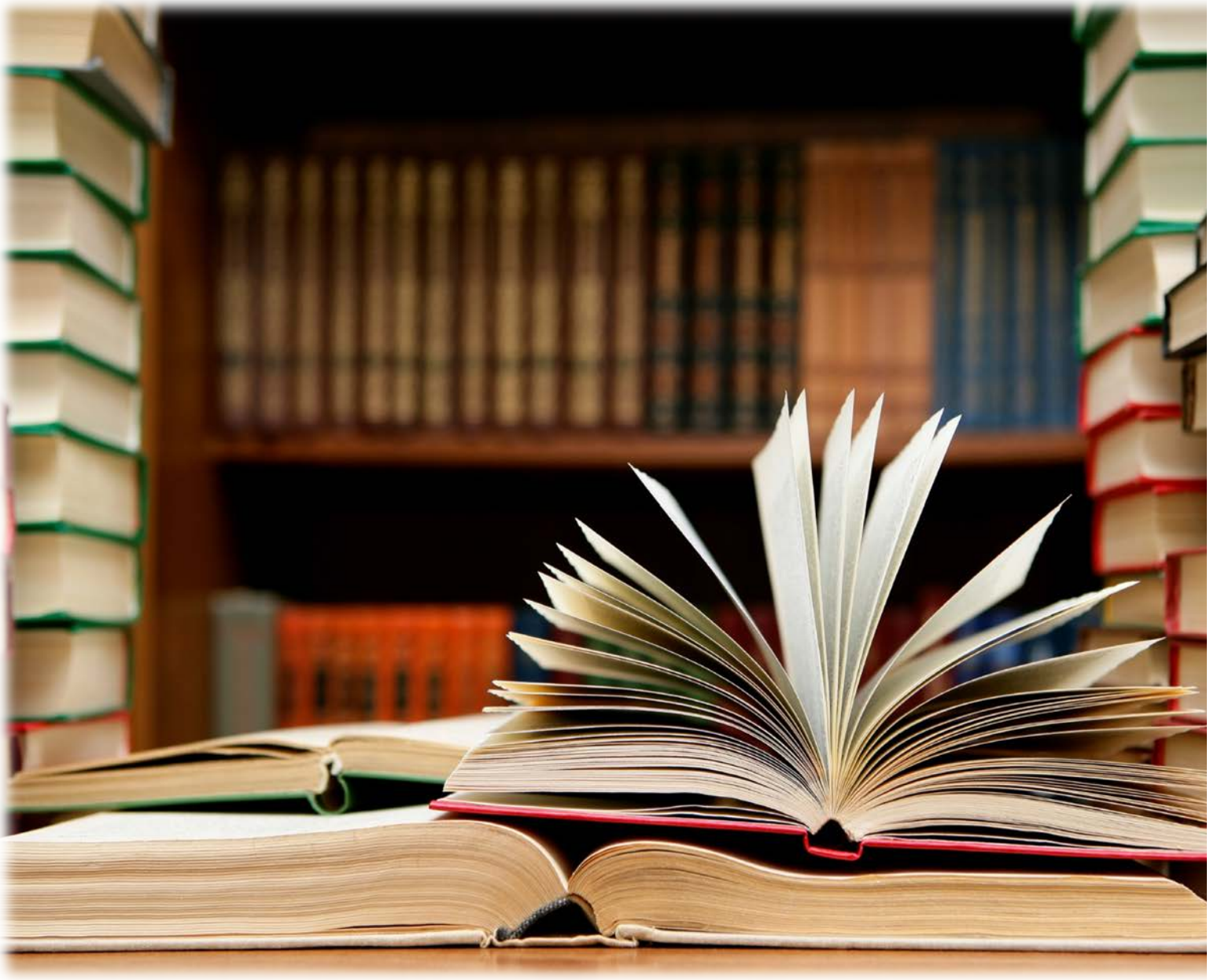
The Non-Random Nature of Fire Safety Inspection Compliance

A Platform for Predicting Fire Risk



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Executive Summary

1. Fire safety inspections in BC are completed for two main reasons:
    (a) To limit the incidence of fires by rectifying situations posing an increased risk of fires occurring; and
    (b) To limit the risk posed by fires when they occur, but ensuring the appropriate risk-limitation tools are present to maximize life safety and restrict fire spread.

2. Fire safety inspections have typically been undertaken in accordance with prescriptive codes, which are historical documents that reflect a summation of previously experience fires and the lessons learned from them. Modern development in this area has seen jurisdictions outside of Canada move towards increasingly flexible, performance-based fire safety codes that emphasize the relationship between the fire, the structure, and the occupants of the structure.

3. Current BC fire safety codes require 'regular' inspections be completed, which has often resulted in fire departments visiting properties in an annual basis (or some variation of this). However, recent research findings have demonstrated that time since last inspection is non-predictive of fire risk and fire outcomes (with respect to property damage and injury/death).

4. Using the outcome for the most recent round of inspections undertaken in Surrey, BC, as a case study, the following trends were identified:
    (a) There is non-random non-compliance of properties, with 74 percent of properties fully compliant at the most recent round of inspections.
    (b) There is non-random failure for fire safety items, with 95 percent of items inspected fully compliant at the most recent round.

5. Analysis of inspections that were undertaken directly before properties experienced fires in Surrey, BC, also revealed that these properties displayed very different failure patterns relative to the norm for all properties that have fire safety inspections. Most notably:
    (a) Properties that experienced fires were non-compliant 2.4 times more frequently than for all inspected properties.
    (b) Items inspected at properties that experienced fires were non-compliant 4.0 times more often than items inspected at properties overall.

6. There is potential to develop a data-driven framework for conducting fire safety inspections based on risk. This approach would require piloting and ongoing evaluation to ensure it was effective and capturing the dynamic nature of risk associated with fire.

Background to Fire Safety Inspections: The Purpose of this Research

This document outlines the logic for rethinking the current approach to conducting fire safety inspections in BC municipalities. Regardless as to how this problem is approached, there are two fundamental reasons for conducting fire safety inspections:

- To limit the incidence of fires, by rectifying situations posing an increased risk of fires occurring. To achieve this end, inspections intend to alter the human habits/behaviours and the physical components of buildings that elevate the risk of causing fires.
- To limit the risk posed by fires when they occur by evaluating whether a structure has the required fire-related tools and techniques in place to limit damage and risk should a fire occur. These risk-limitation tools aim to maximize life safety and restrict the spread of fire, and may include fire detection systems (e.g., smoke alarms and other forms of early detection), fire suppression systems (e.g., fire extinguishers and sprinkler systems), means of egress (e.g., exit doors and fire escapes) and basic fire safety awareness (e.g., fire safety plan designed to influence behaviour before, during, and after a fire).

Analysis of the historical patterns of inspections failures reveals that the variation in risk posed by properties is being ignored. In short, the main findings of this analysis are:

1. The majority of properties that are inspected are compliant.

2. The majority of items that are inspected are compliant.

3. For those properties that experienced fires, there appears to have been greater incidence of non-compliance at the time of the most recent preceding inspection relative to the general patterns of all inspections that are done.

With these findings in mind, and given that the risk posed by any specific property emerges as an interaction between static and dynamic risk factors (as is discussed, below), the authors believe that there is grounds to redesign the current approaches to fire safety inspections to simultaneously maximise the return on investment of fire department resources and reduce fire risk. A potential risk-based framework for this redesign, which would incorporate information about previous inspections performance, the responsible person in charge of the property, the property use, and the structure type, is briefly discussed and will be the focus of subsequent research.

The Need for Fire Safety Inspections

This section briefly examines the need for fire safety inspections, and examines the transition from prescriptive to performance-based fire safety codes, the relevant codes and legislation that governs fire safety inspections in BC, and broadly defined reasons for non-compliance with fire safety requirements.

Prescriptive to Performance-Based Fire Safety Codes

Fire codes are regulations created to promote the safety of the public and reduce the risk of fire exposure, damage, and losses [1, 2]. Fire safety codes are often historical documents that reflect a summation of previously experienced fires and the lessons learned from them [3, 4]. As such, these documents tend to be *prescriptive*, as they contain guidance resulting from previous experiences in the form of new techniques,

practices, and technologies that are introduced to reduce future similar fire safety hazards [3, 5]. A consequence of this process is that fire safety codes become living documents, representing an accumulation of experiences and guidelines, added to after each new threat to fire safety occurs. Two downsides of this prescriptive approach are: (a) fire safety codes are reactive, leading to a repetitive process whereby a major fire occurs and laws are introduced to prevent a re-occurrence, and (b) fire safety codes become complex, inflexible, and resistant to alternative solutions to identified problems.

As a results of these limitations, fire services in many developed nations, including Canada, the UK, Japan, and the US, have moved away from prescriptive approaches in recent years [4, 6]. As an alternative, these areas have preferenced *performance-based* codes (also known as objective codes) that consider the performance of three entities associated with a fire experience: the fire itself, the structure, and the occupants of the structure [4]. By considering how these entities operate separately and how they interact, solutions to theoretical fire-related problems that may occur in the future can be tested and implemented. This increased flexibility surpasses the capabilities of prescriptive codes, enabling performance-based codes to incorporate alternative solutions to similar problems that emerge over time. Such performance-based codes may contain a quantitative element indicating the degree of risk for a fire to occur, and the corresponding risk of harm should a fire occur, which allows fire services to identify priority public buildings to focus their resources upon [5, 7]. The key to making this transition in BC is the capacity to adjust the approach within the confines of existing legislation around fire safety and inspections.

Fire Safety Codes that Influence the BC Fire Service

There are two main pieces of legislation that influence fire safety inspections conducted by BC Fire Services. At a national level, the National Fire Code of Canada 2010, ensures a consistent standard is applied to fire prevention and safety across the country [8, designed to compliment the 2010 National Building Code of Canada]. On a provincial level, BC currently operates under the 2006 Building Code and Fire Code [9]. The national and provincial building codes are enforced during the construction, renovation, and demolition of structures, but once occupancy has occurred, these no longer apply. Post-occupancy, the fire codes are enforced at the municipal government level, meaning that it is incumbent on local fire services to conduct fire-related building inspections. Local fire services are responsible for inspecting properties for compliance with prescribed fire codes, and mandating maintenance should buildings be found to be in violation of those codes. To ensure compliance with these codes, fire safety inspections are undertaken and when infractions are found, inspectors issue an order that requires amendments to be made to bring the building into accordance with the prescribed codes. Inspectors are given the authority to inspect and enforce the fire code on behalf of the Fire Commissioner in *Sections 22* and *23* of the *BC Fire Services Act* [9]. Should the owner/operator of a structure fail to comply with a written order there are a range of available legal sanctions that can be pursued. With respect to the frequency of these inspections, it is stipulated within the *BC Fire Services Act*, *Sections 26(1)* and *36(3)*, that, "[a] municipal council must provide for a regular system of inspection" for public buildings (www.bclaws.ca). 'Regular' within this context is not expected to bind municipal councils to a specific inspections schedule, and instead acts as a guideline within which the frequency of local inspections should be determined, taking into consideration local needs (e.g., ideal level of service and available resources), in addition to level of risk for fire [as per the Interpretive Guide to the BC Fire Services Act, 10].

Reasons for Non-Compliance and the Use of Sanctions

In broad terms, there are two reasons why inspected buildings are not fully compliant with the fire code. First, the responsible person is unaware of the violations. In such instances, rather than relying solely on fines as a negative consequence of non-compliance, the process should ideally convey to owners/operators a sense of

responsibility for complying and encourage them to do so voluntarily (e.g., educating them). With respect to the owners and operators of public buildings, they are essentially taking on the role of the "responsible person" when it comes to providing for the safety of others. However, it is possible that building owners are philosophically in favour of voluntarily meeting all requirements laid out in the fire code but are unaware of all their responsibilities and as such, technically acting non-compliantly. Educating businesses about to comply and why this matters would likely address this problem in many cases and, as such, promoting awareness regarding the regulations associated with things like life safety codes would be an important component in achieving compliance [11]. Part of this process may involve bi-lateral discussions between fire services and owners/operators of public buildings regarding the nature of the regulations and what needs to be done to comply. This type of process would help to identify situations where there is difficulty associated with complying to fire safety regulations, which could lead to revisions of regulations or to injection of resources and support to facilitate voluntary compliance [12]. These types of approaches also provide alternatives to a legal enforcement of code compliance, which can save both fire services and businesses time and money and avoid the use of overly harsh sanctions on businesses that may be willing to comply, but are unable or unaware of how to do so.

The second main reason that inspected buildings are not fully compliant with the fire code is that the responsible person is aware of the violations, but unconcerned about correcting the situation. While many business owners and operators will willingly comply with prescribed safety regulations, particularly when provided with sufficient education to identify and addresses violations when they occur, research suggests that between 10 and 20 percent of owners will not comply until they have considered the costs and benefits of doing so meaning that, for many of those intentionally non-complying with stated rules and regulations, being caught for those violations will have little effect if there is no penalty [13]. Thus, in relation to compliance with fire safety codes, fire services should not only conduct inspections where they can investigate compliance, but should be able to enforce penalties for an identified failure to comply [11]. Examples of enforcement models that invoke a sliding-scale of punishment are available [13]. When minor violations are detected, a warning is often provided and a re-inspection may be ordered. Should non-compliance be detected during the follow-up inspection, a more formal warning may be taken, and more serious repercussions may result. In some instances, compliance may require a legal response, including fines and/or imprisonment. This approach should only be applied to non-compliance on a case-by-case basis (i.e. not as a standard course of action), given the significant investment of money and time likely involved.

In addition to determining the reasons underlying non-compliance with the fire code, with respect to determining what combination of education and enforcement is most appropriate in each case, as the situation currently stands in BC there are additional complications associated with ensuring compliance with the fire codes and for enforcing breaches of the standards. These include:

- There is currently generally no requirement under BC municipal bylaws to demonstrate that a minimum standard of fire safety has been achieved prior to obtaining a business licence (assuming that a business licence has been obtained);
- There is ambiguity surrounding who has the responsibility to address building fire safety violations: e.g., it not always clear who is responsible when the owner and occupier are separate people; and
- There is also ambiguity surrounding the definition of compliance, as it is uncertain if this requires 100 percent pass rate for items at inspection, or if there room for discretion provided the most crucial fire detection and suppression items are present and functioning.

The Non-Predictive Nature of Time

Previous research by these authors has demonstrated that non-predictive nature of 'regular' fire safety inspections in BC in a report entitled, "Examining 'regular' fire-safety inspections: the missing relationship between timing of inspection and fire outcome" [14]. This analysis was undertaken on the most recent 5-years of fire incident reports submitted to the BC Office of the Fire Commissioner for which the date of last inspection was captured (1999-2003): a total of 4,084 fires reported by 168 different reporting locations, 97% of which were located in municipal areas. The key findings of this analysis included:

- The majority of fires (74%), injuries (81%), and deaths (74%) occurred within 1 year of the most recent inspections. The frequency of all of these declined with duration between inspection and fire event, up until the inspection was over 36 months prior to the fire.
- The timing of the most recent inspection did not influence the extent of fire spread. For those buildings that were inspected on a regular basis (at least once every 3 years), the timing of inspection (greater or less than every 12 months) had no significant effect on the extent of fire spread.
- The injury rate per 1,000 fires was significantly greater for residential properties compared to non-residential ones. When looking within these occupancy classes, there was no indication that the rate of injury increased as a consequence with the duration between most recent inspection and fire incident.
- The death rate per 1,000 fires was also significantly greater in residential properties relative to non-residential properties and within-occupancy class analysis revealed no difference in death rates as a function of time since the most recent inspection.

The potential to redesign the inspections process to acknowledge a broader set of risk factors, in addition to time, was discussed [14] with some potential variables including occupancy type, age, condition, maintenance, and degree of cooperation on behalf of the building's responsible person. It is important to re-emphasize that the purpose of this timing analysis was not to suggest that fire safety inspections should not be done. Instead, the motivation was to demonstrate that elapsed time since last inspection does not seem to influence fire outcomes with respect to extent of fire and fire related casualty [14]. With this in mind, it is worth re-thinking 'regular' when determining the priority, approach, and frequency of fire safety inspections.

Clustering of Fire Safety Inspection Failures – Surrey, BC, as a Case Study

Given that time in isolation does not appear a sufficient criteria upon which to base the fire safety inspection process, the question remains what are other measurable factors that could be included in this decision-making process. To address this question, this section uses Surrey, BC, inspections data as a case study to examine the characteristics of non-compliant properties, non-compliant items, and the fire safety inspection failures that preceded fire incidents.

Characteristics of Non-Compliant Properties

There were a total of 13,455 properties that required inspection recorded on the Surrey Fire Service database in February, 2012. Of these, 12,632 (93.9%) could be linked to an inspection event, allowing analysis of compliance at the most recent inspection. Figure 1 displays the number of non-compliant items per inspected property across the 12,632 most recently conducted unique inspections. This figure indicates that 73.6 percent of the properties inspected were fully compliant, and the number of non-compliant items per property ranged from 1 to 16 items. For the purposes of this report, all properties with 1 or more inspection item failure have been classified as 'non-compliant'. Less than one percent of all properties inspected had more than 7 non-compliant items at the most recent inspection.

FIGURE 1. FREQUENCY OF NON-COMPLIANT ITEMS PER INSPECTION FOR THE MOST RECENT INSPECTION PER PROPERTY (N = 12,632 PROPERTIES)

With respect to "level of risk", the *Interpretive Guide to the British Columbia Fire Services Act* r[10] requires the establishment of a comparative scale that takes into consideration the likelihood that certain fire hazards will be present to a greater degree. While the *Interpretive Guide* provides examples of structures that may be classified as low risk for fire (e.g., art galleries, opera houses, hospitals), medium risk for fire (e.g., schools, psychiatric hospitals, rest homes), and high risk for fire (e.g., restaurants, spray painting operations, apartments), it is important to note that these are simply examples, and do not restrict a particular structure type to a pre-defined level of risk. As such, it is important for fire services in each community to create their own risk categories. This approach is consistent with the targeted prevention campaigns that have been driven by variations in fire risk associated with individual characteristics such as age (under 6 or over 64 years) [15-19] and socio-economic disadvantage [18-22], which were the principles underlying the successful fire reduction campaign undertaken in BC between 2008 and 2012 [23].

Associating risk to different building structures is an essential exercise for fire services to engage in as it may have implications for the frequency and manner by which inspections are conducted. To this end, the *Interpretive Guide to the British Columbia Fire Services Act* [10] classifies buildings into different risk categories with unique standards of inspection frequency. These classifications are based on a national standard, but can be amended locally based on community needs. Occupancies are divided as follows:

- Group A involves structures associated with performance arts, arenas, open air structures, or those not classified elsewhere, such as schools, nightclubs, and restaurants;
- Group B applies to care, treatment, and prison occupancies;
  - B1 is which concerned with detention facilities; and
  - B2 applies to care occupancies;
- Group C includes residential occupancies, such as hotels and apartments;
- Group D involves other business and personal services, such as office buildings;
- Group E applies to mercantile, such as retail stores; and
- Group F involves industrial structures, such as power plants, service stations, and distilleries.
  - F1 applies to high hazard industrial structures;
  - F2 applies to medium hazard industrial structures; and
  - F3 applies to those with a low hazard

Overall, there is an uneven distribution of inspections workload across these occupancy classes, as indicated in Table 1. Overall, 'D', 'E', and 'F' properties account for 82 percent of the inspected properties and 77 percent of the inspected items. As could be deducted from Figure 1, 26.4 percent of the properties overall were non-compliant, and Table 1 demonstrates there is a range of non-compliance within occpancy class, with 40.2 percent of inspections at 'C' properties (including hotels and apartments) non-compliant compared to only 40.2 percent of 'D' properties (including office buildings).

TABLE 1. TOTAL PROPERTIES (*N* AND %) AND NON-COMPLIANT PROPERTIES (*N* AND %) IN THE MOST RECENT INSPECTIONS BY OCCUPANCY CLASS

Occupancy class	Total properties inspected	% Total properties inspected	# Non-compliant properties	% Non-compliant properties within occupancy class
A	1	< 0.1%	0	na
A1	10	0.1%	4	40.0%
A2	1,167	9.2%	388	33.2%
A3	17	0.1%	5	29.4%
A4	3	< 0.1%	0	na
B1	1	< 0.1%	1	100.0%
B2	34	0.3%	13	38.2%
C	1,018	8.1%	409	40.2%
D	3,557	28.2%	731	20.6%
E	2,500	19.8%	630	25.2%
F1	29	0.2%	8	27.6%
F2	3,845	30.4%	1,031	26.8%
F3	445	3.5%	109	24.5%
RF	1	< 0.1%	0	na
Missing	4	< 0.1%	1	25.0%
Total	**12,632**	**100.0%**	**3,330**	**26.4%**

In attempt to manage the differential risk posed by these varying occupancy types, the Surrey Fire Service currently inspects properties classified into Group 'A', 'B', and 'C' on a Routine-365 day basis, and properties classified into Groups 'D', 'E', and 'F' are inspected on a Routine-730 day basis. As can be seen, 82 percent of the properties are currently located at properties in the Routine-730 class. Putting these two pieces of information together, it is interesting to consider that the properties which are currently inspected the most frequently are also the ones that demonstrate the greatest non-compliance. As it stands, this classification system does not acknowledge the differences in risk that may well exist within each of these occupancy classes.

Characteristics of Non-Compliant Items

Examination of the outcomes from the most recent round of inspections reveals a huge variation in the frequency at which items are inspected and the compliance rate across items. Table 2 displays the total number of items inspected across occupancy class of properties, along with the corresponding number of these items that were inspected at non-compliant properties and the average frequency of non-compliance for each type of item. Overall, for the 159,510 items inspected at the most recent round, 49,214 (30.9%) of these were inspected at non-compliant properties. Overall, the average item failure rate at non-compliant properties was 25.0 percent, which means that if a property had at least one non-compliant item, it was likely that one-quarter of all items inspected at that property would be non-compliant.

TABLE 2. TOTAL ITEMS (*N* AND %), NON-COMPLIANT ITEMS (*N*) AND AVG. NON-COMPLIANCE (%) FOR ITEMS AT NON-COMPLIANT PROPERTIES IN THE MOST RECENT INSPECTIONS BY OCCUPANCY CLASS

Occupancy class	Total items inspected	% Total items inspected	# Items inspected at non-compliant properties	Avg. failure rate for items at non-compliant properties
A	6	< 0.1%	na	na
A1	180	0.1%	78	24.0%
A2	18,980	11.9%	7,123	19.9%
A3	325	0.2%	98	11.6%
A4	31	< 0.1%	na	na
B1	30	< 0.1%	30	13.3%
B2	733	0.5%	262	30.1%
C	15,737	9.9%	7,628	23.3%
D	39,876	25.0%	9,385	25.6%
E	28,325	17.8%	8,367	24.0%
F1	476	0.3%	153	18.2%
F2	49,436	31.0%	14,727	27.0%
F3	5,347	3.4%	1,361	33.9%
RF	1	< 0.1%	na	na
Missing	27	< 0.1%	2	100.0%
Total	**159,510**	**100.0%**	**49,214**	**25.0%**

Table 3 displays the details for the top 31 most frequently inspected items during the most recent round of inspections, along with the relative within-item non-compliance percentages across all inspections and the ranking of within-item non-compliance percentages. As can be seen, of 159,510 items that were inspected during the most recent round of inspections, only 5.2% were non-compliant. Overall, the most frequently inspected item was fire department access (7.3% of the total inspected items, with a 4.0% non-compliance rate) and the highest ranked non-compliant item was fire safety plans (which failed 19.7% of the 2,512 times they were inspected).

TABLE 3. MOST FREQUENTLY INSPECTED ITEMS (*N* AND %), WITHIN-ITEM NON-COMPLIANCE (%) AND RANKING OF WITHIN-ITEM NON-COMPLIANCE (TOP 31 ITEMS ONLY)

Inspection item	# Inspections per item	% Total # item inspections	% Within-item non-compliance	Ranked % non-compliance*
950 Fire Department Access	11,706	7.3%	4.0%	18
501 Portable Extinguishers	10,629	6.7%	4.6%	15
502 Servicing Extinguishers	10,361	6.5%	11.1%	4
201 Exit Doors	10,170	6.4%	1.9%	26
401 Electrical Panel	10,121	6.3%	2.5%	24
206 Exit Signs & Lights	9,056	5.7%	5.7%	10
204 Exit Passages (Blocked)	8,935	5.6%	3.5%	19
207 Emergency Lighting	8,909	5.6%	12.4%	2
202 Exit Doors (Latching)	8,128	5.1%	1.6%	28
101 Fire Separations	7,440	4.7%	4.5%	16
102 Fire Closures	7,020	4.4%	2.9%	22
404 Electrical Room (Storage)	5,216	3.3%	3.4%	21
707 Outside Waste Container	4,824	3.0%	0.6%	30
602 Fire Lane Blocked	4,525	2.8%	0.3%	31
520 Sprinkler System	3,617	2.3%	8.0%	7
542 Fire Safety Plans	2,512	1.6%	19.7%	1
403 Extension Cord Use	2,509	1.6%	2.8%	23
530 Fire Alarm Panel	2,242	1.4%	9.4%	5

Inspection item	# Inspections per item	% Total # item inspections	% Within-item non-compliance	Ranked % non-compliance*
701 Housekeeping	2,177	1.4%	5.4%	12
915 Compressed Gas Bottles	2,158	1.4%	4.1%	17
703 Storage	2,080	1.3%	8.5%	6
543 No Smoking Signs	1,998	1.3%	1.3%	29
600 Private Hydrant	1,687	1.1%	12.0%	3
909 Fire Alarm System	1,586	1.0%	7.8%	8
523 Fire Department Connections	1,574	1.0%	3.5%	20
801 Flammable liquids (Storage)	1,491	0.9%	4.8%	14
208 Occupancy Load	1,477	0.9%	1.6%	27
522 Sprinkler Coverage	1,299	0.8%	5.4%	13
310 Kitchen Hoods	1,248	0.8%	5.5%	11
914 Dust Accumulation	1,224	0.8%	2.4%	25
320 Special Extinguish System	1,134	0.7%	7.0%	9
All other categories	10,457	6.6%	7.5%	NA
Total	**159,510**	**100.0%**	**5.2%**	

Note. * Rankings were only calculated for items that were inspected at least 1,000 times during the most recent round of inspections.

Fires at Inspected Properties

Table 4 displays the distribution of fires across the different occupancy usages, in a manner that demonstrates the varying frequency at which fires have occurred at inspected properties in Surrey between 2005 and 2011. There were a total of 337 fires that occurred at these properties over this time, at a 7-year rate of 2.7 fires per 100 properties.

TABLE 4. FIRE INCIDENTS (*N* & 7-YEAR RATE) AS A FUNCTION OF OCCUPANCY USAGE

Occupancy class	Occupancy usage	# Properties within usage class	# Fires (7-year period)	7 yr rate of fires per 100 properties within class
A2	Schools Public, non-residential	126	34	27.0
	Gymnasia	5	1	20.0
	Museums	6	1	16.7
	Schools Private, non-residential	36	5	13.9
	Undertaking premises	8	1	12.5
	Clubs, non-residential	26	3	11.5
	Lecture halls	9	1	11.1
	Restaurants Food & Seating <10	362	27	7.5
	Churches and similar places of worship	142	8	5.6
	Banquet Hall	20	1	5.0
	Licensed beverage establishments	47	1	2.1
	Restaurants Food & Seating >10	316	2	0.6
A3	Rinks	5	1	20.0
A4	Grandstands	2	1	50.0
B1	Jails	1	2	200.0
B2	Hospitals	2	7	350.0
	Nursing homes	31	6	19.4
C	Hotel	17	4	23.5
	Motels	17	3	17.6
	Apartments	616	65	10.6
	Daycare	272	1	0.4
D	Dry Cleaning self-service no flammable	27	2	7.4
	Laundries, self service	36	1	2.8
	Beauty Parlour and Spa	213	3	1.4

Occupancy class	Occupancy usage	# Properties within usage class	# Fires (7-year period)	7 yr rate of fires per 100 properties within class
	Offices	2678	14	0.5
	Medical Office	367	1	0.3
E	Stores	2,170	39	1.8
F2	Factories, medium hazard	38	2	5.3
	Workshops, medium hazard industrial	555	17	3.1
	Repair garages	315	9	2.9
	Woodworking factories	75	2	2.7
	Warehouses, medium hazard industrial	2331	59	2.5
	Storage rooms, medium hazard	95	1	1.1
	Wholesale rooms	265	1	0.4
F3	Salesrooms, low hazard	13	2	15.4
	Laboratories, low hazard	21	1	4.8
	Storage garages including open air	85	3	3.5
	Warehouses, low hazard industrial	246	5	2.0
All others		1,036	0	0.0
Total		**12,632**	**337**	**2.7**

The Link between Fire Safety Inspection Non-Compliance and Fires

It is also important to examine the relationship between inspections non-compliance and fire incidents for fires that have occurred in Surrey properties requiring inspections. The initial part of this analysis compares the inspection outcomes that immediately preceded fires that occurred with the inspections outcomes from the most recent round of completed inspections. In comparison to the frequencies of inspections non-compliance demonstrated in Figure 1, above, the patterns displayed in Figure 2 indicate that properties that experienced fires were much less likely to have been fully compliant at their most recent inspection prior to the fire incident. Overall, 98 out of 157 (62.4%) properties were non-compliant at the most recent inspection that preceded the fire. This compares with 26.1% of properties that were non-compliant at the most recent round of inspections (2.4 times the rate).

FIGURE 2. RELATIVE PERCENTAGES OF NON-COMPLIANT ITEMS PER INSPECTION FOR ALL MOST RECENT INSPECTIONS (N = 12,362 PROPERTIES) AND FOR INSPECTIONS PRIOR TO FIRES (*N* = 157 PROPERTIES)

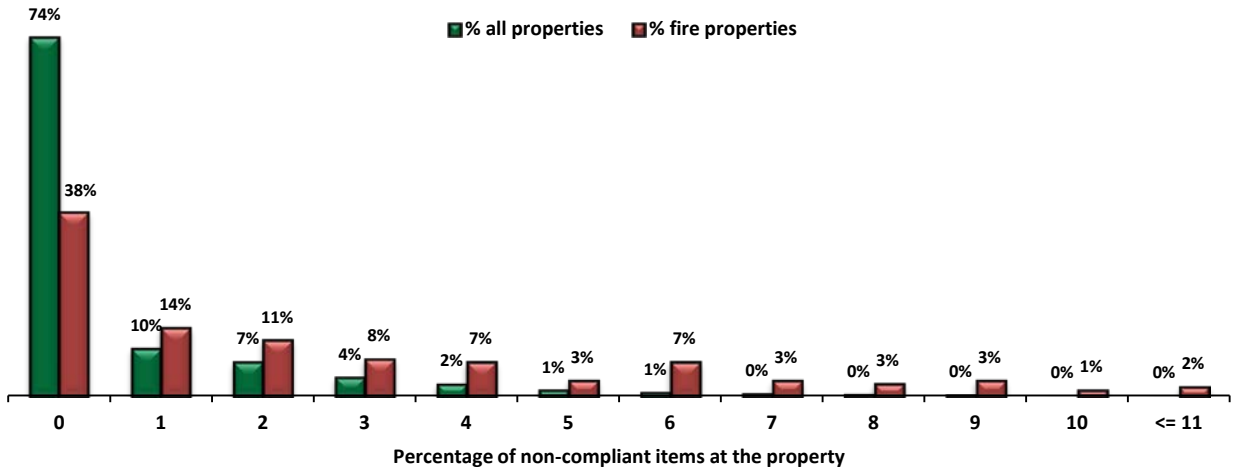


Table 5 displays the relative distribution of Routine-365 and Routine-730 inspections for the 157 properties that experienced fires and could be matched to the inspection incident that directly preceded the fire. In contrast to the frequencies observed for the most recent round of inspections overall (see Table 1, above), almost 70 percent of the properties that experienced fires were scheduled for annual inspections. This is entirely consistent with the findings of the research discussed previously into the non-predictive nature of time for fire safety inspections [14], where 74 percent of fires occurred within 1 year of the most recent inspections.

TABLE 5. PROPERTIES THAT EXPERIENCED FIRES (*N* AND %) AND NON-COMPLIANT PROPERTIES (*N* AND %) IN THE MOST RECENT INSPECTIONS PRIOR TO FIRES BY INSPECTION CLASS FREQUENCY

Inspection class frequency	Total properties that experienced fires	% Total properties that experienced fires	# Non-compliant properties	% Non-compliant properties within occupancy class
Routine-365	94	59.9%	65	69.1%
Routine-730	63	40.1%	33	52.4%
Total	**157**	**100.0%**	**98**	**62.4%**

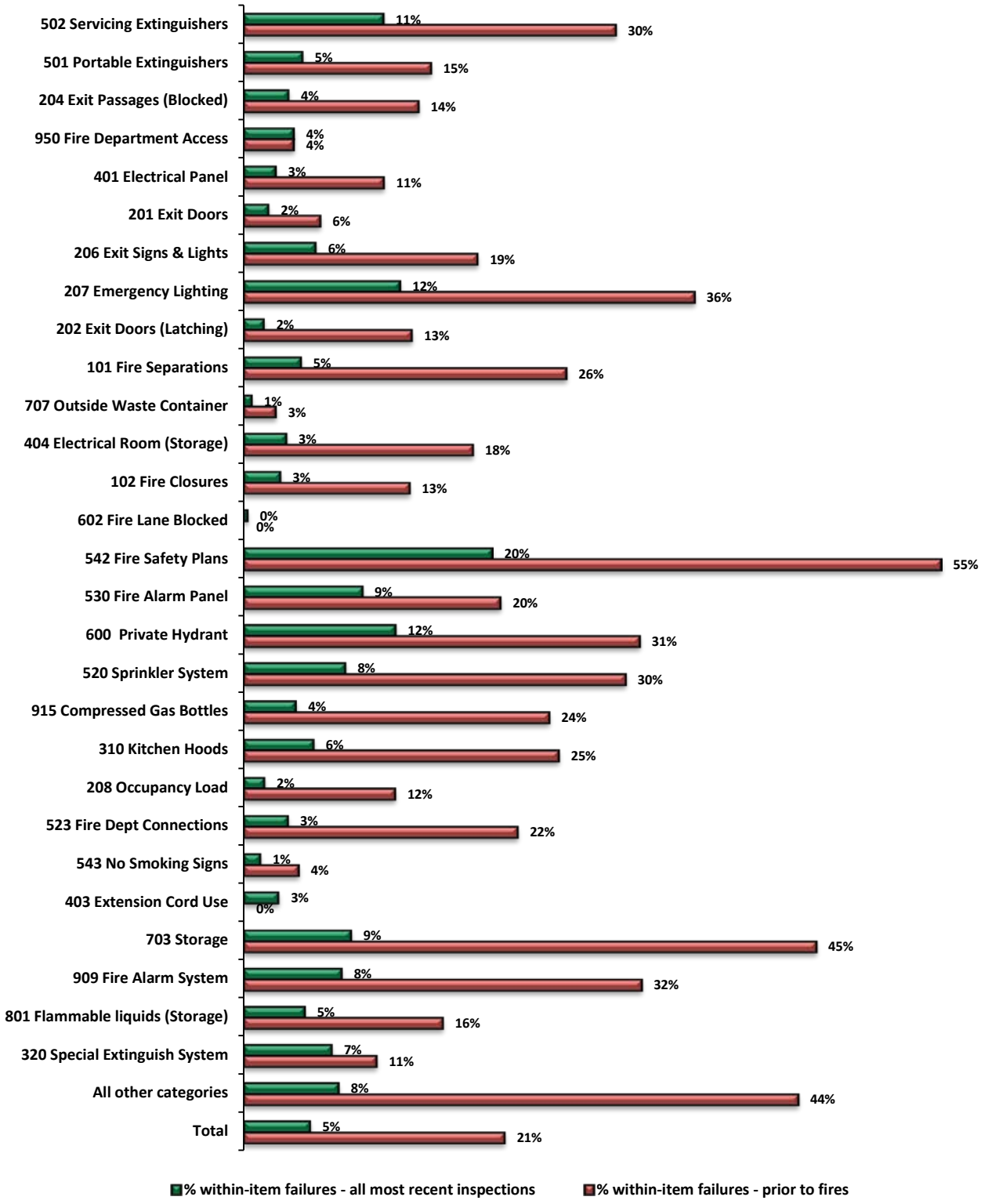
Table 6 examines the number of items examined at these properties that experienced fires, including the number of items inspected at the non-compliant properties (1,340 items at 98 properties), and the average non-compliance percentage for items at these non-compliant properties. The non-compliance for inspected items at these properties was approximately 40 percent, which was 1.6 times greater than the average non-compliance percentage for items identified during the most recent round of inspections for all properties (as discussed in Table 2, above).

TABLE 6. ITEMS (*N* & %), NON-COMPLIANT ITEMS (*N*) & AVERAGE ITEM FAILURE RATE AT NON-COMPLIANT PROPERTIES IN THE MOST RECENT INSPECTIONS PRIOR TO FIRES BY INSPECTION CLASS

Inspection class frequency	# items inspected	% items inspected	# items inspected at non-compliant properties	Avg. non-compliance for items at non-compliant properties
Routine-365	1,201	63.9%	898	44.6%
Routine-730	678	36.1%	442	31.0%
Total	**1,879**	**100.0%**	**1,340**	**39.9%**

Figure 3 displays the relative within-item percentage failures for the most frequently inspected items at properties that experienced fires and for all properties at the most recent round of inspections. This demonstrates that, for nearly every instance which there was inspection item non-compliance at properties that experienced fires, the within-item non-compliance percentage far exceeded the equivalent percentage for the overall sample of the most recent property inspections. Overall, the within-item non-compliance for properties that experienced fires was 20.7 percent, compared with 5.2 percent of the items that failed the most recent round of inspections overall (4.0 times the rate).

FIGURE 3. WITHIN-ITEM NON-COMPLIANCE (%) FOR ALL MOST RECENT INSPECTIONS AND THE MOST RECENT INSPECTIONS PRIOR TO FIRES



Summary and Conclusions

Results Recap and Overview

Summarise the main points from the various sections in the introduction. We know from previous research that the timing of fire safety inspections is non-predictive of fire risk. In addition to this, the current research has demonstrated that:

- There is a non-random non-compliance of properties at the most recent round of fire safety inspections.
    - 74 percent of properties were fully compliant at the most recent round of inspections.
- There is a non-random failure of fire safety inspection items at the most recent round of inspections.
    - 95 percent of items inspected at the most recent round were fully compliant.
    - Properties that had at least one non-compliant inspection item were likely to have had 25 percent non-compliance.
- Prior to experiencing fires, the most recent round of inspections produced very different failure patterns than the 'norm' for all properties.
    - 62 percent of the properties that experienced fires were non-compliant at the most recent inspection that preceded the fire. This was 2.4 times more frequent than the 26 percent of properties that were non-compliant at the most recent round of inspections.
    - 70 percent of the properties that experienced fires were scheduled for annual inspections;
    - 21 percent of the items inspected at properties that experienced fires were non-compliant at the most recent inspection that preceded the fire. This was 4.0 times greater than the 5 percent of items that were non-compliant at the most recent round of inspections.
    - Properties that experienced fires and were non-compliant at the most recent inspection prior to the fire were likely to have had 40 percent item non-compliance. This was 1.6 times greater than the average non-compliance percentage for items identified during the most recent round of inspections for all properties.

In short, inspection non-compliance is non-random for properties and items, and there seems to be a link between experiencing a fire and elevated non-compliance at the most recent inspection preceding the fire event.

Static and Dynamic Risk Factors

The current process that is implemented by the Surrey Fire Service allows for some discretion with respect to the need for re-inspection, as a function of inspection failure on specific items.[1] Based on existing practice re-inspections are not conducted for (a) fire hydrant service failures, (b) exit light functionality, (c) extinguisher failures, such as not serviced, missing, or not mounted, and (up to 16 August, 2011) (d) emergency lighting that was not fully functioning. Point (d) now requires re-inspection. Although the justification for this distinction has resulted from ad-hoc approaches to managing risk associated with specific types of item failures, the decisions have not been driven by analysis of data on inspections failure. However, the current

[1] Pre-16 August, 2011, properties were only invoiced if there were still non-compliance issues after the re-inspection. The original inspection has always been (and continues to be) free. This is regardless of the size of the workload involved with completing the initial inspection. Post-16 August, 2011, properties that require a re-inspection are all invoiced (flat fee of $111.40, plus HST). Again, this cost is a flat rate, regardless of the work involved with undertaking the re-inspection, or as a result of the nature of the initial failure to comply.

inspections process does not exploit a risk-assessment distinction that has been incorporated into areas such as forensic mental health, child protection, and offender recidivism management: the distinction between static and dynamic indicators of risk. In these contexts, static risk factors are those factors that have been demonstrated to relate risk potential. Translating this to a fire context, these risk factors would by the essentially non-changeable aspects of the property that influence fire likelihood, such as construction material, zoning density, geographic location in the city, etc. In contrast, dynamic risk factors are those factors that have a demonstrated association with risk, but are amenable to alteration. Within a fire context, these would refer to the types of risk factors that can alter over time and can be influenced by inspection and improved safety practices (the Three 'E's). Examples of this could include the level of diligence demonstrated by the responsible person (possibly captured in proxy by the prior compliance history at the property), recent compliance history, building use, etc.

Meaningful variations in the risks posed by any structure are going to be identified by considering static and dynamic risk factors in parallel. This needs to be monitored in an ongoing, consistent manner, and the outcome of this assessment should drive the frequency of building inspections. If it is no longer assumed that all inspections failures (for specific items) are of equal significance for compliance (from a safety perspective), it is worth considering further information about the types of failures that occur.

Looking to the Future

With these findings in mind and looking towards the future for fire safety inspections, there is potential to develop a data-driven framework for conducting fire safety inspections, based firmly on risk. This approach would require piloting and ongoing evaluation, but the expectation is that this would address these three concerns and improve the overall safety of the community. This amended strategy would incorporate the *Three E's* of injury prevention [24]: environment (product design or modification), enforcement (of legislation and policies), and education. In addition to being prescriptive and missing the issues associated with dynamic risk and the ill-defined concept of 'compliance' (with relevance to enforcement and the environment), the current process also misses the education component of this process out entirely.

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