 incidents were retained. These were examined based on the frequencies of fires, injuries, deaths, how often the fire department was reported to have extinguished the fire, and the frequency of the fire spread beyond the room of origin by the fire protection system performance.

Fires Classified as Residential Use

Fires classified in "residential use" structures include such structural categories as row housing, garden homes, town houses, condominiums, apartments, tenements, hotels, motels, lodges, hostels, boarding houses, dormitories, single detached houses, duplexes, 3-plexes, semi-detached, educational institutions, camps/RV parks, mobile homes, trailer parks, up to 3 storys.

TABLE 1: FIRES, FIRE-RELATED DEATHS, INJURIES, FIRE DEPARTMENT INVOLVEMENT AND EXTENT OF FIRE SPREAD IN STRUCTURES CLASSIFIED AS RESIDENTIAL USE, 2005 TO 2014.

Smoke Alarm Working	Partial and/ or Full Sprinkler	Fires (%)Total	Injuries (%)Total	Injury Rate per 1,000 Fires (95% CI)	Death (% Total)	Death Rate per 1,000 fires (95%CI)	% Fire Department Extinguish (95% CI)	% Beyond Room of Origin (95% CI)
Yes	Yes	2,054	169	82.3	6	2.9	33.5%	6.1%
		1.6%	*1.9%*	*(70.4 - 94.2)*	*0.4%*	*(0.6 - 5.3)*	*(25.8% - 41.3%)*	*(2.7% - 9.4%)*
No	Yes	1,526	92	60.3	6	3.9	34.9%	14.4%
		1.2%	*1.0%*	*(48.3 - 72.2)*	*0.4%*	*(0.8 - 7.1)*	*(25.7% - 44.1%)*	*(8.4% -20.3%)*
Yes	No	38,750	3,704	95.6	303	7.8	43.2%	12.7%
		29.8%	*41.5%*	*(92.7 - 98.5)*	*21.4%*	*(6.9 - 8.7)*	*(41.2% - 45.2%)*	*(11.6% - 13.8%)*
No	No	87,580	4,954	56.6	1,103	12.6	43.9%	21.9%
		67.4%	*55.5%*	*(55.0 - 58.1)*	*77.8%*	*(11.9 - 13.3)*	*(42.6% - 45.3%)*	*(21.0% - 22.9%)*
Total		129,910	8,919	68.7	1,418	10.9	43.4%	18.8%
		100%	*100%*	*(67.3 - 70.0)*	*100.0%*	*(10.4 - 11.5)*	*(42.3% - 44.5%)*	*(18.1% - 19.6%)*

Table 1 summarizes fire-related casualties, fire department involvement and fire spread by whether there was a functional smoke alarm or sprinkler system present. Briefly, Table 1 shows that:

- almost two-thirds of these residential fires had no present functioning life safety system—that is, no functioning smoke alarm or sprinkler system— and these fires resulted in 78% of the deaths;
- fires in structures with a life safety system in place—fires with a working smoke alarm and complete sprinkler protection—are much less likely to result in death (2.9 per 1,000 vs. 10.9 per 1,000 overall), less likely to require fire department intervention (33.5% vs. 43.4% overall), less likely to extend beyond the room of origin (6.1% vs. 18.8% overall); and,
- the compound effect of both sprinkler protection and working smoke alarm, required the least amount of fire department intervention and these fires resulted in only 6 deaths and did not extend past the room of origin 93.9 % of the time.

TABLE 2: SEVERITY OF CASUALTIES, INCLUDING INJURY RATES FOR CIVILIAN AND FIREFIGHTERS, FIRE-RELATED CIVILIAN DEATHS, INJURIES, FIRE-RELATED FIREFIGHTER INJURIES AND DEATHS IN STRUCTURES CLASSIFIED AS RESIDENTIAL USE, 2005 TO 2014.

			Civilian		Firefighter		Civilian		Firefighter	
Smoke Alarm Working	Partial and/ or Full Sprinkler	Fires (%) Total	Injuries (%) Total	Injury Rate per 1,000 Fires (95% CI)	Injuries (%) Total	Injury Rate per 1,000 Fires (95% CI)	Death (%) Total	Death Rate per 1,000 fires (95% CI)	Death (%) Total	Death Rate per 1,000 fires (95% CI)
Yes	Yes	2,054	146	71.1	23	11.2	6	2.9	0	0.0
		1.6%	*2.1%*	*(60.0 - 82.2)*	*1.2%*	*(6.6 - 15.7)*	*0.4%*	*(0.6 - 5.3)*	*0.0%*	*0.0*
No	Yes	1,526	82	53.7	10	6.6	6	3.9	0	0.0
		1.2%	*1.2%*	*(42.4 - 65.0)*	*0.5%*	*(2.5 - 10.6)*	*0.4%*	*(0.8 - 7.1)*	*0.0%*	*0.0*
Yes	No	38,750	3,028	78.1	676	17.4	289	7.5	0	0.0
		29.8%	*43.5%*	*(75.5 - 80.8)*	*34.6%*	*(16.1 - 18.7)*	*21.5%*	*(6.6 - 8.3)*	*0.0%*	*0.0*
No	No	87,580	3,706	42.3	1,247	14.2	1,044	11.9	2	0.023
		67.4%	*53.2%*	*(41.0 - 43.6)*	*63.8%*	*(13.5 - 15.0)*	*77.6%*	*(11.2 - 12.6)*	*100.0%*	*(-0.009 - 0.054)*
Total		129,910	6,962	53.6	1,956	15.1	1,345	10.4	2	0.015
		100%	*100.0%*	*(52.4 - 54.8)*	*100.0%*	*(14.4 - 15.7)*	*100.0%*	*(9.8 - 10.9)*	*100.0%*	*(-0.006 - 0.037)*

Table 2 indicates that:

- two firefighter deaths occurred where there was not a functioning fire protection system with no firefighter deaths when either a smoke alarm, sprinkler system or both were functioning at the time of a fire;
- firefighter injures were less likely in the presence of a working fire protection system such as a combination of sprinkler protection and smoke alarm (1.2%), sprinkler system (0.5%), smoke alarm (34.6%) as opposed to no working system (63.8%); and,
- civilian injuries were reported to a lesser extent in the presence of a working fire protection system such as a combination of sprinkler protection and smoke alarm (2.1%), sprinkler system (1.2%), smoke alarm (43.5%) as opposed to no working system (53.6%).

To gain further insight into the severity of the injuries sustained, an analysis was conducted based on an injured victim's length of hospitalization. Those results are presented in Table 3.

TABLE 3: SEVERITY OF INJURIES BY INJURY RATES FOR CIVILIAN AND FIREFIGHTERS, IN COMBINATION OF A WORKING SMOKE ALARM AND OR SPRINKLER SYSTEM IN STRUCTURES CLASSIFIED AS RESIDENTIAL USE, 2005 TO 2014.

		Civilian Injuries (n = 6,927)				Firefighter Injuries (n =1,956)			
	Smoke Alarm Working	Yes	No	Yes	No	Yes	No	Yes	No
	Sprinkler Present	Yes	Yes	No	No	Yes	Yes	No	No
Severity Of Injury	Minor < 1 day in Hospital / off work	80	45	2,044	2,205	10	7	549	971
	(% Total)	*54.8%*	*54.9%*	*67.6%*	*60.0%*	*43.5%*	*70.0%*	*81.2%*	*77.9%*
	Light 1-2 days in Hospital and/ or off work 1-15 days	51	30	377	558	13	3	25	88
	(% Total)	*34.9%*	*36.6%*	*12.5%*	*15.2%*	*56.5%*	*30.0%*	*3.7%*	*7.1%*
	Serious ≥ 3 days in Hospital and/ or off work 15 days	15	7	604	911	0	0	102	188
	(% Total)	*10.3%*	*8.5%*	*20.0%*	*24.8%*	*0.0%*	*0.0%*	*15.1%*	*15.1%*
	Total	146	82	3,025	3,674	23	10	676	1,247
	(% Total)	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*
	InJury Rate per 1,000 fires	71.1	53.7	78.1	42.0	11.2	6.6	17.4	14.2

Note: An additional 35 incidents, 32 had no working smoke alarm and no sprinkler, and 3 working smoke alarm and no sprinkler displayed. Civilian injuries of unknown seriousness are not included in this analysis.

Table 3 indicates that:

- in the presence of, and with the combination of a sprinkler and a working smoke alarm, both civilian and firefighter injuries represented the lowest number of total injuries at 2% (n= 146) and 1% (n=23) respectively. As might be expected, fire fighter injuries were notably less severe than those of civilians;
- the presence of a sprinkler without a smoke alarm produced the lowest total injuries to both civilians and firefighters; and,
- by far the greatest risk of injury to civilians and firefighters is posed when neither a smoke alarm nor a sprinkler is present

Fire Performance – Extent of Fire Spread

Methods of fire control can be expressed by the extent of how much damage occurs as the fire advances. There were some notable differences in the extent to which the fires spread between sprinkler-controlled fires and the fires that occurred in buildings without sprinkler protection. The main results, based on the percentages indicated in Figure 1 and 2 are as follows:

FIGURE 1: EXTENT OF FIRE SPREAD FOR SPRINKLER PROTECTED BUILDINGS BY PROPERTY CLASSIFICATION.

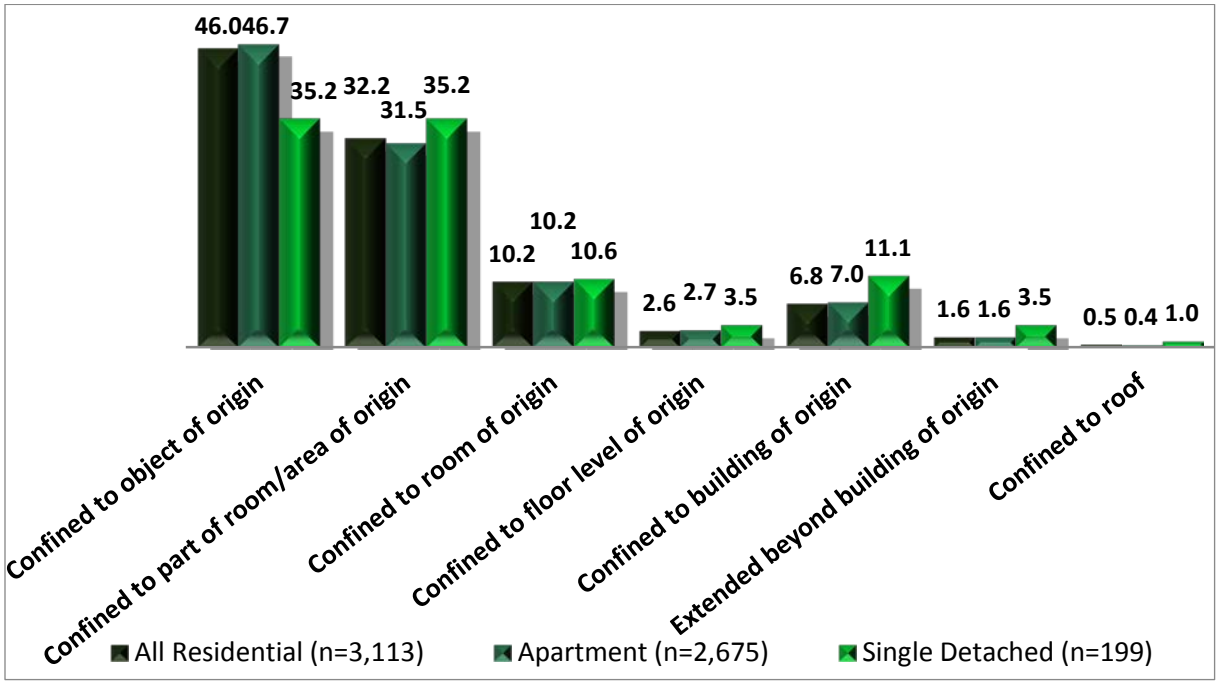
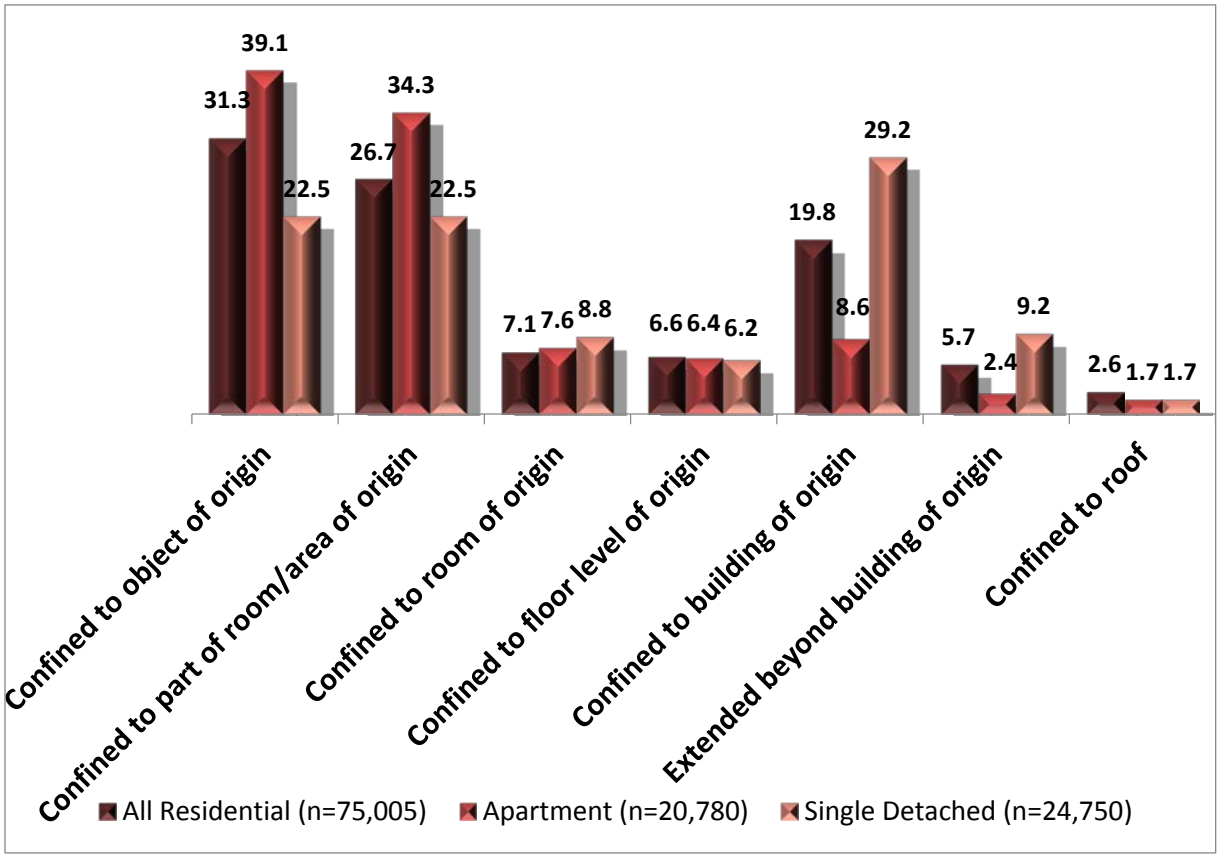


Figure 1: Which presents data for buildings protected by sprinklers, shows that fires in all residential use buildings containing sprinklers were confined to the room of origin 93.9% of the time. In most instances, the fire was confined either to the object of origin or to part of the room where it started. This pattern was only slightly less pronounced for fires in apartment buildings where 93.5% of fires in buildings controlled by sprinklers were confined to at least the room of origin.

It is instructive to compare Figures 1 and 2. The bars in Figure 1 represent results for buildings *with* sprinklers installed. Figure 2 presents the same results for buildings *without* a sprinkler system installed. We can see that in all residential fires in buildings controlled by sprinkler systems, fires were less likely to extend past the floor of origin (9%) compared with fires in buildings without sprinklers (28%), this is calculated by adding the categories "confined to the building of origin" and "extended beyond the building of origin". The difference for apartment fires was generally less at 9% and 12% respectively, but was more pronounced for fires in single detached dwellings at 15.6% and 40% respectively. It should be noted, however, that sprinkler installations in single detached buildings are uncommon.

In all other observations of extension of fire, there was an increased likelihood of the fire spreading from to the building, beyond the building, and not being confined to the roof for fires in buildings *without* sprinkler protection as opposed to those *with* sprinkler protection.

FIGURE 2: EXTENT OF FIRE SPREAD FOR BUILDINGS WITHOUT SPRINKLER PROTECTION, BUILDINGS BY PROPERTY CLASSIFICATION.



Fires in Residential Apartment Use

Residential apartment use typically includes buildings providing living quarters for families living independently of each other with independent cooking facilities. These may be designated as apartment houses, tenements, garden apartments, townhouses, or row houses. Apartment hotels are classified as a separate group because they are potentially subject to transient occupancy like that of hotels. These structures typically have multiple units and may or may not have a business occupant.

From the NFID dataset, we combined two variables, major occupancy (n=24,486) and property ((n=36,214) information), to capture all apartments, townhouses, condominiums, and tenements. Overlapping data was calculated as a single fire incident, with a final combined count of 40,653 residential apartment fire incidents.

Among the 40,653 residential apartment fire incidents contained in the data base, 2,200 incidents were classified as unknown in one or more categories; consequently, 38,453 were retained in this analysis.

TABLE 4: FIRES, FIRE RELATED CAUSALITIES DEATHS, INJURIES, FIRE DEPARTMENT INVOLVEMENT AND EXTENT OF FIRE SPREAD CLASSIFIED AS RESIDENTIAL APARTMENT USE, 2005 TO 2014.

Smoke Alarm Working	Partial and/ or Full Sprinkler	Fires (%)Total	Injuries (%)Total	Injury Rate per 1,000 Fires (95% CI)	Death (% Total)	Death Rate per 1,000 fires (95%CI)	% Fire Department Extinguish (95% CI)	% Beyond Room of Origin (95% CI)
Yes	Yes	1,807	145	80.2	6	3.3	33.5%	6.5%
		4.7%	*3.8%*	*(67.7 - 92.8)*	*1.7%*	*(0.7 - 6.0)*	*(25.2% - 41.8%)*	*(2.8% - 10.2%)*
No	Yes	1,312	78	59.5	4	3.0	34.1%	13.9%
		3.4%	*2.1%*	*(46.7 - 72.2)*	*1.1%*	*(0.1 - 6.0)*	*(24.3% - 44.0%)*	*(7.6% - 20.3%)*
Yes	No	15,649	1,836	117.3	138	8.8	36.2%	6.7%
		40.7%	*48.3%*	*(112.3 - 122.4)*	*38.7%*	*(7.4- 10.3)*	*(33.2% - 39.1%)*	*(5.5% - 8.0%)*
No	No	19,685	1,740	88.4	209	10.6	33.4%	13.0%
		51.2%	*45.8%*	*(84.4 - 92.4)*	*58.5%*	*(9.2 - 12.0)*	*(30.9% - 35.9%)*	*(11.4% - 14.6%)*
Total		38,453	3,799	98.8	357	9.3	34.6%	10.2%
		100%	*100%*	*(95.8 - 101.8)*	*100.0%*	*(8.3 - 10.2)*	*(32.7% - 36.4%)*	*(9.2% - 11.2%)*

Note: 234 cases had missing injury data and 66 cases had missing sprinkler data, these cases were excluded from analysis

The distribution of fires, fire-related causalities or deaths, injuries, fire department involvement and extent of fire spread in residential apartments by whether there was a fire alarm or sprinkler system is presented in Table 4.

Briefly, Table 4 indicates that:

- slightly over half of these residential fires had no present functioning life safety system and these fires resulted in 58.5% of the deaths;
- relative to fires with no life safety system in place, fires in apartments with either a working smoke alarm or complete sprinkler protection are much less likely to result in death (3.3 per 1,000 vs. 9.3 per 1,000 overall) and less likely to extend beyond the room origin (6.5% vs. 10.2% overall); and,
- the compound effect of both sprinkler protection and working smoke alarm resulted in 6 deaths (out of 327 total) and required the least amount of fire department intervention, and these fires did not extend past the room of origin 93.5 % of the time.

TABLE 5: SEVERITY OF INJURIES – INJURY RATES FOR CIVILIAN AND FIREFIGHTERS, FIRE RELATED CIVILIAN DEATHS (N=340), INJURY'S (N=3,137), FIRE RELATED FIREFIGHTER INJURES (N=662), DEATHS (N=0) CLASSIFIED AS RESIDENTIAL APARTMENT USE 2005 TO 2015

			Civilian		Firefighter		Civilian		Firefighter	
Smoke Alarm Working	Partial and/ or Full Sprinkler	Fires (%) Total	Injuries (%) Total	Injury Rate per 1,000 Fires (95% CI)	Injuries (%) Total	Injury Rate per 1,000 Fires (95% CI)	Death (%) Total	Death Rate per 1,000 fires (95% CI)	Death (%) Total	Death Rate per 1,000 fires (95% CI)
Yes	Yes	1,807	126	69.7	19	10.5	6	3.3	0	-
		4.7%	*4.0%*	*(58.0 - 81.5)*	*2.9%*	*(5.8 - 15.2)*	*1.8%*	*(0.67- 6.0)*	*0.0%*	-
No	Yes	1,312	69	52.6	9	6.9	4	3.0	0	-
		3.4%	*2.2%*	*(40.5 - 64.7)*	*1.4%*	*(0.1 - 6.0)*	*1.2%*	*(0.1 - 6.0)*	*0.0%*	-
Yes	No	15,649	1,570	100.3	266	17.0	135	8.6	0	-
		40.7%	*50.0%*	*(95.6 - 105.0)*	*40.2%*	*(15.0 - 19.0)*	*39.7%*	*(7.2 - 10.1)*	*0.0%*	-
No	No	19,685	1,372	69.7	368	18.7	195	9.9	0	-
		51.2%	*43.7%*	*(66.1 - 73.3)*	*55.6%*	*(16.8 - 20.6)*	*57.4%*	*(16.8 - 20.6)*	*0.0%*	-
Total		38,453	3,137	81.6	662	17.2	340	8.8	0	-
		100%	*100.0%*	*(78.8 - 84.3)*	*100.0%*	*(15.9 - 18.5)*	*100.0%*	*(7.9 - 9.8)*	*0.0%*	-

Overall, Table 5 indicates that:

- there were no firefighter deaths in these apartment use structures regardless of whether a smoke alarm, sprinkler system or both were either present or functioning at the time of a fire;
- civilian deaths were far less likely in buildings with either both a working smoke alarm or sprinkler or a sprinkler only (3.3 per 1,000 and 3.0 per 1,000 respectively vs. 8.8 per 1,000 overall) than in situations where there was no sprinkler.
- firefighter injures were less likely in the presence of a working fire protection system such as a combination of sprinkler protection and smoke alarm (10.5 per 1,000), sprinkler system only (6.9 per 1,000), than where there was a smoke alarm only (17.0 per 1,000) as opposed to no working system (18.7 per 1,000) and,
- civilian injuries were generally undifferentiated by presence or absence, and type of fire protection system.

TABLE 6: SEVERITY OF INJURIES FOR CIVILIAN AND FIREFIGHTERS IN PRESENCE OF A WORKING SMOKE ALARM AND OR SPRINKLER SYSTEM IN BUILDINGS CLASSIFIED AS RESIDENTIAL APARTMENT USE, 2005 TO 2015

		Civilian Injuries (n = 3,137)				Firefighter Injuries (n =662)			
	Smoke Alarm Working	Yes	No	Yes	No	Yes	No	Yes	No
	Sprinkler Present	Yes	Yes	No	No	Yes	Yes	No	No
Severity Of Injury	Minor < 1 day in Hospital / or off work	70	32	1,059	860	9	7	213	294
	(% Total)	*55.6%*	*46.4%*	*67.5%*	*62.7%*	*47.4%*	*77.8%*	*80.1%*	*79.9%*
	Light 1-2 days in Hospital and/ or off work 1-15 days	43	30	158	155	10	2	11	14
	(% Total)	*34.1%*	*43.5%*	*10.1%*	*11.3%*	*52.6%*	*22.2%*	*4.1%*	*3.8%*
	Serious ≥ 3 days in Hospital and/ or off work 15 days	13	7	353	357	0	0	42	60
	(% Total)	*10.3%*	*10.1%*	*22.5%*	*26.0%*	*0.0%*	*0.0%*	*15.8%*	*16.3%*
	Total	126	69	1,570	1,372	19	9	266	368
	(% Total)	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*
	InJury Rate per 1,000 fires	69.7	52.6	100.0	69.7	10.5	6.9	17.0	18.7

Table 6 indicates that:

- where there was no sprinkler system present, both civilian and firefighter injuries were more likely to be in the *most severe* category (3 or more days in hospital or off work) than when a sprinkler system was present; and,

- by far the greater risk of injury to civilians and firefighters is when neither a smoke alarm or a sprinkler is present.

Summary and Conclusions

This study demonstrates that sprinkler protection systems in combination with smoke alarms in buildings create the best chances for civilian and firefighter survival when a fire occurs. It further shows that when an injury does occur, it tends to be less serious in buildings with appropriate alarm/suppression mechanisms than those without one.

Residential sprinkler systems are designed to automatically discharge to either extinguish fires or to mitigate them with a view to giving building occupants time to escape. These systems, which have been available for over a century, have been developed to a point where they are able to react within 35 seconds of a fire starting. These systems have been demonstrated to increase civilian and firefighter survival rates and reduce property losses relative to buildings without sprinkler protection. Essentially, analysis on the NFID data suggests:

- Residential sprinkler systems alone reduce the chances of a death occurring by 68.8% and smoke alarms and residential sprinkler systems operating in tandem reduce the risk of a death in the event of a fire by 76.8%.

- The presence of sprinkler systems and smoke alarms mitigates the impact of fires such that, when they occur, these fires are contained to the room of origin 93.9% of the time for residential dwellings and 93.5 % of the time for residential apartment buildings.

- In both residential dwellings and residential apartments with sprinkler systems and smoke alarms installed and functioning, civilian and firefighter injuries were reduced dramatically. Furthermore, the severity of injuries observed in the residential dwellings and residential apartment with sprinkler systems were far less serious as measured by length of hospitalization or days off.

Overall, fires in sprinklered buildings are less likely to result in extensive resource consumption from fire departments. Less damage (spread of fire) occurs and the fires that occurred were less likely to result in injury and death.

While these are important findings in themselves, the results have considerable implications for future developments. One policy implication is that incorporating sprinklers into newly constructed single-family dwellings would likely be highly cost-effective regarding fire incidents and casualties.

These results are also significant when placed in the context of the amendments made to the NBCC. When extrapolating these findings to anticipate how fire safety systems should perform in mid-rise wood frame buildings that are now permitted in Canada, it is assumed that the risk posed by these new structures will be substantially less than the fire incidents analyzed in this paper.

The primary reason for this is that all buildings constructed under the *NBCC* will be fully sprinklered to be compliant with National Fire Protection Association (NFPA 13) standards relating to the installation of sprinkler systems. In addition, these buildings will be constructed with a range of other built-in protection systems, such as being required to use non-combustible exterior cladding and the use of electromagnetic devices that release doors in the event of a fire.

Revisions were made to the *BCBC* in January 2009, and came into effect in April 2009 (Office of Housing and Construction Standards) and were incorporated in the *NBCC* in 2015. Essentially, the amended provisions allowed for mid-rise residential and office buildings of up to 6 stories in height be built using combustible construction. The amendments to the BCBC and *NBCC* involved alterations to related undertakings involving sprinklers (to be NFPA 13 compliant), energy efficiency, occupancy, local government, and education and/or training. In addition, there were a range of specific new code provisions concerned with building height, combustibility of cladding, earthquake load and effects, configuration of timber shear wall systems, fire doors in public corridors, and issues focused on shrinkage of wood in structural designs.

Throughout this evolution of building code changes from the 2009 *British Columbia Building Code* revisions to the adoption of the *NBCC* in 2015 that provided for mid-rise combustible construction, extensive retrospective quantitative research has occurred to exploit actual and potential vulnerabilities to civilians, firefighters and building fire safety in this new building system. Despite this work other additional provisions have been implemented in Ontario, namely;

Ontario Building Code requires 1.5 hour enclosed fire resistance ratings in addition to expressing the following concerns as being vulnerable:

- Safety and integrity of the stair shaft if a floor collapses
- Continual safety of the stair shaft as a place of safe refuge and for use as a staging area by the fire service
- Preventing fire spread into the shaft

The retrospective research in this paper and in the referenced research was not able to establish a benefit from the additional provisions in the Ontario Building Code that will improve the safety of civilians, firefighters or buildings warrant these provisions. Clearly fire spread in like buildings to midrise (n=38,453) over a 10 year span were contained to the room of origin 93.5% of the time and seldom progressed beyond the floor of origin. It was not possible to find an incident where a floor or building collapsed in a fully sprinklered building. Finally, since such a large portion of the fires rarely spread beyond the room of origin and even less beyond the floor

of origin, in reference to this we believe that fire-resistance rated exit stair shafts made of combustible construction are unlikely to become a factor for concern.

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

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