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Adaption of a Fire Risk Index Method to Canadian Mid-Rise Residential Buildings

Report prepared for

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1 Objectives

The objective of this study was to develop a simple performance-based fire-risk index method applicable to Canadian mid-rise buildings (FRIM-CMB) based on the European fire-risk index method for multi-storey apartment buildings (FRIM-MAB) [1-3]. The European method needs to be suitably modified to reflect the structure and requirements of the 2010 National Building Code of Canada [4]. The method could also be used to estimate the fire risk in both combustible and non-combustible mid-rise residential buildings (group C major occupancy).

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3 Introduction

The steep decline of the North American housing market has adversely affected the Canadian wood products industry. Under the Transformative Technologies Program which was established by Natural Resources Canada, FPInnovations has been working towards increasing the use of wood-based components in building systems for multi-storey wood construction. Fire safety of multi-storey wood construction is an important issue that can be addressed by employing performance-based design techniques to develop an "*alternative solution*" in compliance with the objective-based format of the 2010 National Building Code of Canada (NBCC).

Prescriptive solutions found in Division B of the NBCC (also referred to as "*acceptable solutions*") historically limit wood construction of residential and office buildings to four storeys (occupancy groups C and D respectively), depending on whether an active fire protection system is installed or not (i.e. an automatic sprinkler system).

In May of 2008, the British Columbia government announced its intention to increase the maximum height for combustible residential construction from four to six storeys. The new BC Building Code was approved in January 2009 and became effective on April 6, 2009. Other provinces in Canada, like Ontario and Quebec, are also in the process of revising their provincial building codes to permit six storey buildings of combustible construction. Life safety and property protection are major concerns in this implementation. The fire risk in combustible residential construction is as high as for any other type of construction, and is dependent on many factors. There is a need to comprehensively evaluate the fire risk in combustible residential construction, as well as any other type of construction prescribed in the NBCC, and to compare their attributed fire risk.

Therefore, except for residential buildings in British Columbia, an alternative solution has to be provided when designing mid-rise combustible buildings (5- and 6-storeys). The alternative solution needs to demonstrate that it meets the minimum level of performance for an applicable deemed-to-satisfy prescribed solution (or acceptable solution found in Division B) which it replaces, i.e. a non-combustible construction as defined in the NBCC.

There is a large number of building code requirements that are intended to ensure a building is fire safe. How all of these requirements work together to deliver fire safety is rarely considered; rather compliance with the individual requirements is usually considered one at a time. Fire risk assessment tools are under

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development around the world to remedy this situation. Such tools are designed to predict the overall level of fire safety in a building that accrues as a result of the combined effects of the entire suite of fire safety features installed in the building. In Canada, the National Research Council (NRC) has developed a complex fire-risk analysis tool FiRECAM [5] and Carleton University has also been developing a complex computer fire risk analysis model CUrisk [6]. Both models have been proven to be good research tools for fire risk analysis; however, they require advanced fire safety knowledge to be properly used and understood.

To promote mid-rise combustible buildings, it is necessary to develop a simple yet comprehensive fire-risk analysis tool for authorities having jurisdiction (AHJ) and designers wishing to develop an alternative solution using wood components, without the need for users to have full qualifications in fire safety engineering, but having expertise and knowledge in that field of practice. The use of such a model can help in evaluating the level of performance of buildings of combustible construction when alternative solutions are proposed.

4 Previous Work

4.1 Fire Risk Index Method for Multi-storey Apartment Building (FRIM-MAB)

4.1.1 Introduction

In 2002, the Department of Fire Safety Engineering at Lund University in Sweden published a Fire Risk Index Method for Multi-storey Apartment Buildings (FRIM-MAB) [1-3]. The method was based on a hierarchy structure for the fire safety measures in a building. The components from high to low level in the hierarchy structure are: one policy, two objectives, four strategies, and seventeen parameters. Each of the parameters and sometimes sub-parameters are prescribed in decision tables. For a specified building, the user works through the decision tables and grades every parameter and sub-parameter. The grades entered by the user are multiplied by their respective weights. The weighted grades are summed up and a risk index is calculated. The method was evaluated by comparing the risk index with the risk rank calculated using a quantitative risk analysis computer model. The comparison showed good agreement between the two methods.

4.1.2 The Structure of the Fire Risk Index Method

The Fire Risk Index Method is a hierarchy system. Each “decision making level” of the hierarchy has “attributes” accounting for components of an acceptable fire safety design. The “attributes” are established based on the National Fire Protection Association (NFPA) Fire Safety Concepts Tree [7].

The top level of the hierarchy system is “*Policy*”, which is to provide an acceptable level of fire safety in multi-storey apartment buildings.

The next level of the hierarchy system is “*Objectives*” which are to assure life safety and property protection.

Then the next level of the hierarchy system is “*Strategies*” which are to control fire growth by active means, to confine the fire by construction, to establish safe egress, and to establish safe rescue.

The bottom level of the hierarchy system contains seventeen “*Parameters*” which impact fire safety. They are linings in apartments, suppression system, fire service, fire-rated compartmentation, separating structure, doors, windows, facades, attic, adjacent buildings, smoke control system, detection system,

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signal system, escape routes, load-bearing structure, maintenance and information, and lastly, ventilation system.

Some of these parameters are divided into sub-parameters. Each parameter and sub-parameter can be quantified with grades from 0 to 5, with the highest and better grade being 5. Different weights are assigned to each attribute. A risk index is calculated by summing up the grades of the seventeen parameters multiplied by their assigned weights. This index evaluates the fire risk of a specific building and provides a comparison basis with similar buildings or other design options. The structure of the fire risk index method and the weights assigned to each attribute were determined by a consultation working group. The structure of the fire risk index method is shown in Table 1.

$$Risk\ Index = 5 - \sum_{i=1}^{17} W_i P_i \tag{1}$$

4.1.3 The Project Group and the Delphi Panel

The Fire Risk Index Method was developed at Lund University (Sweden), with a Project Group and a Delphi Panel. The Project Group had one member from each of the Nordic countries. The Delphi Panel consisted of 5 experts from 4 Nordic countries, for a total of 20 experts working on fire safety in various areas. The Project Group formulated questionnaires, sent them to the Delphi Panel, and collected and summarized the results. Then the Project Group formulated another new questionnaire and sent it to the Delphi Panel members. The responses from the Delphi Panel members were used to gradually improve the structure of the Fire Risk Index Method and the weighing factors.

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Table 1 Structure of Fire Risk Index Method

Policy	Provide acceptable fire safety in multi-storey apartment buildings	
Objectives	*O1*	Provide life safety
	O2	Provide property protection
Strategies	*S1*	Control fire growth by active means
	S2	Confine fire by construction
	S3	Establish safe egress
	S4	Establish safe rescue
Parameters	P_1	Linings in apartments
	P_2	Suppression system
	P_3	Fire service
	P_4	Compartmentation
	P_5	Non-load-bearing fire separations
	P_6	Doors and Openings
	P_7	Windows
	P_8	Facades
	P_9	Attic
	P_{10}	Adjacent buildings
	P_{11}	Smoke control system
	P_{12}	Detection system
	P_{13}	Signal (Alarm) system
	P_{14}	Means of egress
	P_{15}	Structure (Load-bearing)
	P_{16}	Maintenance and information
	P_{17}	Ventilation system

4.2 VALERIE Project in Italy

The Fire Brigade of Trento and ISAQ Studio organized a “VALERIE” Project [8]. The project developed a multi-level hierarchical analysis along with the assignment of the appropriate “weight” to each fire safety measure element. The quality of the results given by the VALERIE model is directly related to the appropriate choice of these “weights”. To guarantee an unbiased assessment of the influence of each parameter relevant to the fire safety, a reference ranking has been built-up. The fire-safety measures assessed in this method are very similar to those of the FRIM-MAB method, with the primary difference that the FRIM-MAB only addresses multi-storey apartment buildings whereas VALERIE addresses all buildings including industrial buildings. The weightings assigned to the various measures are similar, but the FRIM-MAB is better suited for combustible construction than the VALERIE method, for example when considering fire stops in separations between compartments.

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5 Review and Development of a Fire Risk Index Method for Canadian Mid-rise Buildings

Although the Fire Risk Index Method for Multi-storey Apartment Buildings (FRIM-MAB) was developed in Europe, using European fire safety strategies and test methodologies, the fire safety measures and approaches are similar to those used in Canada.

Based on the European FRIM-MAB method, a Fire Risk Index Method for Canadian Mid-rise Buildings (FRIM-CMB) has been developed. The hierarchy structure of the European index method was maintained but the attributes for the components of each level have been revised to reflect the requirements, objectives and functional statements of the NBCC. Consequently, the seventeen parameters, P_i, identified in FRIM-MAB were maintained and the weighting, W_i, assigned to each parameter was not altered. However, the methods for assigning a grade to each parameter and sub-parameter have been revisited and revised where necessary.

5.1 Policy – Top Level of the Hierarchy System

5.1.1 Definition of Policy in the European Method: FRIM-MAB

All buildings, including multi-storey apartment buildings, shall be designed in a way that ensures sufficient life safety and property protection in accordance with their respective Code objectives listed below.

5.1.2 Definition of Policy in the Canadian Method: FRIM-CMB

This definition is the same as in FRIM-MAB method.

5.2 Objectives – Second Level of the Hierarchy System

5.2.1 Definition of Objectives in the European Method: FRIM-MAB

5.2.1.1 O_1 - Provide life safety

Objective 1 in the FRIM-MAB is to provide life safety of occupants in the compartment of fire origin, the remaining parts of the building, outside and inside adjacent buildings as well as life safety for fire fighters to perform their duty.

5.2.1.2 O_2 - Provide property protection

Objective 2 in the FRIM-MAB is to provide protection of property in the compartment of fire origin, in the remaining part of the building, as well as outside and inside adjacent buildings.

5.2.2 Definition of Objectives in the Canadian Method: FRIM-CMB

The definition of the objectives has been adapted to comply with the requirements of the objective-based NBCC. The objectives are described in detail in Volume 1, Division A of the NBCC. Relevant objectives are outlined in the following subsections of this report. More specifically, the FRIM-CMB method aims at evaluating fire safe alternative solutions and will therefore, focus on NBCC's fire-related objectives only.

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5.2.2.1 OS1 - Fire Safety

This objective aims at limiting the probability that, as a result of the design or construction of the building, a person in or adjacent to the building will be exposed to an unacceptable risk of injury due to fire caused by:

OS1.1 – fire or explosion occurring;
OS1.2 – fire or explosion impacting areas beyond its point of origin;
OS1.3 – collapse of physical elements due to a fire or explosion;
OS1.4 – fire safety systems failing to function as expected;
OS1.5 – persons being delayed in or impeded from moving to a safe place.

5.2.2.2 OP1 - Fire Protection of Buildings

This objective aims at limiting the probability that, as a result of its design or construction, the building will be exposed to an unacceptable risk of damage due to fire caused by:

OP1.1 – fire or explosion occurring;
OP1.2 – fire or explosion impacting areas beyond its point of origin;
OP1.3 – collapse of physical elements due to a fire or explosion;
OP1.4 – fire safety systems failing to function as expected.

5.3 Strategies – Third Level of the Hierarchy System

5.3.1 Definition of Strategies in the European Method: FRIM-MAB

5.3.1.1 S_1- Control fire growth by active means

This strategy is related to controlling the fire growth by active systems (such as suppression systems and smoke control systems) and by the fire service (fire fighters).

5.3.1.2 S_2 - Confine fire by construction

This strategy is related to providing structural stability, controlling the movement of fire through containment, and the use of fire safe materials (such as linings and facade material). This relates to passive systems or materials that are constantly in place.

5.3.1.3 S_3 - Establish safe egress

This strategy is related to objects, designs, or strategies which cause movement of occupants and provide movement means for occupants. This is done by designing detection systems and signal systems, by designing escape routes and by educating or training the occupants. In some cases the design of the escape route may envision action by the fire brigade (i.e., escape by a ladder through a window).

5.3.1.4 S_4 - Establish safe rescue

This strategy aims at protecting the lives of occupants and ensuring safety of fire brigade personnel during rescue. This is done by providing structural stability and preventing rapid unexpected fire spread and collapse of building parts.

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5.3.2 Definition of Strategies in the Canadian Method: FRIM-CMB

The strategies in the Canadian FRIM-CMB are similar in intent to those in the European FRIM-MAB, but are more specific. They have been aligned with the functional statements defined in the NBCC. The functional statements that relate to fire safety are:

F01 – to minimize the risk of accidental ignition;
F02 – to limit the severity and effects of fire or explosions;
F03 – to retard the effects of fire on areas beyond its point of origin;
F04 – to retard failure or collapse due to the effects of fire;
F05 – to retard the effects of fire on emergency egress facilities;
F06 – to retard the effects of fire on facilities for notification, suppression & emergency response;
F10 – to facilitate the timely movement of persons to a safe place in an emergency;
F11 – to notify persons, in a timely manner, of the need to take action in an emergency;
F12 – to facilitate emergency response;
F13 –to notify emergency responders, in a timely manner, of the need to take action in an emergency.

5.4 Parameters –Bottom Level of the Hierarchy System

There are 17 parameters, P_i, which are each weighted by a parameter denoted by W_i. The sum of the 17 grades' weightings must equal 1; therefore, if all parameters were given the same value for W_i then W_i would equal 1÷17 = 0.05884 for all parameters P_i. The relative importance of a parameter can be judged by whether its weighting is greater than 0.05884 (a more important parameter) or less than 0.05884 (a less important parameter). While the weightings of parameters are mainly adopted from the FRIM-MAB, some parameters have been changed to reflect the requirements of the NBCC and their respective weights have been changed accordingly.

5.4.1 P_1 – Linings in apartment

The weighting assigned to P_1 is W_1 = 0.0576, indicating that it is of average importance among the parameters. The weighted grade for this parameter is equal to W_1P_1.

The purpose of this parameter is to assess the possibility of whether internal linings in an apartment will delay the ignition of the structure and therefore reduce fire growth. It is determined by the performance of the worst lining materials on a wall or ceiling within an apartment of the building. In Europe, the performance of interior finishes for walls and ceilings is expressed in terms of its Euroclass. The Euroclass of a material is based on its performance in a non-combustibility test and a single-burning item test in accordance with EN 13501 [9]. Table 2 summarizes the grades assigned to materials as a function of the Euroclass for the worst lining material within any apartment. The table also provides examples of materials that fall into the various Euroclasses.

Table 2 Parameter P_1 in Europe according to Euroclass

Typical Products	Possible Euroclass	Grade P_1
Stone, concrete	A1	5
Gypsum boards	A2	5
Best fire retardant treated woods	B	4
Textile wall cover on gypsum board	C	3
Wood (untreated/uncoated)	D	2
Low density wood fiberboard	E	1
Some plastics	F	0

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As specified in Subsection 3.1.13 of Division B of the NBCC, in Canada, the fire performance of interior finishes for walls and ceilings are expressed in terms of Flame-Spread Ratings (FSR). The FSR of a material or assembly is determined by the average of not less than three tests conducted in conformance with CAN/ULC-S102, "Surface Burning Characteristics of Building Materials and Assemblies" [10]. Sentence 3.1.13.2.(2) of the NBCC indicates that the interior wall and ceiling finishes within an apartment must not exceed 150. The objectives and functional statements attributed to this sentence are [F02-OS1.2] and [F02-OP1.2].

Relating the Euroclass destinations A1, A2, B, C, D, E and F to Canadian FSRs is, in practice, not a straightforward matter. However the FSRs of many of the materials listed in Table 2 are well known. Consequently, one can assign the same weighting in the Canadian index method to these materials and infer what FSRs apply as has been done in Table 3.

Table 3 Parameter P_1 grading according to Flame-Spread Ratings of NBCC [4]

Fire Performance	Typical Products	Grade P_1
Non-combustible	Stone, concrete	5
FSR ≤ 25	Gypsum board[1]	5
FSR ≤ 25	Fire-retardant-treated wood[2]	4
25 < FSR ≤ 75	Some textile covers on gypsum board[3]	3
75 < FSR ≤ 150	Most wood products[4]	2
150 < FSR ≤ 200	Some low density wood fiberboards	1
FSR > 200	Some plastics	0

1. See Table D-3.1.1.A in the NBCC.
2. See Article 3.1.4.7 in the NBCC.
3. An inference based on the European method.
4. See Table D-3.1.1.A in the NBCC.

If low-density materials (≤ 100 kg/m³) are employed as room linings, whether they are combustible or non-combustible, they very effectively trap heat in the apartment causing rapid fire growth and early flashover. Although this index method has not been calibrated to address such scenarios, it is recommended that the grade of such materials be decreased by one over the entries in Table 3.

Since Sentence 3.1.13.2.(2) of the NBCC specifies that the interior wall and ceiling finishes within an apartment must not exceed 150, it is clear from Table 3 that the minimum acceptable solution (FSR = 150) yields a grade of $P_1 = 2$.

5.4.2 P_2 – Suppression system

The weighting assigned to P_2 is $W_2 = 0.0668$, therefore it is of major importance.

In Europe, this parameter is used to characterize fire suppression equipment and systems. P_2 is sub-divided into P_{2a} and P_{2b}. The first sub-parameter, P_{2a}, is dependent on the type of automatic sprinkler system: no sprinkler, residential sprinkler, or ordinary sprinkler; and the location of the sprinkler system installed in the building: in apartments, in escaping routes, or in both. The second sub-parameter, P_{2b}, is dependent on the location of portable fire suppression equipment. Tables 5 to 7 summarise the assignment of values to P_{2a} and P_{2b}.

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Table 3 Sub- Parameter P_{2a} Grading of Automatic Sprinkler System in Europe

Survey Items	Decision Rules						
Type of sprinkler	N	R	R	R	O	O	O
Location of sprinkler	-	A	E	B	A	E	B
Grade P_{2a}	N	M	L	H	M	L	H

Type of sprinkler: N = no sprinkler, R = residential sprinkler, O = ordinary sprinkler;
Location of sprinkler: A = in apartment, E = in escape route, B = both in apartment and escape route;
Grade P_{2a}: L = low level of protection, M = moderate level of protection, H = high level of protection

Table 4 Sub- Parameter P_{2b} Grading of Location of Portable Equipment in Europe

N	None
F	Extinguishing equipment on every floor
A	Extinguishing equipment in every apartment

Table 5 Parameter P_2 Grading for Suppression System in Europe

Sub-Parameters	Decision Rules											
P_{2a}: Automatic sprinkler system	N	N	N	L	L	L	M	M	M	H	H	H
P_{2b}: Portable equipment	N	F	A	N	F	A	N	F	A	N	F	A
Grade P_2	0	0	1	1	1	2	4	4	4	5	5	5

In Canada, whether a residential building must be sprinklered, or not, is specified in Articles 3.2.2.47 to 3.2.2.53 from Division B of the NBCC. The objectives and functional statements attributed to the requirement for sprinklers are [F02, F04-OS1.2, OS1.3] and [F02, F04-OP1.2, OP1.3].

Article 3.2.5.12 from Division B of NBCC specifies the National Fire Protection Association (NFPA) standards that govern the design, construction, installation and testing of sprinkler systems in buildings as follows:

a) NFPA 13R “Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height” [11], is permitted for use in a residential building that is not more than 4 storeys in building height and conforms to area, height and structural fire-resistance rating requirements of Articles 3.2.2.47, 3.2.2.48, 3.2.2.50 or 3.2.2.53.
b) The default and more stringent standard is NFPA 13 “Standard for the Installation of Sprinkler Systems” [12].

Portable extinguishing equipment is not required in apartment buildings in the NBCC (see Article 3.2.5.16) and so unlike with the FRIM-MAB it is not included in the FRIM-CMB.

To the best of our knowledge, there are as of 2012 only few buildings, namely the Vancouver Convention Centre and the CSN FondAction office building in Quebec City, that have been constructed using alternative solutions with enhanced sprinkler protection (beyond what is called for in the NBCC and NFPA 13) [13]. Therefore an enhanced sprinkler system is an option, and parameter P_2 is assigned with a grade from 0 to 5 depending on which standard is followed for the sprinkler system installation. Table 6 provides suggested P_2 grade values for use with the FRIM-CMB. The weighted grade for this parameter is equal to W_2P_2.

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Table 6 Parameter P_2 Grading of Automatic Sprinkler System in Canada

Sprinkler Protection	Typical Scenario	Grade P_2
None	No sprinkler protection	0
NFPA 13 or 13R	Partial protection (not NBCC compliant)	1
NFPA 13R	NBCC compliant (up to 4 storey buildings)	3
NFPA 13	NBCC compliant (more than 4 storey buildings)	4
Enhanced Protection	Enhanced beyond NBCC or NFPA requirements	5

5.4.3 P_3 – Fire Service

The weighting assigned to P_3 is W_3 = 0.0681, therefore it is of major importance. In fact, this parameter is assigned the second highest weighting of all 17 parameters.

Parameter P_3 accounts for the possibility of whether fire services will be able to save lives and to prevent further fire spread after their arrival on the scene. The FRIM-MAB includes three sub-parameters: capability of responding fire service, response time of fire service to the site, accessibility and equipment, such as the number of windows (or balconies), that are accessible by the fire service ladder trucks.

As noted in the non-mandatory discussion of firefighting assumptions in Appendix A-3 of NBCC, the requirements of the NBCC are based on the assumption that firefighting capabilities are available in the event of a fire emergency. It is assumed that a municipality will limit the size and type of construction based on the municipal firefighting capabilities. Consequently, with one exception, the NBCC does not link fire safety requirements with fire department capabilities. The exception which is explicitly stated in Sentence 3.2.3.1.(8) is that the limiting distances mandated in Subsection 3.2.3 apply only if the time from receipt of notification of fire by the fire department until the arrival of the first fire department vehicle at the building site does not exceed 10 minutes; otherwise the prescribed limiting distance must be halved.

The sub-parameter P_{3a} is intended to address the capability of the fire department; Table 7 lists values that are used in Europe. Since fire departments are assessed differently in Canada the P_{3a} values used in the FRIM-CMB are adjusted accordingly and are listed in Table 8 .

Table 7 Sub-Parameter P_{3a} Grading for Fire Service Capability in Europe

Capability of Responding Fire Service	Grade P_{3a}
No brigade available	0
Firefighting capability only outside the building	1
Firefighting capability but no smoke diving capability	2
Firefighting and smoke diving capability	4
Simultaneous firefighting, smoke diving and external rescue by ladders	5

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Table 8 Sub-Parameter P_{3a} Grading for Fire Service Capability in Canada

Capability of Responding Fire Department	Grade P_{3a}
No fire department available	0
Fully volunteer department	2
Mixed volunteer - professional fire department	3
Fully professional fire department	4
Fully professional fire department with mutual aid from nearby departments if necessary	5

The sub-parameter P_{3b} is intended to address the response time for a fire department (Table 9). This parameter is the same in both methods, although as mentioned above, the NBCC requirements become more stringent if the fire department response time exceeds 10 minutes. (This specific feature of the NBCC is addressed more directly by Parameter P_{10} Adjacent Buildings.)

Table 9 Sub-Parameter P_{3b} Grading for Fire Service Response Time in Europe and Canada

Response Time (min)	Grade P_{3b}
> 20	0
15 - 20	1
10-15	2
5-10	3
0 - 5	5

The sub-parameter P_{3c} is intended to address accessibility for the fire department. Table 10 gives the grades for P_{3c} used in the FRIM-MAB. Based on the NBCC requirements for accessibility to the sides of a building, P_{3c} is graded as in Table 11 in the FRIM-CMB.

Table 10 Sub-Parameter P_{3c} Grading for Accessibility of Fire Service and Equipment in Europe

Accessibility of Fire Service and Equipment	Grade P_{3c}
Less than one window in each apartment accessible by fire service ladders	0
At least one window in each apartment accessible by fire service ladders	3
All windows accessible by fire service ladder	5

Table 11 Sub-Parameter P_{3c} Grading for Accessibility of Fire Service and Equipment in Canada

Accessibility of Responding Fire Department and Equipment	Grade P_{3c}
Building is not easily accessible from any side	0
Building is accessible (faces) from one street	2
Building is accessible (faces) from two streets	3
Building is accessible (faces) from three streets	4
Building is accessible from all sides	5

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In the NBCC, article 3.2.7.9 requires an emergency power supply for a firefighter elevator so as to reach the fire origin as quickly as possible. Although this is a requirement for high-rise residential buildings (as defined in clause 3.2.6.1.1) d) of Division B), it would be optional for other buildings, so sub-parameter P_{3d} is included in the FRIM-CMB. P_{3d} grades are shown in Table 12.

Table 12 Sub-Parameter P_{3d} Grading for Availability of Fire Department Elevator in Canada

Fire Department (FD) Elevator	Grade P_{3d}
Without FD elevator	0
With FD elevator	5

In the FRIM-MAB, the parameter P_3 is calculated based on the first 3 sub-parameters as follows:

$$P_3 = 0.31P_{3a} + 0.47P_{3b} + 0.22P_{3c} \tag{2a}$$

In the FRIM-CMB, the parameter P_3 is calculated based on all 4 sub-parameters as follows:

$$P_3 = 0.28P_{3a} + 0.42P_{3b} + 0.20P_{3c} + 0.10P_{3d} \tag{2b}$$

5.4.4 P_4 – Compartmentation

The weighting assigned to P_4 is $W_4 = 0.0666$, therefore it is of major significance. Parameter P_4 is used to define the extent to which building space is divided into fire-rated compartments. This parameter is used the same way in both FRIM-MAB and FRIM-CMB, grading values are given in Table 13.

While the European FRIM-MAB model acknowledges the importance of the size of compartments in a residential building, it does not address the building area (maximum area per storey). The NBCC puts an upper limit on building areas for residential buildings depending on the number of storeys, whether sprinklers are present and depending on the fire-resistance rating of the structure (see Articles 3.2.2.47 to 3.2.2.53 in the NBCC). NBCC, in a very simple way of limiting the fire risk, also typically reduces the allowable area of buildings of combustible construction to 20% of those allowed for non-combustible construction buildings. It has yet to be decided whether the FRIM-CMB needs further adjustments to address these NBCC requirements.

Table 13 Parameter P_4 Grading for Compartmentation in the Building

Maximum Area in the Fire-Rated Compartment	GRADE P_4
> 400 m2	0
200 - 400 m2	1
100 – 200 m2	2
50 – 100 m2	3
< 50 m2	5

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5.4.5 P_5 – Non-load-bearing Fire Separations

The weighting assigned to P_5 is $W_5 = 0.0675$, therefore it is of major importance. In fact, this parameter has been assigned the third highest weighting of all 17 parameters.

Parameter P_5 is used to define the fire resistance of building assemblies which separate fire compartments. Only non-load-bearing fire separations are addressed by this parameter. Any fire separation which is also load-bearing is addressed under P_{15}: Structure (Load-bearing).

In Europe the fire resistance of a building assembly intended to be a fire separation is rated by its integrity (E) and insulation (I). Therefore, sub-parameter P_{5a} is categorized with EI 15, EI 30, EI 45, or EI 60 (i.e. EI 60 meaning the rating for both E and I is 60 minutes), as shown in Table 14. In Canada, a building assembly intended to be a fire separation is rated by its fire-resistance rating (FRR) and categorized into 30 minutes, 45 minutes or 60 minutes. The FRR of a non-loadbearing fire separation is often established based on three performance properties: integrity (E), insulation (I) and structure (R). That is the FRR assigned to many non-loadbearing fire separations was often established based on a load-bearing test so may underestimate its performance when used in a non-loadbearing application as intended in this section. As noted above in the discussion of compartmentation and building areas, Article 3.3.4.2 of the NBCC specifies that apartments must be separated from each other and the remainder of the building by fire separations having a FRR not less than one hour. An exception is granted in a building where the structure only requires a 45-minute rating: in such buildings the fire separations defining an apartment need only exhibit a 45-minute rating. The objectives and functional statements attributed to these compartmentation requirements are [F03-OS1.2] [F05-OS1.5] [F06-OS1.5, OS1.2] and [F03, F06-OP1.2]. Therefore, P_{5a} is graded by fire-resistance rating for building assemblies in Canada as shown in Table 15.

Table 14 Sub-Parameter P_{5a} Grading for Integrity and insulation for a Building Assembly in Europe

Integrity and Insulation (EI)	Grade P_{5a}
EI < 15 min	0
15 ≤ EI < 30 min	1
30 ≤ EI < 45 min	3
45 ≤ EI < 60 min	4
EI ≥ 60 min	5

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Table 15 Sub-Parameter P_{5a} Grading for Fire Resistance Rating for a Building Assembly in Canada

Fire Resistance Rating (FRR) required for Building's Structural Elements	Fire Resistance Rating (FRR) of non-loadbearing Fire Separations	Grade P_{5a}
FRR ≥ 60 min	FRR < 45 min	0
FRR ≥ 60 min	45 ≤ FRR < 60 min	2
FRR ≥ 60 min	60 ≤ FRR < 90 min	3
FRR ≥ 60 min	90 ≤ FRR < 120 min	4
FRR ≥ 60 min	FRR ≥ 120 min	5
FRR = 45 min	FRR < 30 min	0
FRR = 45 min	30 ≤ FRR < 45 min	2
FRR = 45 min	45 ≤ FRR < 60 min	3
FRR = 45 min	60 ≤ FRR < 90 min	4
FRR = 45 min	90 ≤ FRR	5

Sub-parameter P_{5b} is used to indicate the use of fire stops at joints, intersections and concealed spaces, Table 16 shows the grade values for the FRIM-MAB.

Table 16 Sub-Parameter P_{5b} Grading for Fire Stops at Joints, Intersections and Concealed Spaces in Europe

Structure and Firestop Design	Grade P_{5b}
Timber-frame structure with voids and no fire stops	0
Ordinary design of joints, intersections and concealed spaces, without special	1
Joints, intersections and concealed spaces are specially designed for preventing fire spread and deemed by engineers to have adequate performance.	2
Joints, intersections and concealed spaces have been tested and shown to have endurance in accordance with the EI of other parts of the construction	3
Homogenous construction with no voids	5

Subsection 3.1.11 in the NBCC addresses the use of fire blocks (i.e. fire stopping strategies) in concealed spaces. The specific requirements are found in:

a) Article 3.1.11.2 for fire blocks within wall assemblies. The objectives and functional statements attributed to these requirements are [F03-OS1.2, OP1.2];
b) Article 3.1.11.4 for fire blocks between vertical and horizontal spaces. The objectives and functional statements attributed to these requirements are [F03-OS1.2, OP1.2];
c) Article 3.1.11.5 for fire blocks within horizontal concealed spaces, The objectives and functional statements attributed to these requirements are [F03, F04-OS1.2][F03, F04-OP1.2;
d) Article 3.1.11.6 for fire blocks in crawl spaces, The objectives and functional statements attributed to these requirements are [F03, F04-OS1.2][F03, F04-OP1.2].

Sub-parameter P_{5b} is simplified for the FRIM-CMB as shown in Table 17.

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Table 17 Sub-Parameter P_{5b} Grading for Fire Stops at Joints, Intersections and Concealed Spaces in Canada

Structure and Firestop Design	Grade P_{5b}
Timber-frame structure with voids and no fire stops	0
Ordinary design of joints, intersections and concealed spaces, without special attention to fire spread	1
Joints, intersections and concealed spaces are in full compliance with NBCC requirements	3
Homogenous construction with no voids	5

Sub-parameter P_{5c} is used to indicate penetrations of fire separations between fire compartments. Table 18 shows the grades for the FRIM-MAB.

Table 18 Sub-Parameter P_{5c} Grading For Penetrations in Fire Separations between Fire Compartments in Europe

Penetrations	Grade P_{5c}
Penetrations with no seals between fire compartments	0
Non-certified sealing systems between fire compartments	1
Certified sealing systems between fire compartments	2
Special installation shafts or ducts in an own fire compartment with certified sealing systems to other fire compartments	3
No penetrations between fire compartments	5

Subsection 3.1.9 in the NBCC addresses the protection of penetrations in rated fire separations by fire stops. A fire stop is a system consisting of a material, component and means of support used to fill gaps between fire separations or between fire separations and other assemblies (so relevant for P_{5b}) or used around items that wholly or partially penetrate a fire separation (so relevant for P_{5c}). The specific requirements for protection of penetrations are found in:

a) Sentence 3.1.9.1.(1) for fire penetrations of rated fire separations that are required to be sealed by a fire stop which when tested to CAN/ULC-S115 “Fire Tests of Firestop Systems” [14] has an F rating not less than the fire-protection rating required for closures in the fire separation (See the discussion below on P_6 for requirements for fire-protection ratings). An F rating implies that the fire stop remains in place during a fire test for the rating period without permitting the passage of flame through the opening or the occurrence of flames on elements on the unexposed side of the fire stop. The objectives and functional statements attributed to these requirements are [F03-OS1.2, OP1.2] [F04-OS1.3, OP1.3];

b) Sentence 3.1.9.1.(2) for fire penetrations of a firewall or a rated **horizontal** fire separations that are required to be sealed by a fire stop which when tested to CAN/ULC-S115 has an FT rating not less than the fire-resistance rating required for the fire separation. An FT rating implies that the fire stop remains in place during a fire test for the rating period meeting both the F rating requirements and with no element the unexposed side of the fire stop incurring a temperature rise

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exceeding 181°C. The objectives and functional statements attributed to these requirements are [F03-OS1.2, OP1.2, OP1.3];.

c) Sentence 3.1.9.1.(4) permits sprinklers (pipes) to penetrate a fire separation or a membrane forming part of an assembly required to have a fire-resistance rating without having to meet the fire stop requirements of Sentences (1) or (2) provided the annular space created by the penetration is covered by a metal escutcheon plate in accordance with NFPA 13 "Installation of Sprinkler Systems".;

d) Sentence 3.1.9.1.(5) permits fire dampers (not specifically designed with a fire stop) to penetrate a fire separation or a membrane forming part of an assembly required to have a fire-resistance rating without having to meet the fire stop requirements of Sentences (1) or (2) provided the fire damper is installed in conformance with NFPA 80 "Fire Doors and Other Opening Protectives" [15].

Additional NBCC requirements for the protection of penetrations are contained in Article 3.1.9.2 (Combustibility of Service Penetrations), Article 3.1.9.3 (Penetration by Wires, Cables, and Outlet Boxes), Article 3.1.9.4 (Combustible Piping Penetrations) and Article 3.1.9.5 (Openings through a Membrane Ceiling).

For the Canadian FRIM-CMB, the grades for P_{5c} are listed in Table 19.

Table 19 Sub-Parameter P_{5c} Grading For Penetrations between Fire Separations between Fire Compartments in Canada

Penetrations	Grade P_{5c}
Penetrations with no fire stops between fire compartments	0
Penetrations are protected by fire stop systems that are not compliant with NBCC requirements	2
Penetrations are protected by fire stop systems that are compliant with NBCC requirements	4
No penetrations between fire compartments	5

Sub-parameter P_{5d} defines the combustibility of any combustible elements used in building separations. The concern is that, despite the use of fire stop systems, if the fire separation being penetrated is combustible or contains combustible insulation, fire may break out within the fire separation near the penetration. While this would seem unlikely with an approved fire stop system, the European method considers it to be a possibility. Table 20 shows the grades for the sub-parameter P_{5d} for both the FRIM-MAB and the FRIM-CMB methods.

Table 20 Sub-Parameter P_{5d} Grading for Combustibility of Combustible Elements of Separating Construction in Europe and Canada

Combustible Part	Grade P_{5d}
Both separating structure and insulation are combustible	0
Only the insulation is combustible	2
Only the separating structure is combustible	3
Both separating structure and insulation are non-combustible	5

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Using the allocated weighing factors for the 4 sub-parameters, parameter P_5 is calculated as follows in the FRIM-CMB:

$$P_5 = 0.35P_{5a} + 0.28P_{5b} + 0.24P_{5c} + 0.13P_{5d} \quad (3)$$

5.4.6 P_6 – Doors and Openings

The weighting assigned to P_6 is W_6 = 0.0698, therefore it is of major importance. This parameter has been assigned the highest weighting of all 17 parameters. The concern is that doors and other openings typically represent the weakest links in a fire separation intended to ensure compartmentation. Parameter P_6 is used to define the fire separating function of doors and other openings between fire compartments.

In Article 3.1.8.10 from Division B of the NBCC, the required fire performance of closures for openings is expressed in terms of their fire-protection rating. A fire-protection rating is the time that a closure will withstand the passage of flame when exposed to a standard fire.

The fire-protection rating of a closure is determined on the basis of a test conducted in compliance with:

- CAN4-S104-M, “Fire Tests of Door Assemblies”[16];
- CAN4-S106-M, “Fire Tests of Window and Glass Block Assemblies” [17]; or
- CAN/ULC-S112-M, “Fire Test of Fire-Damper Assemblies” [18].

These tests are similar to the standard fire-resistance test, but the failure criteria are different. Table 3.1.8.4 of the NBCC prescribes the fire-protection rating that a closure must exhibit if it is within a fire separation (for example, a door between an apartment and a public corridor) as shown in Table 21. These values apply to all building occupancies. The objectives and functional statements attributed to these requirements are [F03-OS1.2, OP1.2].

Table 21 Required fire protection rating of a closure according to the NBCC

Required FRR of the Fire Separation	Minimum Fire Protection Rating of a Closure
45 min	45 min
1 hour	45 min
1.5 hour	1 hour
2 hours	1.5 hours
3 hours	2 hours
4 hours	3 hours

According to Article 3.2.2.48 through Article 3.2.2.53 of the NBCC, the structural fire-resistance requirements for a mid-rise residential building are 45 minutes or 1 hour. Furthermore, Article 3.1.10.2 requires that fire walls between adjoining residential buildings only need to exhibit a 2-hour fire resistance rating.

There is a significant relaxation permitted for a door between an apartment and a public corridor that applies to any mid-rise apartment building since fire separations in such buildings never need exhibit a fire-resistance rating greater than 1 hour. Such doors are permitted to exhibit a fire-protection rating not less than 20 minutes (See Article 3.1.8.10 from Division B).

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Finally, in compliance with Article 3.1.8.11, all doors between an apartment and a public corridor must be equipped with self-closing devices. The same objectives and functional statements are attributed to these requirements; namely [F03-OS1.2, OP1.2].

As doors are considered to be the weakest link in ensuring adequate fire compartmentation, the parameter P_6 is graded solely on the performance of doors. It should therefore, be assumed when using this method, that all other closures have been designed to meet the requirements of the NBCC. The sub-parameters P_{6a} and P_{6b} in the FRIM-CMB accordingly reflect these code provisions for doors in the NBCC; however, the weighting factor for P_6 has been kept the same as in the FRIM-MAB.

Table 22 Sub-Parameter P6a Grading for Doors Leading to Escape Route in the FRIM-MAB

Survey Items	Decision Rules							
Integrity and insulation[1]	A	A	B	B	C	C	D	D
Type of closing[2]	M	S	M	S	M	S	M	S
GRADE P_{6a}	0	1	1	3	2	4	3	5

[1]Integrity and insulation = EI
A = EI < EI 15, B = EI 15 ≤ EI < EI 30, C = EI 30 ≤ EI < EI 60, D = EI ≥ EI 60
[2]Type of closing M = manually, S = self-closing

Table 23 Sub-Parameter P_{6b} Grading for Doors in Escape Route in the FRIM-MAB

Survey Items	Decision Rules								
Integrity and insulation[1]	A	A	B	B	C	C	D	D	-
Type of closing[2]	M	S	M	S	M	S	M	S	-
GRADE P_{6b}	0	1	1	3	2	4	3	5	5

[1]Integrity and insulation = EI
A = EI < EI 15, B = EI 15 ≤ EI < EI 30, C = EI 30 ≤ EI < EI 60, D = EI ≥ EI 60
[2]Type of closing M = manually, S = self-closing

Table 24 Sub-Parameter P_{6a} Grading for Doors Leading to Escape Route (that is, between an apartment a public corridor) in the FRIM-CMB

Survey Items	Decision Rules							
Fire Protection Rating [1]	A	A	B	B	C	C	D	D
Type of closing[2]	M	S	M	S	M	S	M	S
GRADE P_{6a}	0	1	1	3	2	4	3	5

[1]A = Fire Protection Rating < 20 min, B = 20min ≤ Fire Protection Rating < 45 min,
C = 45 min ≤ Fire Protection Rating < 60 min, D = Fire Protection Rating ≥ 60 min
[2]Type of closing: M = manually, S = self-closing

Table 25 Sub-Parameter P_{6b} Grading for Doors within Escape Routes in the FRIM-CMB

Survey Items	Decision Rules					
Fire Protection Rating[1]	A	A	B	B	C	C
Type of closing[2]	M	S	M	S	M	S

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GRADE P_{6b}	0	1	2	4	3	5
[1]A = Fire Protection Rating < 45 min, B = 45 min ≤ Fire Protection Rating < 60 min, C = Fire Protection Rating ≥ 60 min. [2]Type of closing: M = manually, S = self-closing						

Parameter P_6 is calculated as follows in the FRIM-CMB:

$$P_6 = 0.67P_{6a} + 0.33P_{6b} \tag{4}$$

5.4.7 P_7 – Windows

The weighting assigned to P_7 is $W_7 = 0.0473$, therefore it is of less importance.

In the FRIM-MAB, Parameter P_7 is used to account for the contribution of windows (including other facade openings) and any means of protection, to the possibility that flames issuing through the openings on one storey cause fire to spread to the storey above through openings on that storey. Two sub-parameters are defined: P_{7a} which relates to relative vertical distance (r) equal to the height of the window (h) (plus the horizontal extension of a balcony if present) divided by the vertical distance between windows (l), and P_{7b} which relates to the class of window which is graded based on its integrity class. Clearly then the goal here is to prevent flames from jumping from one storey to another. Table 26 presents the grades assigned to windows in the FRIM-MAB.

Table 26 Parameter P_7 Grading for Windows in the FRIM-MAB

Sub-Parameters	Decision Rules					
P_{7a} Relative vertical distance[1]	A	A	A	B	B	B
P_{7b} Class of window[2]	C	D	E	C	D	E
GRADE P_7	0	3	5	2	5	5
[1]A = r < 1, B = r ≥ 1, [2]C = window class < E 15, D = window class ≥ E 15, E = tested special design solution)						

This possibility though potentially important, is not directly addressed in the NBCC for residential buildings. However, Article 3.2.3.17 does require attention be paid to this issue for windows in a non-sprinklered storey classified as Group E (Mercantile) or Group F, Division 1 or 2 (high or medium hazard industrial) and a storey above. Consequently, it has been decided to include P_7 in the FRIM-CMB. In Canada, the fire performance of windows is evaluated by their fire protection rating determined using ULC-S106-M "Fire Tests of Window and Glass Block Assemblies" [17]. Thereby, sub-parameters P_{7a} and P_{7b} are modified accordingly in the FRIM-CMB as indicated in Table 27 (unsprinklered) and Table 28 (sprinklered). Note that the impact of the presence of sprinklers has been added to reflect the intent of 3.2.3.17.(3).

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Table 27 Parameter P_7 Grading for Windows in the FRIM-CMB in the absence of sprinklers

Sub-Parameters	Decision Rules (No Sprinklers)					
P_{7a} Relative vertical distance[1]	VA	VA	VA	VB	VB	VB
P_{7b} Fire Protection Rating[2]	A	B	C	A	B	C
GRADE P_7	0	4	5	1	5	5

[1]VA = r < 1, VB = r ≥1
[2]A = Fire Protection Rating < 45 min, B = 45min ≤ Fire Protection Rating < 60 min
C = Fire Protection rating ≥ 60min

Table 28 Parameter P_7 Grading for Windows in the FRIM-CMB in the presence of sprinklers

Sub-Parameters	Decision Rules (With Sprinklers)					
P_{7a} Relative vertical distance[1]	VA	VA	VA	VB	VB	VB
P_{7b} Fire Protection Rating[2]	A	B	C	A	B	C
GRADE P_7	2	5	5	3	5	5

[1]VA = r < 1, VB = r ≥ 1
[2]A = Fire Protection Rating < 45 min, B = 45min ≤ Fire Protection Rating < 60 min
C = Fire Protection rating ≥ 60min

5.4.8 P_8 - Façades

The weighting assigned to P_8 is W_8 = 0.0492, therefore it is of less importance. The weighted grade for this parameter is equal to W_8P_8.

In the FRIM-MAB, the parameter P_8 accounts for the façade material and factors affecting the possibility of fire spread along the façade. The sub-parameter P_{8a} defines the combustible part of the façade, Table 29, P_{8b} defines combustible material above the windows, Table 30, and P_{8c} defines the void between the façade and its supporting wall, Table 31.

Table 29 Sub-Parameter P_{8a} Grading for Combustible Part of Façade in the FRIM-MAB

Combustible Part	Grade P_{8a}
> 40 %	0
20 – 40 %	2
< 20 %	3
0 %	5

Table 30 Sub-Parameter P_{8b} Grading for Combustible Material above Windows in Europe

Combustible Material Above Windows?	Grade P_{8b}
Yes	0
No	5

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Table 31   Sub-Parameter P_{8c} Grading for whether a Continuous Void Exists between the Facade Material and the Supporting Wall in Europe

Type of Void	Grade P_{8c}
Continuous void in combustible facade	0
Void with special design solution for preventing fire spread	3
No void	5

The NBCC has requirements governing the size of unprotected openings in exterior walls and the limiting distance to the property line to assure that radiant heat transfer due to fire in one building does not cause fire to spread to a neighbouring building. Those requirements are addressed through parameter P_{10} presented below. To assure that size of the exposing surface does not grow larger than the maximum permitted size of unprotected openings by spreading along the facade, there is a set of NBCC requirements governing such properties of exterior walls as their fire resistance rating and their combustibility. The grading of the parameter P_8 as presented in Table 32 reflect the strategy employed in the NBCC to limit the spread of fire out of an unprotected opening and along a façade.

Finally if the maximum permitted area of unprotected openings is greater than 10% of the exposing building face, foamed plastic insulation used in the exterior wall of a mid-rise residential building must be protected on its exterior surface as specified in Article 3.2.3.8.

The objectives and functional statements attributed to these NBCC requirements are [F02, F03-OP3.1].

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Table 32 Parameter P_8 Grading for Combustible part of façade in the FRIM-CMB

NBCC	% Area	Limiting Distance	Sprinklers	FRR	Construction	Cladding	Grade P_8
3.2.3.7.(2) & 3.1.5.5.(2)	0 to 10	≥ 0 m	Y or N	1 hr	NC	NC 3.1.5.5 C	5 0 0
3.2.3.7.(2,3) & 3.1.5.5.(1,3,4)	> 10 to 25	≥ 0 m	Y	1 hr	NC or C	NC 3.1.5.5 C	5 4 0
3.2.3.7.(2,3) & 3.1.5.5.(1,3,4)	> 10 to 25	≥ 0 m	N	1 hr	NC or C	NC 3.1.5.5 C	5 2 0
3.2.3.7.(2,3) & 3.1.5.5.(1,3,4)	> 25 to 50	≥ 0 m	Y	45 min	NC or C	NC 3.1.5.5 C	5 4 0
3.2.3.7.(2,3) & 3.1.5.5.(1,3,4)	> 25 to 50	≥ 0 m	N	45 min	NC or C	NC 3.1.5.5 C	5 2 0
3.2.3.7.(2,4) & 3.1.5.5.(1,3,4)	> 25 to 50	≥ 5 m	Y	45 min	NC or C	NC 3.1.5.5 C	5 4 3
3.2.3.7.(2,3) & 3.1.5.5.(1,3,4)	> 50 but < 100	≥ 0 m	Y	45 min	NC or C	NC 3.1.5.5 C	5 4 3
3.2.3.7.(2,3) & 3.1.5.5.(1,3,4)	> 50 but < 100	≥ 0 m	N	45 min	NC or C	NC 3.1.5.5 C	5 3 2

- The 1st column (NBCC) refers to the pertinent Sentence in the NBCC;
- The 2nd column (% Area) refers to the maximum area of unprotected openings permitted as a percentage of the exposing building face;
- The 3rd column (Limiting Distance) refers to the minimum permitted limiting distance;
- The 4th column (Sprinklers) refers to whether the building is sprinklered (Y) or not (N);
- The 5th column (FRR) refers to the minimum fire resistance rating of the exterior wall (as assessed from the inside of the building);
- The 6th column (Construction) refers to the type of construction: Non-combustible (NC) or Combustible (C);
- The 7th column (Cladding) refers to the type of cladding: Non-combustible (NC), Combustible (C) or Combustible but compliant with Sentence 3.1.5.5 (3.1.5.5);
- The 8th column (Grade) refers to the grade assigned to the exterior wall and cladding combination.

5.4.9 P_9 – Attic

The weighting assigned to P_9 is W_9 = 0.0515, therefore it is of less importance. Parameter P_9 is used to assess the design features intended to prevent fire spread to and within the attic, see Table 33. The weighted grade for this parameter is equal to W_9P_9.

Sub-parameter P_{9a} describes the protection of eaves or soffits, see Table 34. The NBCC requirements for the protection of soffits are provided in Article 3.2.3.16. Designs that are compliant with this article (or

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can be demonstrated to be superior to the requirement) are considered to be adequate (see Table 34). The objectives and functional statements attributed to the soffit requirements are [F03-OS1.2, OP1.2].

Sub-parameter P_{9b} characterizes fire compartmentation in the attic; that is, it describes the extent to which the attic area is separated into fire compartments, Table 35. The NBCC classifies an attic as a horizontal service space. As a consequence, Article 3.1.8.3 specifies that fire separation walls delineating compartments in the topmost residential floor must continue vertically through the attic to the underside of the roof. Therefore, the roof space must be subdivided into compartments. The objective and functional statement attributed to this requirement are [F03-OS1.2, OP1.2].

These two sub-parameters are the same for both the Canadian index method and FRIM-MAB.

Table 33 Parameter P_9 - Grading for Prevention of Fire Spread to and in Attic in Europe and Canada

Sub-Parameters	Decision Rules							
P_{9a} Prevention of fire spread to attic	N	N	N	N	Y	Y	Y	Y
P_{9b} Fire separation in attic	N	L	M	H	N	L	M	H
Grade P_9	0	1	2	5	2	3	4	5

Table 34 Sub-Parameter P_{9a} - Grading for Protection of Eaves in Attic in Europe andCanada

N	Not adequate
Y	Adequate.

Table 35 Sub-Parameter P_{9b} - Grading for Fire Compartmentation area in Attic in Europe and Canada

Maximum Area of Fire Compartment in Attic	*Grade P_{9b}*
No attic	H
< 100 m^2	M
100 – 300 m^2	L
300 – 600 m^2	L
> 600 m^2	N

5.4.10 P_{10} – Adjacent Buildings

The weighting assigned to P_{10} is W_{10} = 0.0396, therefore it is of less importance. In fact, this parameter has been assigned the lowest weighting of all 17 parameters. The weighted grade for this parameter is equal to $W_{10}P_{10}$.

The parameter P_{10} addresses the potential for fire spread from one building to a neighbouring building. In the European FRIM-MAB, the grade of P_{10} is based solely on the minimum separation distance between buildings, see Table 36. If the buildings are separated by a fire wall, when following the European FRIM-MAB, it is deemed to be equivalent to an 8 m separating distance. Buildings separated by a NBCC compliant fire wall are assigned a grade P_{10} = 4.

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Table 36 Parameter P_{10} Grading for Distance to Adjacent Buildings in Europe

Distance to Adjacent Building	Grade P_{10}
D < 6 m	0
6 ≤ D < 8 m	1
8 ≤ D < 12 m	2
12 ≤ D < 20 m	3
D ≥ 20 m	5

Subsection 3.2.3 of the NBCC entails a much more comprehensive treatment of safe spatial separations and of appropriate exposure protection. Articles 3.2.3.1 through 3.2.3.5 prescribe limiting distances to a property line and safe sizes of unprotected openings for both sprinklered and unsprinklered mid-rise residential buildings. The objective and functional statement attributed to these spatial separation requirements are [F03-OP3.1].

Articles 3.2.3.6 to 3.2.3.9 go on to prescribe the fire-resistance ratings, type of construction (combustible vs noncombustible) and type of cladding (combustible vs noncombustible) of exterior walls as a function of the limiting distance and size of unprotected openings. These properties of an exterior wall are explicitly addressed by P_8 in the Canadian index method. P_{10} addresses safe spatial separations in terms of limiting distances and safe sizes of unprotected opening in the presence and absence of sprinklers.

The layout of a property may make it appropriate to consider some minor variances for spatial separations for new projects. For example if buildings on neighbouring properties are very far from the property line, it may be agreed that there is no need to be overly strict about the limiting distance to the property line for the new building. Some variance could be allowed if overall fire safety is not jeopardized. In order to comply with the NBCC requirements and offer AHJs and designers a flexible and simple method, parameter P_{10} is graded as in Table 37 for the FRIM-CMB.

Table 37 Parameter P_{10} Grading for Limiting Distance and Unprotected Openings in Canada

Nature of the Spatial Separations and Project	Grade P_{10}
Minor variances from NBCC (new or renovation project)	2
Compliant with NBCC (new or renovation project)	4
Exceeds NBCC (new or renovation project)	5

5.4.11 P_{11} – Smoke Control System

The weighting assigned to P_{11} is $W_{11} = 0.0609$, therefore it is of average importance. The weighted grade for this parameter is equal to $W_{11}P_{11}$.

Parameter P_{11} is used to assess equipment and systems in escape routes for limiting spread of toxic fire products, Table 38 for FRIM-MAB. Sub-parameter P_{11a} defines the way to active the smoke control system. Sub-parameter P_{11b} defines the type of smoke control system, Table 40.

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Table 38 Parameter P_{11} Grade for Smoke Control System

Sub-Parameters	Decision Rules								
P_{11a} Activation of smoke control system	N	M	M	M	M	A	A	A	A
P_{11b} Smoke vent openings	-	N	M	PN	PM	N	M	PN	PM
Grade P_{11}	0	2	2	3	3	4	4	5	5

Table 39 Sub-Parameter P_{11a} – Grading for How to Active Smoke Control System

N	No smoke control system
M	Manually
A	Automatically

Table 40 Sub-Parameter P_{11b} - Grading for Type of Smoke Control System

N	Natural ventilation through openings near ceiling
M	Mechanical ventilation
PN	Pressurization and natural ventilation for exiting smoke
PM	Pressurization and mechanical ventilation for exiting smoke

According to Article 3.2.6.1 in the NBCC, a residential building with a floor level more than 18 m above grade is considered a high building. In such high buildings Article 3.2.6.2 requires that measures be implemented to limit the movement of smoke from a fire in a floor area into upper storeys. It is unlikely that a mid-rise residential building of up to 6 storeys in building height would have any floor levels more than 18 m above grade. Consequently in Canada, mid-rise residential buildings are not considered to be high buildings so do not require active smoke control. Nonetheless, a designer may wish to implement the smoke control requirements of Article 3.2.6.2 to offset other non-compliant design features. The objectives and functional statements attributed to Article 3.2.6.2 are [F02, F03, F06 - OS1.2, OP1.2] and [F02, F03, F05, F06].

In Canada, for mid-rise residential buildings, the parameter P_{11} is assessed the values listed in Table 41.

Table 41 Parameter P_{11} for use in the Canadian Index System FRIM-CMB

Smoke Control System Installed in the Building	Grade P_{11}
No smoke control system (compliant with NBCC)	0
Smoke control measures of NBCC 3.2.6.2 implemented (exceeds NBCC requirements)	5

5.4.12 P_{12} – Detection System

The weighting assigned to P_{12} is W_{12} =0.0630, therefore it is of high importance. The weighted grade for this parameter is equal to $W_{12}P_{12}$.

Parameter P_{12} is used to assess the ability of equipment and systems to detect fires. Table 42 lists values for the FRIM-MAB and Table 45 lists values for the FRIM-CMB. Sub-parameter P_{12a} defines the location and number of detectors, Sub-parameter P_{12b} defines the reliability of detectors.

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Table 42 Sub-Parameter P_{12} - Grading for Detection System in Europe

Sub-Parameters	Decision Rules									
P_{12a} Amount of detectors	N	L	L	L	M	M	M	H	H	H
P_{12b} Reliability of detectors	-	L	M	H	L	M	H	L	M	H
Grade P_{12}	0	1	2	2	2	3	3	3	4	5

Table 43 Sub-Parameter P_{12a} - Grading for the Location and Amount of Detectors in Europe

Survey Items	Decision Rules					
Detectors in apartment[1]	N	N	A	R	A	R
Detectors in escape route[2]	N	Y	N	Y	N	Y
Grade P_{12a}	N	L	L	M	H	H

[1]N = none, A = at least one in every apartment, R = more than one in every apartment
[2]N = no, Y = yes

Table 44 Sub-Parameter P_{12b} Grading for Reliability of Detectors in Europe

Survey Items	Decision Rules					
Detector type[1]	H	H	H	S	S	S
Detector power supply[2]	B	P	BP	B	P	BP
Grade P_{12b}	L	M	M	M	H	H

[1]H = heat detectors, S = smoke detectors
[2]B = battery, P = power grid, BP = power grid and battery backup

The relevant NBCC requirements are contained in Subsection 3.2.4 – Fire Alarm and Detection Systems. Article 3.2.4.1 requires that a fire alarm system be installed in a mid-rise residential building whether the building is:

- Sprinklered (Sentence 3.2.4.1.(1)): The objectives and functional statements attributed to this requirement are [F11-OS1.5], [F13-OS1.5, OS1.2] and [F13-OP1.2];
- Nonsprinklered (Sentence 3.2.4.1.(4)): The objective and functional statement attributed to this requirement are [F11-OS1.5].

The NBCC makes a distinction between fire detectors, heat detectors and smoke detectors.

- A fire detector is a device that detects a fire condition and automatically initiates an electrical to actuate an alert signal or an alarm signal, and includes heat detectors and smoke detectors;
- A heat detector is a fire detector designed to operate at a predetermined temperature or rate of temperature rise;
- A smoke detector is a fire detector designed to operate when the concentration of airborne combustion products exceeds a predetermined level.

According to Sentence 3.2.4.11.(2) a mid-rise residential building that is not sprinklered, hence is of non-combustible construction, must have fire detectors installed in the following spaces provided they are not within dwelling units: storage rooms, service rooms, janitor's rooms, elevator hoistways, and laundry rooms. The objective and functional statement attributed to this requirement is [F11-OS1.1].

According to Sentence 3.2.4.11.(3) a mid-rise residential building that is sprinklered does not require fire detectors in the spaces listed in Sentence 3.2.4.11.(2). This is because Article 3.2.4.16 requires that an

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automatic sprinkler system be equipped with waterflow detecting devices that are connected to the fire alarm system. Therefore, a sprinkler system can also be considered to be a fire detector system. Furthermore, the relevant sprinkler standard for a mid-rise residential building requires sprinkler protection throughout these spaces and within dwelling units. The objective and functional statement attributed to this requirement is also [F11-OS1.1].

Finally, in a mid-rise residential building smoke detectors that are connected to the fire alarm system must be installed within public corridors (Clause 3.2.4.12.(1).(d)) and within dwelling units (Sentence 3.2.4.21.(7)). The objectives and functional statements attributed to the requirement for smoke detectors within dwelling units are [F11, F81-OS1.5] and in public corridors [F11-OS1.5].

The NBCC requirements for detection systems in residential buildings (particularly mid-rise buildings) are strictly enforced by an AHJ for new construction. However, it is conceivable that some small allowances could be made for renovation of an existing building. The following grading, Table 45, is proposed for Canadian index method.

Table 45 Parameter P_{12} - Grading for Detection System in Canada

Nature of Detection System and Project	Grade P_{12}
Major variances from NBCC (new or renovation project)	0
Minor variances from NBCC (renovation project)	2
Compliant with NBCC (new or renovation project)	4
Exceeds NBCC (new or renovation project)	5

5.4.13 P_{13} – Signal (Alarm) System

The weighting assigned to P_{13} is W_{13} = 0.0512, so it is of less than average importance. The weighted grade for this parameter is equal to $W_{13}P_{13}$.

Parameter P_{13} is to assess the ability of equipment and systems to effectively transmit an alarm of fire, as shown in Table 46 for the FRIM-MAB and Table 49 for the FRIM-CMB. Sub-parameter P_{13a} defines the type of signal, and sub-parameter P_{13b} defines the location of signal system.

Table 46 Parameter P_{13} - Grading for Signal System in Europe

Sub-Parameters	Decision Rules						
P_{13a} Type of signal	N	L	L	M	M	H	H
P_{13b} Location of signal	-	A	B	A	B	A	B
Grade P_{13}	0	1	2	3	4	4	5

Table 47 Sub-Parameter P_{13a} - Grading for the Type of Signal in Europe

Survey Items	Decision Rules					
Light signal	N	Y	N	N	Y	Y
Sound signal	N	N	A	S	A	S
Grade P_{13a}	N	L	M	H	M	H

Table 48 Sub-Parameter P_{13b} - Grading for the Location of Signal in Europe

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A	The signal is sent to the compartment only.
B	It is possible to send a signal manually to the whole building or at least to a large section of the building.

The relevant NBCC requirements are contained in Subsection 3.2.4 - Fire Alarm and Detection Systems. Article 3.2.4.1 requires that a fire alarm system be installed in a mid-rise residential building whether the building is:

- Sprinklered (Sentence 3.2.4.1.(1)): The objectives and functional statements attributed to this requirement are [F11-OS1.5], [F13-OS1.5, OS1.2] and [F13-OP1.2];
- Nonsprinklered (Sentence 3.2.4.1.(4)): The objective and functional statement attributed to this requirement are [F11-OS1.5].

Article 3.2.4.3 requires that either a single-stage or a two-stage alarm system be installed in mid-rise residential building. The objective and functional statement attributed to this requirement are [F11, OS1.5]. A single-stage alarm system causes an alarm signal to sound throughout the building upon operation of any manual station, detecting device or fire detector. A two-stage alarm system causes an alert signal to sound upon operation of any manual station, detecting device or fire detector. An alarm signal follows if further signals are received from detectors or if 5 minute elapses without the alert signal being acknowledged.

Article 3.2.4.8 requires that the alarm system notify the fire department under the following conditions:

- A waterflow-indicating device initiates an alarm signal;
- A two-stage fire alarm system when a device initiates an alert signal.

The objectives and functional statements attributed to these requirements are [F13-OS1.5, OS1.2] and [F13-OP1.2].

Article 3.2.4.9 prescribes requirements for an annunciator and zone indication. The objectives and functional statements attributed to these requirements are [F12-OS1.5, OS1.2].

The NBCC requirements for alarm systems in residential buildings (particularly mid-rise buildings) are strictly enforced by an AHJ for new construction. However, it is conceivable that some small allowances could be made for renovation of an existing building. The following grading, Table 49, is proposed for the FRIM-CMB:

Table 49 Parameter P_{13} - Grading for Signal System in Canada

Nature of the Signal System and Project	Grade P_{13}
Major variances from NBCC (new or renovation project)	0
Minor variances from NBCC (renovation project)	2
Compliant with NBCC (new or renovation project)	4
Exceeds NBCC (new or renovation project)	5

5.4.14 P_{14} – Means of Egress

The weighting assigned to P_{14} is W_{14} = 0.0620, therefore it is high importance. The weighted grade for this parameter is equal to $W_{14}P_{14}$.

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Parameter P_{14} is used to quantify the adequacy and reliability of escape routes. Sub-parameters are used in the FRIM-MAB method; P_{14a} defines the type of escape routes, Table 50; P_{14b} defines dimensions and layout of an escape route, Table 51; P_{14c} defines the kind of guidance signs, lighting and emergency lighting, Table 52; P_{14d} defines the worst lining or flooring class that is to be found in an escape route, Table 53. Euroclass is used in the FRIM-MAB. While in NBCC, the fire performance of interior finishes for walls and ceiling is expressed in terms of Flame-Spread Ratings (FSR).

Table 50 Sub-Parameter P_{14a} - the type of escape routes in Europe

Survey Items	Decision Rules												
Detectors in apartment[1]	A	A	A	A	B	B	B	B	C	C	C	C	C
Detectors in escape route[2]	E	F	G	H	E	F	G	H	D	E	F	G	H
Grade P_{14a}	0	1	1	3	2	3	3	4	4	5	5	5	5

[1] A = one staircase may be used as an escape route
B = escape route leading to two independent staircases
C = direct escape to two independent staircases
[2] D = windows and balconies cannot be used as escape routes
E = one window may be used as an escape route
F = at least two independent windows may be used as escape routes
G = the balcony may be used as an escape route
H = at least one window and the balcony may be used as escape routes

Table 51 Sub-Parameter P_{14b} - Grading for Dimensions and Layout of an Escape Route in Europe

Survey Items	Decision Rules											
Travel distance to an escape route[1]	C	C	C	C	B	B	B	B	A	A	A	A
Number of floors[2]	E	E	D	D	E	E	D	D	E	E	D	D
Number of apartments per floor[3]	G	F	G	F	G	F	G	F	G	F	G	F
Grade P_{14b}	0	1	2	2	3	3	4	4	4	4	5	5

[1] Maximum travel distance to an escape route: $A < 10$ m, $B = 10 – 20$ m, $C > 20$ m
[2] $D \leq 4$, $E = 5$ to 8
[3] Maximum number of apartments per floor connected to an escape route: $F \leq 4$, $G \geq 5$

Table 52 Sub-Parameter P_{14c} - Grading for Guidance Signs, Lighting and Emergency Lighting in Europe

Survey Items	Decision Rules											
Guidance signs[1]	A	A	A	A	B	B	B	B	C	C	C	C
General lighting[2]	D	D	E	E	D	D	E	E	D	D	E	E
Emergency lighting[3]	F	G	F	G	F	G	F	G	F	G	F	G
Grade P_{14c}	0	3	3	4	2	4	3	4	2	4	3	5

[1] A = none, B = normal, C = illuminating light
[2] D =manually switched on, E = always on
[3] F = not provided, G = provided

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Table 53 Sub-Parameter P_{14d} Grading for Linings and floorings in Europe

Typical Products	Possible Euroclass	Grade P_{14d}
Stone, concrete	A1	5
Gypsum boards	A2	5
Best fire retardant treated (FRT) woods	B	4
Textile wall cover on gypsum board	C	3
Wood (untreated/uncoated)	D	2
Low density wood fibreboard	E	1
Some plastics	F	0

The NBCC requirements for means of egress are very detailed and are found mostly, although not entirely, in Section 3.3 – Safety within Floor Areas and in Section 3.4 - Exits. As with P_{12} – Detection System and P_{13} –Signal System, the NBCC requirements for the means of egress in residential buildings (particularly mid-rise buildings) are strictly enforced by an AHJ for new construction.

A large number of objectives and functional statements are attributed to the means of egress. The most prevalent ones relating to fire safety appear to be: [F05, F06, F12 – OS1.2, OP1.2] and [F05, F06 – OS1.5].

Again, it is conceivable that some small allowances could be made for renovation of an existing building. The following grading, shown in Table 54, is proposed for the Canadian index method:

Table 54 Parameter P_{14} Means of Egress in Canada

Nature of the Means of Egress	Grade P_{14}
Major variances from NBCC (new or renovation project)	0
Minor variances from NBCC (new or renovation project)	2
Compliant with NBCC (new or renovation project)	4
Exceeds NBCC (new or renovation project)	5

5.4.15 P_{15} – Structure (Load-bearing)

The weighting assigned to P_{15} is W_{15} = 0.0630, therefore it is important.

Parameter P_{15} is used to assess the structural stability of a building when exposed to fire. Sub-parameter P_{15a} assesses the load-bearing members' fire resistance. Table 55 lists grading values for the FRIM-MAB. The fire resistance of a load-bearing member is categorized by its load-bearing capacity (R): R30, R60 or R90 in Europe (where R60 meaning that the structural resistance achieves a 60 minutes rating). It is determined by the standard test "EN 1363-1: Fire resistance tests – General requirements" [19].

Table 55 Sub-Parameter P_{15a} grading for load-bearing member fire resistance capability in Europe

Load-bearing Capacity (LBC)	Grade P_{15a}
LBC < R 30 min	0
R 30 ≤ LBC < R 60 min	2
R 60 ≤ LBC < R 90 min	4
LBC ≥ 90 min	5

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Table 56 lists the proposed grading values for the FRIM-CMB in Canada. The objectives and functional statements attributed to the structural fire resistance requirements for floors in residential buildings (Articles 3.2.2.47 to 3.2.2.53) are [F03-OS1.2] [F04-OS1.2, OS1.3] and [F03-OP1.2] [F04-OP1.2, OP1.3]. The objectives and functional statements attributed to the structural fire-resistance requirements for elements supporting floors are [F04-OS1.3] and [F04-OP1.3]. In Canada, load-bearing members are tested according to CAN/ULC-S101: "Fire Endurance Tests of Building Construction and Materials" [20], and are categorized by their fire-resistance rating (FRR): 30 min, 45 min, 60 min or 120 min. Note that the structural fire resistance requirements in Canada for tall buildings (namely 120 min) are significantly more stringent than in Europe (90 min).

Table 56 Sub-Parameter P_{15a} grading for load-bearing member fire resistance capability in Canada

Fire-Resistance Rating (FRR) of Load-bearing Members	Grade P_{15a}
FRR < 30 min	0
30 ≤ FRR < 45 min	2
45 ≤ FRR < 60 min	3
60 ≤ FRR < 90 min	4
90 ≤ FRR < 120 min	5

Sub-parameter P_{15b} grades the combustibility of insulation and load-bearing members in the building as indicated in Table 57. When both the load-bearing members and insulation are combustible, the lowest grade is assigned when both the load-bearing structure and insulation are non-combustible, the highest grade is assigned. In Canada the objectives and functional statements attributed to the requirement that structural elements in residential buildings be of noncombustible construction (see Articles 3.2.2.47 to 3.2.2.53) are [F02-OS1.2] and [F02-OP1.2]. The objectives and functional statements attributed to the structural fire-resistance requirements for elements supporting floors are [F04-OS1.3] and [F04-OP1.3]. The same grading system is proposed for FRIM-CMB as for FRIM-MAB; see Table 57.

Table 57 Sub-Parameter P_{15b} grading for combustibility of insulation and load-bearing member in Europe and Canada

Combustible components	Grade P_{15b}
Both load-bearing structure and insulation are combustible	0
Only the insulation is combustible	2
Only the load-bearing structure is combustible	3
Both load-bearing structure and insulation are non- combustible	5

With the same weighing function as in the FRIM-MAB, the parameter P_{15} in the FRIM-CMB is calculated as follows:

$$P_{15} = 0.74P_{15a} + 0.26P_{15b} \tag{5}$$

5.4.16 P_{16} – Maintenance and Information

The weighting assigned to P_{16} is $W_{16} = 0.0601$, therefore it is of average importance. The weighted grade for this parameter is equal to $W_{16}P_{16}$.

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Parameter P_{16} is used to assess the inspection and maintenance of fire safety equipment, escape routes etc. and information available to occupants on suppression and evacuation. Sub-parameter P_{16a} grades maintenance of fire safety systems, Table 58; P_{16b} grades inspection of escape routes, Table 59; P_{16c} grades how information is available to occupants on suppression and evacuation, Table 60.

Table 58 Sub-Parameter P_{16a} Grading for Maintenance of Fire Safety Systems in Europe

Maintenance of Fire Safety Systems	Grade P_{16a}
Carried out less than every three years	0
Carried out at least once every three years	2
Carried out at least once a year	4
Carried out at least twice a year	5

Table 59 Sub-Parameter P_{16b} Grading for Inspection of Escape Routes in Europe

Inspection of Escape Routes	Grade P_{16b}
Carried out less than every three years	0
Carried out at least once a year	1
Carried out at least once every three months	3
Carried out at least once per month	5

Table 60 Sub-Parameter P_{16c} Grading for Information to Occupants on Suppression and Evacuation in Europe

Survey Items	Decision Rules											
Written information[1]	A	A	A	A	B	B	B	B	C	C	C	C
Drills[2]	D	E	F	G	D	E	F	G	D	E	F	G
Grade P_{16c}	0	1	1	2	1	3	3	4	2	4	4	5

[1]A = no information, B = written information on evacuation and suppression available in a prominent place in the building, C = written information available in a prominent place and distributed to new inhabitants
[2]D = no drills, E = suppression drill carried out regularly, F = evacuation drill carried out regularly, G = suppression and evacuation drills carried out regularly

Parameter P_{16} is calculated as follows in the FRIM-MAB:

$$P_{16} = 0.40P_{16a} + 0.27P_{16b} + 0.33P_{16c} \tag{6}$$

In Canada, the National Building Code of Canada governs the design and construction of a building for fire safety. The National Fire Code of Canada (NFCC) governs the operation of a building to ensure continuing fire safety during its use. Maintenance and information are to be spelled out in a Fire Safety Plan that is to be developed by the building owner or operator in compliance with the NFCC. Usually such a plan is prepared during the design stage and reviewed by the AHJ and local fire department. The local fire department is to inspect the building occasionally during its use to ensure maintenance is being carried out in accordance with sprinkler, detection, and alarm standards. They also ensure that fire escapes are not blocked or illegally locked from the inside and that the fire safety plan (including information for evacuation) is implemented. Maintenance depends upon are the resources available to the local fire department (to inspect) and the resources available to the operator of the building (to ensure ongoing compliance).

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The following grading of parameter P_{16}, Table 61, is proposed for the FRIM-CMB:

Table 61 Parameter P_{16} for the Canadian Index Method

Resources	Grade P_{16}
No Fire Dept. // No onsite building manager	0
Volunteer Fire Dept. // No onsite building manager	1
Volunteer Fire Dept. // Onsite building manager	3
Full-time Fire Dept. // No onsite building manager	3
Full-time Fire Dept. // Onsite building manager	5

5.4.17 P_{17} – Ventilation System

The weighting assigned to P_{17} is W_{17} = 0.0558, so it is of less importance. The weighted grade for this parameter is equal to $W_{17}P_{17}$.

Parameter P_{17} is used to quantify the extent to which the spread of smoke through the ventilation system can be prevented. In the FRIM-MAB, this parameter is graded as indicated in Table 62.

Table 62 Parameter P_{17} Grading for Ventilation System in FRIM-MAB

Type of Ventilation System	Grade P_{17}
No specific smoke spread prevention through the ventilation system	0
Central ventilation system, designed to let smoke more easily into the external air duct than ducts leading to other fire compartments.	2
Ventilation system specially designed to be in operation under fire conditions with sufficient capacity to hinder smoke spread to other fire compartments	3
Ventilation system with a non-return damper, or a smoke detector controlled fire gas damper, in ducts serving each fire compartment.	4
Individual ventilation system for each fire compartment	5

Subsection 3.6.5 of the NBCC addresses the fire safety characteristics of heating, ventilating and air-conditioning systems. Specific characteristics addressed include:

- Limits on the use of combustible materials in duct systems;
- Flame-spread ratings and smoke-developed ratings of duct and pipe materials, and coverings;
- Installation of equipment relative to property lines;
- Requirements for fire dampers and fire stop flaps.

The principal sub-objectives and functional requirements attributed to these requirements are [F01, F02-OS1.2]. It is proposed that, for the FRIM-CMB, P_{17} be graded as indicated in Table 63.

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Table 63 Parameter P_{17} Grading for Ventilation System in FRIM-CMB

Type of Ventilation System	Grade P_{17}
No specific smoke spread prevention through the ventilation system	0
HVAC system has minor variances from the requirements of Article 3.6.5	2
HVAC system complies with the requirements of Article 3.6.5	4
HVAC system exceeds the requirements of Article 3.6.5	5

5.5 Parameter Summary Table – Fire Risk Index Method

Once grades are selected for each parameter they can be inserted into the summary Table 64 and then be multiplied by the corresponding weighting factor. The maximum individual grade for each parameter is 5.00. The sum of the weighted grades for all parameters results in a score with a maximum possible value of 5.00. The weighting factors have been kept the same in both methods. The "*Risk Index*" is calculated by subtracting the score from 5, where a low *Risk Index* means a low fire risk, thus a high level of fire safety.

Table 64 Summary Table to Calculate Fire Risk Index FRIM-CMB

Parameter	Weight	Grade	Weighted Grade
P_1 Linings in apartment	0.0576		
P_2 Suppression system	0.0668		
P_3 Fire service	0.0681		
P_4 Compartmentation	0.0666		
P_5 Non-load-bearing fire separations	0.0675		
P_6 Doors and Openings	0.0698		
P_7 Windows	0.0473		
P_8 Facades	0.0492		
P_9 Attic	0.0515		
P_{10} Adjacent buildings	0.0396		
P_{11} Smoke control system	0.0609		
P_{12} Detection system	0.0630		
P_{13} Signal (alarm) system	0.0512		
P_{14} Means of Egress	0.0620		
P_{15} Structure (Load-bearing)	0.0630		
P_{16} Maintenance and information	0.0601		
P_{17} Ventilation system	0.0558		
Sum	1.0000		
SCORE (Sum of weighted grades)			
***RISK INDEX* (= 5 – Score)**			

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6 Conclusion and Future Study

A simple yet comprehensive fire risk analysis tool for authorities having jurisdiction (AHJ) and designers wishing to develop an alternative solution using wood components has been developed in this study. The fire risk analysis method - Fire Risk Index Method for Canadian Mid-rise Buildings - has been developed based on the requirements of the 2010 NBCC and the fire risk index method developed in European countries. The method has a hierarchy structure with policy as the top level, objectives at the second level, strategies at the third level, and seventeen parameters at the bottom level to comprehensively consider the fire safety measures in a building.

The user of the method does not need to be a fully qualified fire safety engineer, but should have knowledge and expertise in the field of practice as well as be familiar with fire safety measures prescribed in the NBCC and the NFCC. The use of this model can help in evaluating the level of fire performance of designs and buildings, identify which fire protection measures have the most influence on the fire performance, and optimise the design by comparing alternative solutions. This method provides an overall fire safety index for proposed alternative solutions. That is the method accounts for how the entire suite of fire protection features in the building work together to calculate a global fire risk index for a proposed alternative solution.

Provided the global fire risk index of the alternative solution is equal to or exceeds that of the acceptable solution(s), the alternative solution can be assumed to assure that a minimum acceptable level of fire safety is achieved.

Due to the structure of the objective-based NBCC, for some design scenarios it may be become necessary to undertake comparisons at a finer scale than the global scale. For example, it might be necessary on occasion to work with a fine-tuned index that reflects all of the NBCC provisions that work towards achieving specific sub-objectives and functional statements as well as with a global risk index. Such decisions should be made in consultation with the AHJ.

There is a need for continuing refinement of this method to better reflect the fire protection requirements set forth in Part 3 of Division B of NBCC. In addition, future research should be conducted using a case study which will evaluate the fire risk in a mid-rise residential building built with combustible material versus one built with a prescriptive "Code-compliant" non-combustible construction. The model should also be validated or calibrated with other fire risk analysis tools.

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