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RAPPORT

Björn Karlsson

Fire Risk Index Method – Multistorey Apartment Buildings

FRIM-MAB

Version 1.2

Trätek

INSTITUTET FÖR TRÄTEKNISK FORSKNING

Björn Karlsson

FIRE RISK INDEX METHOD – MULTISTOREY APARTMENT BUILDINGS

FRIM-MAB

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Trätek, Rapport I 0009025

ISSN 1102 – 1071
ISRN TRÄTEK – R – – 00/025 – – SE

Nyckelord

fire safety
multistorey buildings
residential buildings
risk analysis
risk assessment
timber-frame structures
wood products

Nordic Wood **Lunds universitet**

Stockholm september 2000

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The Swedish Institute for Wood Technology Research serves the five branches of the industry: sawmills, manufacturing (joinery, wooden houses, furniture and other woodworking plants), fibre board, particle board and plywood. A research and development agreement between the industry and the Swedish National Board for Industrial and Technical Development forms the basis for the Institute's activities. The Institute utilises its own resources as well as those of its collaborators and other outside bodies. Our research units are located in Stockholm, Jönköping and Skellefteå.

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FÖRORD

De senaste åren har ett antal flervåningshus med trästomme byggts i de nordiska länderna. Sådana konstruktioner har tidigare inte tillåtits av byggreglerna, till stor del på grund av brandrisken. De nordiska länderna har därför i några år samarbetat inom Nordic Wood för att ta fram konstruktionslösningar som avsevärt minskar brandriskerna i hus med trästomme. Bl a har en nordisk handbok "Brandsäkra trähus - kunskapsöversikt och vägledning" publicerats hösten 1999.

Det är dock svårt att jämföra brandriskerna i hus av obrännbar stomme med brandrisker i hus av trästomme. Dessa risker beror på en mängd olika faktorer. Det mest praktiska angreppssättet är därför att utveckla en så kallad indexmetod, som kan användas för att rangordna brandsäkerheten i olika byggnader.

Indexmetoden har utvecklats vid Lunds Tekniska Högskola, avdelningen för Brandteknik. En första version presenterades 1998 av Sven-Erik Magnusson och Tomas Rantatalo. Metoden har därefter vidareutvecklats av Björn Karlsson i nära samverkan med en nordisk projektgrupp och en nordisk s k Delphi-panel. Arbetet ingår i det nordiska projektet Brandsäkra trähus som stöds av Nordic Wood-programmet.

Nordic Wood är den nordiska träindustrins FoU-program med målsättning att öka träanvändningen. Programmet finansieras av den nordiska träindustrin, Nordisk Industrifond och de nationella FoU-organen: Erhvervsfremmestyrelsen i Danmark, TEKES i Finland, Islands forskningsråd, Norges Forskningsråd och NUTEK i Sverige. I programmet ingår ett femtiotal projekt.

Arbetet med Indexmetoden har finansierats med stöd av Svenska Byggbranschens Utvecklingsfond, SBUF, genom NCC och Skanska, svensk byggmaterialindustri genom Rockwool och Svenska Träskivor samt Närings- och teknikutvecklingsverket, NUTEK.

Vi tackar varmt för detta stöd. Tack också till den nordiska projektgruppen, Delphi-panelen samt övriga som bidragit till utvecklingen av Indexmetoden. Vi hoppas att den ska bidra till ett brandsäkert och ökat trähusbyggande.

Stockholm september 2000
Birgit Östman
Projektkoordinator

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SVENSK SAMMANFATTNING

En ny indexmetod för brandrisker i bostadshus i flera våningar har tagits fram.

Indexmetoden bygger på att strukturen för brandsäkerheten i en byggnad kan ordnas i ett antal nivåer. Överst ligger den *policy* som gäller, sedan specificeras *målen*, på nästa nivå *strategierna* och sist ett stort antal *parametrar*. Parametrarna delas in i *underparametrar* som är kvantifierbara, organiseras i *beslutstabeller* och ges ett mätbart *betyg*. När indexmetodens struktur är fastställd ges målen, strategierna och parametrarna *vikter*.

Indexmetodens struktur och de vikter som tilldelas målen, strategierna och parametrarna har bestämts genom s k Delphi-metod, en välprövad metod för att strukturera en expertgrupps åsikter. Fem experter deltog (med bakgrund i dimensionering, provning, brandförsvar, försäkring och forskning) från varje nordiskt land (Danmark, Finland, Norge och Sverige) d v s totalt 20 experter.

Genom matrismultiplikation av betygen och vikterna fås ett relativt mått på vikten av varje parameter. Summan av de viktade betygen ger ett enda indexvärde för det aktuella byggobjektet. Detta värde kan sedan jämföras med ett indexvärde för andra byggnader eller användas för att jämföra olika brandskyddsåtgärder. Förutsättningen är givetvis att byggnormens grundkrav är uppfyllda.

För att utvärdera den framtagna indexmetoden utfördes samtidigt en kvantitativ riskanalys (QRA) av fyra flervåningshus i trästomme, nyligen uppförda i de nordiska länderna. Både indexmetoden och den kvantitativa riskanalysen användes för att rangordna byggnaderna vad gäller brandsäkerhet. Jämförelsen visar ett relativt samstämmigt resultat med tanke på att metoderna är väldigt olika.

Indexmetoden kan användas direkt för alla bostadshus i flera våningar, utvärderingen kräver cirka en dags arbete samt att utvärderaren är ingenjör eller har en bakgrund inom brandområdet. En kvantitativ riskanalys kräver å andra sidan att varje byggnad individuellt studeras och att ett flertal antaganden görs i varje fall för sig, om t.ex. byggnaden, de boende och brandkårens agerande. En sådan analys kräver i storleksordningen en till två veckors arbete och utvärderaren måste vara specialist inom området brandteknik och riskvärdering.

Detta dokument innehåller de beslutstabeller som resulterar i ett s k riskindex för brandriskerna i ett flervånings bostadshus. Dokumentet ger en översiktlig beskrivning av indexmetoden, beskriver kortfattat metodens bakgrund, ger en kort beskrivning av arbetsgången och diskuterar de kommentarer som användare hittills har gett.

En svensk kortversion av Indexmetoden finns utgiven som Trätek Kontenta 0009024.

PREFACE

In the last few years a number of multistorey apartment buildings have been constructed in the Nordic countries using timber as load bearing material. Such constructions have earlier not been allowed by the authorities, mainly due to the fire risk. The Nordic countries have therefore co-operated for some years, within an organisation named Nordic Wood, with the aim of developing construction methodologies that seriously diminish the fire risk in timber-frame multistorey buildings. As a part of this work, a Nordic handbook on the topic was published in 1999.

It is however difficult to compare the fire risk in a building of non-combustible frame and a timber-frame building. These risks are based on a large number of different factors. The most practical way to rationally deal with this is to develop a so-called index method that can be used to rank different buildings with respect to fire risk.

The Index Method has been developed at Lund University, Department for Fire Safety Engineering. A first version was presented 1998 by Sven-Erik Magnusson and Tomas Rantatalo. The method has then been further developed by Björn Karlsson in close cooperation with a Nordic project team and a Nordic Delphi-panel. The work is part of the Nordic project Fire safe wooden buildings and supported by the Nordic Wood programme.

Nordic Wood is a R&D programme with the aim to increase the use of wood products. The programme is financed by the Nordic Timber industries, the Nordic Industrial Fund and national R&D funds. About fifty projects are run in the Nordic Wood programme.

The development of the Index method has been financed by Svenska Byggbranschens Utvecklingsfond, SBUF, through NCC and Skanska, Swedish producers of building materials through Rockwool and Svenska Träskivor and the Swedish national fund, NUTEK.

The financial support is kindly acknowledged. Thanks also to the Nordic project team, the Nordic Delphi-panel and for other contributions to the Index method. We hope that the method will contribute to a fire safe and increased use of timber in buildings.

Stockholm September 2000
Birgit Östman
Project coordinator

ENGLISH SUMMARY

A new Index method for fire risks in multistorey apartment buildings has been developed.

The Index method is based on a hierarchy structure for the fire safety in a building. The highest level is the *policy*, then the *objectives*, at next level the *strategies* and finally several *parameters*. The parameters are subdivided into quantitative *sub parameters*, organised in *decision tables* and given a *grade*. When the structure is fixed, the objectives, strategies and parameters are given *weights*.

The Index method was developed together with a Nordic project group, using a so-called Delphi panel for fine-tuning the method and defining the weights. The Delphi panel was made up of 20 Nordic experts who work with fire safety in various areas (consultancy, fire brigade, fire testing, fire research and insurance).

The grades and weights are multiplied giving a relative value for each parameter. The sum of these weighted grades results in a single index value for the whole building which can be used to compare with index values for other buildings or different fire safety measures. Basic requirements in the building law must of course be fulfilled.

To evaluate the index method, a quantitative risk analysis (QRA) was carried out on four multistorey timber-frame buildings, recently constructed in four Nordic countries. Both the index method and the quantitative risk analysis were used to rank the buildings with respect to fire risk. The comparison showed a reasonably good agreement, keeping in mind that the two methods are very different in nature.

The index method can be used directly on all multistorey apartment buildings. To derive a fire risk index takes roughly one days work and demands that the user is an engineer or has some background in fire safety. A quantitative risk analysis, on the other hand, demands that each building be studied separately and that different assumptions be made in each case on, for example, the building, the occupants and fire brigade tactics. Such an analysis may take a number of weeks in each case and demands that the analyst is a specialist in fire safety and risk analysis.

This document contains the decision-making tables that result in an index value for the fire risk in a multistorey apartment building. The document gives a summary description of the index method, gives a short description of the development process, describes how to use the method and discusses the comments received from users.

BACKGROUND

During the last few years the trend in a great part of the world has been to introduce performance-based building regulations instead of the detailed regulations used earlier. The new regulations, based on functional requirements, have also been accepted in the Nordic countries. The new possibilities have opened the way for new design solutions, e.g. new applications for timber-structures.

From a fire safety point of view a wider use of timber-structures is of course of considerable interest. It is, however, necessary to verify that the fire safety, with respect to both life safety and property protection, is as high in timber-frame buildings as in other types of buildings. To allow a comparison it has been observed that there is a need of developing a new fire risk assessment technique. Such a technique has to answer questions from society on the fire safety in a building. It has to be possible to compare the level of safety in a specific building to other buildings and to an acceptable risk. The level of fire safety in a building depends on a great number of factors and there is a need of systemising the way of identifying, analysing and evaluating these.

As a result of these needs, a research program called Nordic Wood has supported the development of a risk index method to assess the level of fire risk in multistorey apartment buildings. For short, Nordic Wood is a research- and development program initiated by the Nordic Industrial Fund and the Nordic wood industry. The main aim of the program is to consolidate the position of wood as a construction material, e.g. in multi-storey buildings.

The Nordic Wood project "Fire-safe Wooden Houses" focuses on the fire safety problems, which always have been connected to timber-frame buildings. For a long period of time wood-structures and wood-facades have not been used in multistorey buildings, at least not in the Nordic countries. The main reason has of course been the bad experiences from fires in these types of buildings over the years. The state-of-art knowledge with respect to the use of wood as a construction material has, however, grown rapidly through the last decade. As a part of the research work, a Nordic handbook on the fire safety design of timber-frame buildings was published in 1999[1].

For the above reasons, industry and authorities found that it was necessary to develop a simple technique to evaluate the fire risk in multistorey apartment buildings. The only method that is simple to use and at the same time takes account of the many different objectives and parameters that constitute building fire safety is an index method of the type that is presented here. The method was developed by a Nordic project group, using a so-called Delphi panel for fine-tuning the method. The Delphi panel was made up of 20 Nordic experts who work with fire safety in various areas (consultancy, fire brigade, fire testing, fire research and insurance). The development process is described in detail in two reports[2,3].

To evaluate the index method, a quantitative risk analysis (QRA) was carried out on four multistorey timber-frame buildings, recently constructed in four Nordic countries. Both the index method and the quantitative risk analysis were used to rank the buildings with respect to fire risk. The comparison showed a reasonably good agreement, keeping in mind that the two methods are very different in nature. The comparison is described in a separate report[4].

The advantage of using an index method for fire risk ranking is that the ranking takes little time and can be carried out by an engineer or a fire safety professional. All other rational methods for this purpose would take much longer time and must be carried out by specialists in fire safety design and risk analysis.

USING THE METHOD

This document first describes the policy, objectives and strategies of the fire safety system used and then gives a list of the parameters. Subsequently, each parameter is described, sometimes using sub-parameters and decision tables. The user works through each parameter until all parameters have been given a grade. On the last page the grades are entered in a table and multiplied by weights. These weighted grades are then summed up and result in an index value, a risk index.

During the development and the evaluation of the index method, professionals that have tried out the method or have investigated its background have raised a number of questions. Many of the comments have been included as "Comments from users" for each parameter.

One general comment was that some parameters allow that alternatives lesser than the minimum requirements according to the building regulations be chosen. For example, Parameter 1 (Lining materials) allows that a plastic material be chosen as a lining material, which is not at all acceptable in the building regulations in the Nordic countries. Such choices are, however, made possible in the index method, since sometimes a combination of choices can be compensated for by making other parameters much more safe. Nevertheless, a designer must of course always adhere to the building regulations.

The user must therefore both aim for a reasonably high index grade (a safe building), but at the same time make certain that the minimum requirements according to building law are met. Sometimes authorities allow that lesser requirements than the minimum be used, given that this is compensated by higher requirements in other parameters. For example, installing a sprinkler can lead the authorities to agree on lesser than minimum requirements for distance between buildings (or some other parameter).

However, minimum requirements differ considerably within the Nordic countries and there is a considerable difference in how the authorities allow or disallow lesser requirements and how these are compensated for by higher requirements in other parameters. In using the index method, the engineer is encouraged to have a continuous and open dialogue with the authorities.

The index method is also available on Internet at http://www.brand.lth.se/frim-mab. This web site contains a simple computer program for automatic calculation of the Risk index from input data for a building.

The development of the method is by no means over; in fact it is only now starting. New developments will be discussed on the web site given above. Users who have comments on the method are asked to contact Birgit Östman at Trätek or give comments through the web site.

A short version of the Index method is available also in Swedish.[5]

The overall structure of the Index method is summerised below.

Policy	Provide acceptable fire safety level in multistorey apartment buildings
Objectives	O_1 Provide life safety O_2 Provide property protection
Strategies	S_1 Control fire grooth by active means S_2 Confine fire by construction S_3 Establish safe egress S_4 Establish safe rescue
Parameters	P_1 Linings in apartment P_2 Suppression system P_3 Fire service P_4 Compartmentation P_5 Structure - separating P_6 Doors 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 system P_{14} Escape routes P_{15} Structure – load-bearing P_{16} Maintenance and information P_{17} Ventilation system

POLICY, OBJECTIVES AND A LIST OF PARAMETERS

Policy:

Provide acceptable fire safety level in multistorey apartment buildings
Definition: Multistorey apartment buildings shall be designed in a way that ensures sufficient life safety and property protection in accordance with the objectives listed below.

Objectives:

O_1 Provide life safety
Definition: Life safety of occupants in the compartment of origin, the rest of the building, outside and in adjacent buildings and life safety of fire fighters

O_2 Provide property protection
Definition: Protection of property in the compartment of origin, in the rest of the building, outside and in adjacent buildings

Strategies:

S_1 Control fire growth by active means
Definition: Controlling the fire growth by using active systems (suppression systems and smoke control systems) and the fire service.

S_2 Confine fire by construction
Definition: Provide structural stability, control the movement of fire through containment, use fire safe materials (linings and facade material). This has to do with passive systems or materials that are constantly in place.

S_3 Establish safe egress
Definition: Cause movement of occupants and provide movement means for occupants. This is done by designing detection systems, signal systems, by designing escape routes and by educating or training the occupants. In some cases the design of the escape route may involve action by the fire brigade (escape by ladder through window).

S_4 Establish safe rescue
Definition: Protect the lives and ensure safety of fire brigades personnel during rescue. This is done by providing structural stability and preventing rapid unexpected fire spread and collapse of building parts.

Parameters:

P_1 **Linings in apartment**
Definition Possibility of internal linings in an apartment to delay the ignition of the structure and to reduce fire growth

P_2 **Suppression system**
Definition: Equipment and systems for suppression of fires

P_3 **Fire service**
Definition: Possibility of fire services to save lives and to prevent further fire spread

P_4 **Compartmentation**
Definition: Extent to which building space is divided into fire compartments

P_5 **Structure - separating**
Definition: Fire resistance of building assemblies separating fire compartments

P_6 **Doors**
Definition: Fire and smoke separating function of doors between fire compartments

P_7 **Windows**
Definition: Windows and protection of windows, ie. factors affecting the possibility of fire spread through the openings

P_8 **Facade**
Definition: Facade material and factors affecting the possibility of fire spread along the facade

P_9 **Attic**
Definition: Prevention of fire spread to and in attic

P_{10} **Adjacent buildings**
Definition: Minimum separation distance from other buildings

P_{11} **Smoke control system**
Definition: Equipment and systems for limiting spread of toxic fire products

P_{12} **Detection system**
Definition: Equipment and systems for detecting fires

P_{13} **Signal system**
Definition: Equipment and systems for transmitting an alarm of fire

P_{14} **Escape routes**
Definition: Adequacy and reliability of escape routes

P_{15} **Structure - load-bearing**
Definition: Structural stability of the building when exposed to a fire

P_{16} **Maintenance and information**
Definition: Inspection and maintenance of fire safety equipment, escape routes etc. and information to occupants in suppression and evacuation

P_{17} **Ventilation system**
Definition: Extent to which the spread of smoke through the ventilation system is prevented.

P_1 LININGS IN APARTMENT

DEFINITION: Possibility of internal linings in an apartment to delay the ignition of the structure and to reduce fire growth

PARAMETER GRADE P_1:
This refers to the worst lining class (wall or ceiling) that is to be found in an apartment. (Excluding the small amounts allowed by building code.)

	LINING CLASS					
Typical products	Possible Euroclass	DK	FIN	NO	SWE	**GRADE P_1**
Stone, concrete	A1	A	1/I	In1	I	**5**
Gypsum boards	A2	A	1/I	In1	I	**5**
Best FR woods (impregnated)	B	A	1/I	In1	I	**4**
Textile wall cover on gypsum board	C		1/II 2/-	In2	II	**3**
Wood (untreated)	D	B	1/-	In2	III	**2**
Low density wood fibreboard	E	U	U	U	U	**1**
Some plastics	F	U	U	U	U	**0**

(Minimum grade = 0 and maximum grade = 5)

Resulting grade:

Comments from users: Inhabitants may change linings and different linings may be used in different parts of the building. The user must therefore give an engineering estimate of a reasonable lining class to reflect this.

P_2 SUPPRESSION SYSTEM

DEFINITION: Equipment and systems for suppression of fires

SUB-PARAMETERS:

P_{2a} Automatic sprinkler system
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)

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**

(N = no grade, L = low grade, M = medium grade and H = high grade)

P_{2b} Portable equipment

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

PARAMETER GRADE P_2:

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**

(Minimum grade = 0 and maximum grade = 5)

Resulting grade:

Comments from users: Residential sprinkler systems can be different in different countries. A rough rule of thumb is that if the sprinkler operates on the ordinary water supply to the building, it is said to be a "residential sprinkler", but if it is fed from a specially designed water reservoir and has a relatively high capacity, it is termed an "ordinary sprinkler".

P_3 FIRE SERVICE

DEFINITION: Possibility of fire services to save lives and to prevent further fire spread

SUB-PARAMETERS:

P_{3a} **Capability** of responding fire service

CAPABILITY OF RESPONDING FIRE SERVICE	GRADE P_{3a}
No brigade available	**0**
Fire fighting capability only outside the building	**1**
Fire fighting capability but no smoke diving capability	**2**
Fire fighting and smoke diving capability	**4**
Simultaneous fire fighting, smoke diving and external rescue by ladders	**5**

(Minimum grade = 0 and maximum grade = 5)

P_{3b} **Response time** of fire service to the site

RESPONSE TIME (min)	GRADE P_{3b}
> 20	**0**
15 - 20	**1**
10 - 15	**2**
5 - 10	**3**
0 - 5	**5**

(Minimum grade = 0 and maximum grade = 5)

P_{3c} **Accessibility and equipment** (ie. number of windows (or balconies) that are accessible by the fire service ladder trucks)

ACCESSIBILITY 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**

(Minimum grade = 0 and maximum grade = 5)

PARAMETER GRADE:

$P_3 = (0.31 \times P_{3a}$ Capability $+ 0.47 \times P_{3b}$ Response time $+ 0.22 \times P_{3c}$ Accessibility and equipment)

Resulting grade:

Comments from users: No comments yet.

P_4 COMPARTMENTATION

DEFINITION: Extent to which building space is divided into fire compartments

PARAMETER GRADE P_4:

MAXIMUM AREA IN FIRE COMPARTMENT	GRADE P_4
> 400 m^2	**0**
200 - 400 m^2	**1**
100 – 200 m^2	**2**
50 – 100 m^2	**3**
< 50 m^2	**5**

(Minimum grade = 0 and maximum grade = 5)

Resulting grade:

Comments from users: No comments yet

P_5 STRUCTURE - SEPARATING

DEFINITION: Fire resistance of building assemblies separating fire compartments

SUB-PARAMETERS:

P_{5a} Integrity and insulation

INTEG.RITY AND INSULATION (EI)	GRADE P_{5a}
EI < EI 15	**0**
EI 15 ≤ EI < EI 30	**1**
EI 30 ≤ EI < EI 45	**3**
EI 45 ≤ EI < EI 60	**4**
EI ≥ EI60	**5**

(Minimum grade = 0 and maximum grade = 5)

P_{5b} Firestops at joints, intersections and concealed spaces

STRUCTURE AND FIRESTOP DESIGN	GRADE P_{5b}
Timber-frame structure with voids and no firestops	**0**
Ordinary design of joints, intersections and concealed spaces, without special consideration for fire safety.	**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**

(Minimum grade = 0 and maximum grade = 5)

P_{5c} Penetrations

Penetrations between separating fire compartments

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**

(Minimum grade = 0 and maximum grade = 5)

P_{5d} Combustibility

Combustible part of the separating construction

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**

(Minimum grade = 0 and maximum grade = 5)

PARAMETER GRADE:

P_5 = (0.35 × P_{5a} Integrity and insulation + 0.28 × P_{5b} Firestops + 0.24 × P_{5c} Penetrations + 0.13 × P_{5d} Combustibility)

Note: If grade for penetrations = 0, then the parameter grade $P_5 = 0$

Resulting grade:

Comments from users: Some users have had constructions that are made up of timber studs, combustible insulation and gypsum board, and have asked how the separating structure should be graded. Since the insulation is combustible the grade 2 is recommended.

P_6 DOORS

DEFINITION: Fire separating function of doors between fire compartments

SUB-PARAMETERS:

P_{6a} Doors leading to escape route
Integrity and insulation (= EI)
(A = EI < EI 15, B = EI 15 ≤ EI < EI 30, C = EI 30 ≤ EI < EI 60, D = EI ≥ EI 60)
Type of closing (M = manually, S = self-closing)

SURVEY ITEMS	DECISION RULES							
Integrity and insulation	A	A	B	B	C	C	D	D
Type of closing	M	S	M	S	M	S	M	S
GRADE P_{6a}	**0**	**1**	**1**	**3**	**2**	**4**	**3**	**5**

(Minimum grade = 0 and maximum grade = 5)

P_{6b} Doors in escape route
Integrity and insulation (= EI)
(A = EI < EI 15, B = EI 15 ≤ EI < EI 30, C = EI 30 ≤ EI < EI 60, D = EI ≥ EI 60)
Type of closing (M = manually, S = self-closing)
If no doors are needed in the escape routes the highest grade is received.

SURVEY ITEMS	DECISION RULES								
Integrity and insulation	A	A	B	B	C	C	D	D	-
Type of closing	M	S	M	S	M	S	M	S	-
GRADE P_{6b}	**0**	**1**	**1**	**3**	**2**	**4**	**3**	**5**	**5**

(Minimum grade = 0 and maximum grade = 5)

PARAMETER GRADE:

P_6 = (0.67 × P_{6a} Doors leading to escape route + 0.33 × P_{6b} Doors in escape route)

Resulting grade:

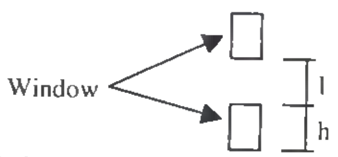
Comments from users: Some users have asked if a lift-door should be counted as a door in the escape route. Where the elevator is used as an escape route (with the very special requirements that need to be fulfilled for the authorities to accept such a solution), the elevator door should be counted as a door in the escape route.

P_7 WINDOWS

DEFINITION: Windows (and other facade openings) and protection of these, ie. factors affecting the possibility of fire spread through the openings

SUB-PARAMETERS:

P_{7a} Relative vertical distance
This is defined as the height of the window divided by the vertical distance between windows



Relative vertical distance, r = l/h
(A = r < 1, B = r ≥ 1)

P_{7b} Class of window
(C = window class < E 15, D = window class ≥ E 15, E = tested special design solution e.g. automatic closing skield, or window class ≥ E 30)

PARAMETER GRADE P_7:

SUB-PARAMETERS	DECISION RULES					
P_{7a} Relative vertical distance	A	A	A	B	B	B
P_{7b} Class of window	C	D	E	C	D	E
GRADE P_7	**0**	**3**	**5**	**2**	**5**	**5**

(Minimum grade = 0 and maximum grade = 5)

Resulting grade:

Comments from users: Some users have commented that the relative vertical distance between windows can vary. Again, a reasonable engineering estimate should be used here. If, for example, all windows have the same relative vertical distance except two windows on the gable, the first mentioned windows should form a basis for giving the grade. A simple sensitivity analysis can then be made, where the two gable windows form a basis for the grade, to see if this influence is of any significance at all. In most cases, it will be of little significance and the problem of different relative vertical distances can be ignored.

P_8 FACADES

DEFINITION: Facade material and factors affecting the possibility of fire spread along the facade

SUB-PARAMETERS:

P_{8a} Combustible part of facade

COMBUSTIBLE PART	GRADE P_{8a}
> 40 %	**0**
20 – 40 %	**2**
< 20 %	**3**
0 %	**5**

(Minimum grade = 0 and maximum grade = 5)

P_{8b} Combustible material above windows

COMBUSTIBLE MATERIAL ABOVE WINDOWS?	GRADE P_{8b}
Yes	**0**
No	**5**

(Minimum grade = 0 and maximum grade = 5)

P_{8c} Void

Does there exist a continuous void between the facade material and the supporting wall?

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**

PARAMETER GRADE:

P_8 = (0.41× P_{8a} Combustible part of facade + 0.30 × P_{8b} Combustible material above windows + 0.29 × P_{8c} Void)

Resulting grade:

Comments from users: The first sub-parameter does not differentiate between different materials, such as fire-impregnated wood or non-impregnated wood. These must therefore be treated equally in the present version of the index method. But the engineer and the authorities should keep this in mind when making overall decisions once the index has been calculated. Also the combustible part of the facade can differ on different facades; one facade may have > 40% combustible material while another facade has < 20%. A "reasonable worst case" engineering estimate should be made, in this case the facade that has >40% combustible material should be deemed to be representative. Also, in buildings with external walkways (meaning that the exit from each apartment leads to an outside balcony and a stairway from there to ground level), flame spread is relatively unlikely across the external gallery and up the rest of the facade. The combustible part of the wall should therefore be significantly reduced when grading buildings with external walkways. Further recommendations will be given in the next version of the index method.

P_9 ATTIC

DEFINITION: Prevention of fire spread to and in attic

SUB-PARAMETERS:

P_{9a} Prevention of fire spread to attic (eg. is the design such that ventilation of the attic is not provided at the eave? The most common mode of exterior fire spread to the attic is through the eave. Special ventilation solutions avoid this.)

N	No
Y	Yes

P_{9b} Fire separation in attic (ie. extent to which the attic area is separated into fire compartments)

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**

(N = no grade, L = low grade, M = medium grade and H = high grade)

PARAMETER GRADE P_{9a}:

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**

(Minimum grade = 0 and maximum grade = 5)

Resulting grade:

Comments from users: This parameter could be further differentiated, giving an extra grade if the attic is separated at each apartment boundaries. In that case only one apartment would be adjacent to each fire compartment in the attic. The Project group considered this but found that this differentiation might be too detailed and might increase complexity. Users are offered to comment on this.

P_{10} ADJACENT BUILDINGS

DEFINITION: Minimum separation distance from other buildings. If the buildings are separated by a fire wall this is deemed to be equivalent to 8 m distance.

PARAMETER GRADE P_{10}:

DISTANCE TO ADJACENT BUILDING, D	**GRADE P_{10}**
$D < 6$ m	**0**
$6 \leq D < 8$ m	**1**
$8 \leq D < 12$ m	**2**
$12 \leq D < 20$ m	**3**
$D \geq 20$ m	**5**

(Minimum grade = 0 and maximum grade = 5)

Resulting grade:

Comments from users: No comments yet.

P_{12} DETECTION SYSTEM

DEFINITION: Equipment and systems for detecting fires

SUB-PARAMETERS:

P_{12a} Amount of detectors
Detectors in apartment (N = none, A = at least one in every apartment, R = more than one in every apartment)
Detectors in escape route (N = no, Y = yes)

SURVEY ITEMS	DECISION RULES					
Detectors in apartment	N	N	A	R	A	R
Detectors in escape route	N	Y	N	N	Y	Y
GRADE P_{12a}	**N**	**L**	**L**	**M**	**H**	**H**

(N = no grade, L = low grade, M = medium grade and H = high grade)

P_{12b} Reliability of detectors
Detector type (H = heat detectors, S = smoke detectors)
Detector power supply (B = battery, P = power grid, BP = power grid and battery backup)

SURVEY ITEMS	DECISION RULES					
Detector type	H	H	H	S	S	S
Detector power supply	B	P	BP	B	P	BP
GRADE P_{12b}	**L**	**M**	**M**	**M**	**H**	**H**

(N = no grade, L = low grade, M = medium grade and H = high grade)

PARAMETER GRADE P_{12}:

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**

(Minimum grade = 0 and maximum grade = 5)

Resulting grade:

Comments from users: No choice is available for combined smoke and heat detectors. The Project group recommends that the sub-parameter "Reliability of detectors" receive the grade "H" if there is a combination of heat and smoke detectors in the building. This will be amended in the next version of the index method.

P_{13} SIGNAL SYSTEM

DEFINITION: Equipment and systems for transmitting an alarm of fire

SUB-PARAMETERS:

P_{13a} Type of signal
Light signal (N = no, Y = yes)
Sound signal (N = no, A = alarm bell, S = spoken message)

SURVEY ITEMS	DECISION RULES					
Light signal	N	Y	N	N	Y	Y
Sound signal	N	N	A	S	A	S
GRADE	N	L	M	H	M	H

(N = no grade, L = low grade, M = medium grade and H = high grade)

P_{13b} Location of signal
Do you just receive a signal within the fire compartmentation or is it also possible to warn other occupants?

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.

PARAMETER GRADE P_{13}:

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**

(Minimum grade = 0 and maximum grade = 5)

Resulting grade:

Comments from users: No comments yet

P_{14} ESCAPE ROUTES

DEFINITION: Adequacy and reliability of escape routes

SUB-PARAMETERS:

P_{14a} Type of escape routes
Staircase (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).
Window/Balcony (D = windows and balconies can not 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)

SURVEY ITEMS	DECISION RULES												
Staircase	A	A	A	A	B	B	B	B	C	C	C	C	C
Window/Balcony	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**

(Minimum grade = 0 and maximum grade = 5)

P_{14b} Dimensions and layout
Maximum travel distance to an escape route (A < 10 m, B = 10 – 20 m, C > 20 m)
Number of floors ($D \leq 4$, E = 5 – 8)
Maximum number of apartments per floor connected to an escape route ($F \leq 4$, $G \geq 5$)

SURVEY ITEMS	DECISION RULES											
Travel distance to...	C	C	C	C	B	B	B	B	A	A	A	A
Number of floors	E	E	D	D	E	E	D	D	E	E	D	D
Number of apartments...	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**

(Minimum grade = 0 and maximum grade = 5)

P_{14c} Equipment
Guidance signs (A = none, B = normal, C = illuminating light), General lighting (D = manually switched on, E = always on)
Emergency lighting (F = not provided, G = provided)

SURVEY ITEMS	DECISION RULES											
Guidance signs	A	A	A	A	B	B	B	B	C	C	C	C
General lighting	D	D	E	E	D	D	E	E	D	D	E	E
Emergency lighting	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**

(Minimum grade = 0 and maximum grade = 5)

P_{14d} Linings and floorings

This refers to the worst lining or flooring class that is to be found in an escape route (excluding the small amounts allowed by building law. The flooring must have at least class D_{FL} which is fulfilled by e.g. solid timber floor.

	LINING CLASS					
Typical products	Possible Euroclass	DK	FIN	NO	SWE	**GRADE P_{14d}**
Stone, concrete	A1	A	1/I	In1	I	**5**
Gypsum boards	A2	A	1/I	In1	I	**5**
Best FR woods (impregnated)	B	A	1/I	In1	I	**4**
Textile wall cover on gypsum board	C		1/II 2/-	In2	II	**3**
Wood (untreated)	D	B	1/-	In2	III	**2**
Low density wood fibreboard	E	U	U	U	U	**1**
Some plastics	F	U	U	U	U	**0**

(Minimum grade = 0 and maximum grade = 5)

PARAMETER GRADE:

P_{14} = (0.34 × P_{14a}Type of escape routes + 0.27 × P_{14b} Dimensions and layout + 0.16 × P_{14d} P_{14c} Equipment + 0.23 × P_{14d} Linings and floorings)

Resulting grade:

Comments from users: There is no provision for buildings with external walkways (meaning that the exit from each apartment leads to an outside balcony and a stairway from there to ground level). The first parameter should reflect this by assuming that escape is also possible from a balcony. Also, sometimes motion detectors turn on the light automatically. These should be graded as if the light were always switched on. Finally, no account is taken of the type of floor material in escape routes. This will be looked at closer by the Project group, amendments will possibly be made in the next version of the index method.

P_{15} STRUCTURE - LOAD-BEARING

DEFINITION: Structural stability of the building when exposed to a fire

SUB-PARAMETERS:

P_{15a} Load-bearing capacity

LOAD BEARING CAPACITY (LBC)	GRADE P_{15a}
LBC < R 30	0
R 30 ≤ LBC < R 60	2
R 60 ≤ LBC < R 90	4
R 90 ≤ LBC	5

(Minimum grade = 0 and maximum grade = 5)

P_{15b} Combustibility
Combustible part of the load-bearing construction

COMBUSTIBLE PART	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

(Minimum grade = 0 and maximum grade = 5)

PARAMETER GRADE:

P_{15} = (0.74 × P_{15a} Load-bearing capacity + 0.26 × P_{15b} Combustibility)

Resulting grade:

Comments from users: No comments yet.

P_{16} MAINTENANCE AND INFORMATION

DEFINITION: Inspection and maintenance of fire safety equipment, escape routes etc. and information to occupants on suppression and evacuation

SUB-PARAMETERS:

P_{16a} Maintenance of fire safety systems ie. detection, alarm, suppression and smoke control system

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**

(Minimum grade = 0 and maximum grade = 5)

P_{16b} Inspection of escape routes

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**

(Minimum grade = 0 and maximum grade = 5)

P_{16c} Information to occupants on suppression and evacuation

Written information (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)
Drills (D = no drills, E = suppression drill carried out regularly, F = evacuation drill carried out regularly, G = suppression and evacuation drills carried out regularly)

SURVEY ITEMS	DECISION RULES											
Written information	A	A	A	A	B	B	B	B	C	C	C	C
Drills	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**

(Minimum grade = 0 and maximum grade = 5)

PARAMETER GRADE:

P_{16} = (0.40 × P_{16a} Maintenance of fire safety systems + 0.27 × P_{16b} Inspection of escape routes + 0.33 × P_{16c} Information)

Resulting grade:

Comments from users: No comments yet.

P_{17} VENTILATION SYSTEM

DEFINITION: Extent to which the spread of smoke through the ventilation system is prevented.

PARAMETER GRADE P_{17}:

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. The ratio between pressure drops in these ducts is in the order of 5:1	**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**

(Minimum grade = 0 and maximum grade = 5)

Resulting grade:

Comments from users: No comments yet

PARAMETER SUMMARY TABLE

Fire Risk Index Method – Multistorey Apartment Buildings: Version 1.2

Grades for each parameter has to be inserted in the Summary table below and multiplied by the weight. Maximum individual grade for each parameter is 5.00. The weights have been developed by the Delphi panel[3]. The weighted grades for all parameters are then summed and result in a score with a maximum value of 5.00.

The Risk Index is defined as 5 – Score. A low Risk Index means low risk and high fire safety level in the same way as other risk assessment methods [4].

Summary table

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 Structure - separating	0.0675		
P_6 Doors	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 system	0.0512		
P_{14} Escape routes	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)	→	

This summary table is also available at Internet, http://www.brand.lth.se/frim-mab, for automatic calculation of the Risk Index from input data for a building.

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