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RESEARCH ARTICLE

Fire Risk Analysis: A Proposal for Historic Buildings in Brazil

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ABSTRACT
Fire risk analysis is increasingly being applied to buildings as a tool for managing the risk of a fire event, and the extent of its consequences. However, such methods give different results depending on the fire code under which the building was designed, which can compromise the effectiveness of this type of analysis. Given that regulatory requirements for fire safety differ from place to place, methodologies focused on solely one legislation may not be applicable to buildings constructed under other legislation. This paper presents a proposal for a fire risk analysis methodology based on established parameters, independent of local legislation requirements. The method proposed in this article is called *Cálculo Escalonar de Perigo de Incêndio — CEPI* (Scalar Calculation of Fire Hazard). The aim is to make a free method, available to fire safety professionals; and to provide a practical tool for measuring fire safety in Brazilian heritage buildings.

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Fire risk analysis; fire risk analysis method; fire safety

1. Introduction

Fire risk analysis is increasingly being applied to buildings as a tool for managing the risk of a fire event, and the extent of its consequences. Among the various tools available to analyse fire risk, semi-quantitative assessment methods have proven to be a good option for quick and cost-effective analysis.

However, such methods show different results depending on the parameters evaluated, and the fire safety legislation under which the building was designed, which can compromise the efficiency of this type of analysis. In Brazil, each of the 27 states has its own fire safety legislation, with different parameters and requirements. This is also the case in different countries, where the parameters are related to the minimum requirements established by local legislation (Salazar et al. 2021).

Given that regulatory requirements for fire safety differ from place to place, methodologies focused on solely one legislation may not be applicable to buildings constructed under other legislation. According to Salazar et al. (2021), the methods must be accessible so that they can be widely applied.

> [. . .] the development of risk assessment methods for cultural heritage assets should also account for the possibility of implementing them across a large number of cultural heritage assets (e. g. in a region or nationwide) without requiring excessive human and economic resources. (Salazar et al. 2021, 2)

Brazilian fire safety legislation often contains several caveats regarding the mandatory requirements for buildings of historic value. This because such buildings have an added heritage value due to their structural, architectural or decorative features, which make them unique. These features cannot be altered without jeopardising the historic value added to the building.

Consequently, the legislation itself provides for the replacement or even the absence of certain fire protection systems for these buildings. In addition, heritage legislation places several restrictions on the interventions that can be made in this type of building. As Netto (2001) notes,

> Taking as a starting point the fact that there are buildings that make up the architectural heritage and which, due to their historical, cultural, artistic or architectural importance, present restrictions to intervention measures, given the level of conservation required, the principles of fire prevention and protection take on greater relevance (Netto 2001, 61). (free translation)

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Take the Paço de São Cristóvão, which housed the National Museum and is located in Rio de Janeiro, Brazil. The building was completely burnt down in a fire in September 2018, with the loss of both the structure of the building and its contents, both of incalculable value.

The installation of automatic smoke and flame detection systems was not required by local fire regulations. As a result, this lack caused a delay in the detection of the fire, which was a decisive factor in spreading the fire and in the consequent loss of the building (Brasil 2019).

A building with the same structural characteristics as the National Museum, designed and built in 2018, should necessarily have automatic smoke detection systems, a fire hydrant system, a sprinkler system, vertical and horizontal compartmentation, among others. However, as it is an old building of historic value, the local legislation itself excludes the installation of all these systems so as not to cause architectural alterations that would jeopardise its historic value (Minervino 2022).

The complexity of fire safety in historic buildings lies in the fact that they are valuable buildings but are at high risk because they do not have the same protection as a similar contemporary building.

In this context, a proposal for fire risk analysis focusing on parameters, independent of local regulatory requirements, has been developed and will be briefly presented in this paper. The development of this method is based on the architectural and occupancy characteristics from buildings of historic value in Brazil. In addition, existing semi-quantitative methods were studied, such as the Gretener method (Silva 2018) and (UC, Universidade de Coimbra 2019), the FRAME method (De Smet 2008) and (De Smet 2011), the MARIEE method (Correia 2014) and (Pissarra 2014), the Global Risk Analysis method (Gouveia 2006) and the ARICA method (LNEC 2019). For these methods, the calculation processes, the parameters used and the interpretation of the results were compared. The proposed method is called *Cálculo Escalonar de Perigo de Incêndio — CEPI* (Scalar Calculation of Fire Hazard). The application of this method is recommended for Brazilian heritage buildings.

2. Fire risk analysis methods

Fire risk analysis methods generally consider the presence and operation of modern fire protection systems. However, the same systems are not present in most buildings of historic value, as they are exempted by local legislation to ensure the preservation of their architectural features.

Fire risk analyses carried out on this type of building using the Gretener method (Silva 2018) and (UC, Universidade de Coimbra 2019), the FRAME method (De Smet 2008) and (De Smet 2011), the MARIEE method (Correia 2014) and (Pissarra 2014), the Global Risk Analysis method (Gouveia 2006) and the ARICA method (LNEC 2019) have shown that the differences between the requirements for old and new buildings directly affect the fire risk result (Minervino 2022). An old building, even if it does not have the fire protection systems, can be considered safer by all the above methods, simply because it complies with local legislation (Minervino 2021a).

Nevertheless, in the Brazilian context, compliance with local legislation does not directly guarantee the safety of the building, as the laws are extremely lenient when dealing with buildings of historic value. It is necessary to further analyse the real risks and the measures that can guarantee greater security for these assets that must be preserved.

In 2006, the Global Risk Analysis Method (Gouveia 2006) was developed in Brazil specifically for the analysis of historic sites. This method analyses whether the fire systems in the building comply, or not, with local legislation. Yet, as mentioned above, such legislation is extremely lenient on buildings of historic value, which may have an impact on the outcome of the analysis. This aspect shows the need for an analysis regarding structural characteristics and their influence on a fire, and not just in terms of simple compliance with local legislation.

3. The proposed method — CEPI

The proposal of the new method called *CEPI* has been designed so that it does not take into account the requirements or exemptions imposed by local fire safety legislation to determine the level of fire risk of a building of historic value.

The proposal takes into consideration the structure of the building, its internal compartmentation, the risks posed by local activities and structural features, existing fire protection systems and the level of training of the occupants dealing with a fire situation.

The main objective is to assign the building a safety level, which can be used as a reference for analysing the risk to which the building is exposed, and also the interventions necessary to subsidise fire prevention measures such as: controlling the outbreak of a possible fire, evacuating people and preserving the contents and structure of the building.

The analysis is based on five main coefficients, each with specific factors:

- Initiation or ignition hazard: with three factors
- Fire Development: with four factors
- Vulnerability of people: with nine factors
- Vulnerability of contents: with four factors
- Protection level: with nine factors

The parameters considered in this method should not be judged according to the requirements of local legislation. As explained above, this legislation may vary from place to place, and this may affect the result of the analysis. For this reason, the method provides its own tables with unique numerical values for each parameter.

An extensive study was carried out on Brazilian and Portuguese legislation and on the parameters considered by the most widely used semi-quantitative fire risk analysis methods. The selected parameters were analysed and evaluated using the Delphi method with a group of 22 fire safety experts (Minervino 2023). The questionnaire drawn up for the experts contains twenty-four questions, divided into 85 items that deal with structural characteristics, protection measures, the risk situation and other factors that can influence a fire.

The experts expressed their opinions on the importance and efficiency of these structures and systems and were also able to make any observations they deemed pertinent. The Delphi methodology consisted of two rounds of questions. The answers were classified on a 7-point Likert Scale, with consensus being considered when the percentage of answers converged was equal to or greater than 80%. The lowest value, equal to 1, was assigned to the situation considered the highest risk or least safe and the highest value, equal to 7, was assigned to the lowest risk or safest situation, in the opinion of the experts.

Table A-29, which lists the response options and corresponding values on the Likert scale, is attached to this article. After analysing the experts' responses in the two rounds of the questionnaire application, these same parameters were examined in relation to their influence on the fire, their presence in buildings of historic value and whether or not there was consensus among the experts to determine the parameter's value on the scale adopted. Table 1 shows the parameters considered by the method, organised according to the main coefficients and its factors.

Information relevant to the assessment of these parameters should be gathered from the architectural design, fire safety project, emergency plans, operating licence, on-site technical visits and interviews with owners and technical managers of the building.

The values assigned to the 85 parameters considered in Table 1, and a more detailed description of its characteristics, are provided in the tables of the method itself, which are included in the Supplementary appendix. It is up to the analyst to judge the most appropriate values according to the actual installation and conservation situation of each parameter.

To calculate, follow three predefined steps:

- Step 1: Evaluate each of the parameters in accordance with the look-up tables of the proposed method and assign the appropriate values to each situation.
- Step 2: Calculate the arithmetic average of the parameters to determine the respective value of each factor.
- Step 3: Calculate the arithmetic average of the factors to determine the respective hazard coefficients or protection level.

Each factor is calculated by the arithmetic average of the parameters that influence it. In this way, it is possible to have a simple calculation that shows, albeit with elementary results, whether or not the influence of these parameters can offer a degree of safety for each factor. The calculation should be done separately for each of the five coefficients defined in the proposed methodology (CEPI). To analyze buildings that have two or more destinations considered in Table A-1, the destination that predominates or occupies the largest area of the building must be used to support the analysis of the entire building.

The Initial Hazard Coefficient deals with the ignition hazard and fire starting. The values of the three initial hazard factors must be determined: risk factor — F_{risk} (tabulated value), electrical factor — $F_{eletric}$ (equation 1) and liquified petroleum gas (LPG) factor — F_{LPG} (equation 2). The results shall then be used to obtain the value of the initial hazard coefficient according to equation 3.

$$F_{eletric} = \bar{x}(P02 + P03 + P04 + P05) \quad (1)$$

$$F_{LPG} = \bar{x}(P06 + P07 + P08 + P09) \quad (2)$$

$$Initial\,Hazard = \bar{x}(F_{risk} + F_{eletric} + F_{LPG}) \quad (3)$$

The Fire Development Coefficient refers to the possibilities or difficulties of the fire developing and spreading to other rooms, other floors or even other buildings. You need to determine the values of the four factors associated with the fire spread hazard: structural factor — $F_{structural}$ (equation 4), finishing material factor — $F_{finishing\ material}$ (equation 5), compartmentation factor — $F_{compartmentation}$ (tabulated value) and insulation factor — $F_{insulation}$ (tabulated value). The results must then be used to obtain the value of the fire development danger coefficient from equation 6.

$$F_{structural} = \bar{x}(P10 + P11 + P12) \quad (4)$$

$$F_{finishing\ material} = \bar{x}(P13 + P14 + P15) \quad (5)$$

$$Fire\ Development = \bar{x}\left(F_{strutural} + F_{finishing\ material} + F_{compartimentation} + F_{insulation}\right) \quad (6)$$

The Vulnerability of People Coefficient deals with the conditions that facilitate evacuation. The result considers the signalling, lighting and design of escape routes, the fire alarm and the training of people to evacuate the building quickly and safely. The values of the nine factors relating to the danger to people must be determined: escape route factor — $F_{escape\ route}$ (equation 7), population factor — $F_{population}$ (equation 8), width factor — F_{width} (equation 9), lighting factor — $F_{lighting}$ (equation 10), signalling factor — $F_{signalling}$ (equation 11), alarm factor — F_{alarm} (equation 12), volunteer fire brigade factor — $F_{volunteer\ brigade}$ (tabulated value),

Table 1. Factors and parameters considered by the proposed method — CEPI.

Coefficients	Factors	Parameters	
Initial Hazard	initial hazard	occupation and risk	P01
	electric installations	electrical system	P02
		system power	P03
		electrical circuit devices	P04
		system maintenance	P05
	use of liquefied petroleum gas (LPG)	use	P06
		ways of use	P07
		closing devices	P08
		maintenance	P09
Fire Development	structural materials	floor	P10
		walls	P11
		ceiling/slab/roof	P12
	finishing materials	floor	P13
		walls	P14
		ceiling/slab/roof	P15
	compartmentation	type X, type Y or type Z	P16
	insulation	distance between buildings	P17
Vulnerability of People	escape route	distance to travel	P18
		hallway	P19
		stair protection	P20
		balancing the steps	P21
		finishing of the steps	P22
		handrail	P23
		doors	P24
		maintenance	P25
	population	maximum population in the highest risk room	P26
		maximum population of the highest floor	P27
		maximum population in the building	P28
	width of escape route	width of hallway	P29
		width of stairs	P30
		width of doors	P31
	lighting	escape route	P32
		autonomy	P33
		maintenance	P34
	signalling	indicating the exit on the escape route	P35
		warning and ban	P36
		indicating fire protection equipment	P37
		size of plates	P38
		positioning	P39
		symbology	P40
	alarm	location of manual triggers	P41
		installation of manual triggers	P42
		sound alerts	P43
	alarm center	type of alarm center	P44
		surveillance of the alarm center	P45
	fire brigade	volunteer fire brigade	P46
	emergency plan	planning	P47
		disclosure	P48
		training	P49
	evacuation plan	evacuation of people	P50
		people evacuation training	P51
Vulnerability of Contents	emergency plan and evacuation plan	content protection	P52
		secure interim storage	P53
		protection of specific locations	P54
		training	P55

(*Continued*)

Table 1. (Continued).

Coefficients	Factors	Parameters	
Protection Level	extinguishers	coverage area	P56
		special risk areas	P57
		extinguishing agent	P58
		extinguishing capacity	P59
		distance/location	P60
		installation of appliances	P61
		maintenance of equipment and containers	P62
	alarm	location of manuals triggers	P41
		installation of manual triggers	P42
		sound alerts	P43
		type of alarm center	P44
		surveillance of the alarm center	P45
	detection	coverage area	P63
		types of detectors	P64
		distance/location	P65
		installation of appliances	P66
		maintenance of detectors	P67
	fire hydrant	coverage area	P68
		distance/location	P69
		installation of hydrants	P70
		technical fire reserve volume	P71
		flow rate	P72
		pressure	P73
		maintenance	P74
	sprinklers	coverage area	P75
		distance/location	P76
		nozzle installation	P77
		technical fire reserve volume	P78
		maintenance	P79
	fire brigade	professional fire brigade	P80
	urban fire hydrant	distance of urban hydrant	P81
	fire department	response time	P82
	accessibility	building depth	P83
		building height	P84
		free access facades	P85

emergency plan factor — $F_{emergency\ plan}$ (equation 13) and evacuation plan factor — $F_{evacuation\ plan}$ (equation 14). The results should then be used to calculate the vulnerability of people coefficient (Equation 15).

$$F_{escape\ route} = \bar{x}(P18 + P19 + P20 + P21 + P22 + P23 + P24 + P25) \quad (7)$$

$$F_{population} = \bar{x}(P26 + P27 + P28) \quad (8)$$

$$F_{width} = \bar{x}(P29 + P30 + P31) \quad (9)$$

$$F_{lighting} = \bar{x}(P32 + P33 + P34) \quad (10)$$

$$F_{signalling} = \bar{x}(P35 + P36 + P37 + P38 + P39 + P40) \quad (11)$$

$$F_{alarm} = \bar{x}(P41 + P42 + P43 + P44 + P45) \quad (12)$$

$$F_{emergency\ plan} = \bar{x}(P47 + P48 + P49) \quad (13)$$

$$F_{evac.plan} = \bar{x}(P50 + P51) \quad (14)$$

$$Vulnerability\ of\ People\ Coefficient = \bar{x}\begin{pmatrix} F_{esccape\ route} + F_{population} + F_{width} + F_{lightinh} + F_{signalling} + F_{alarm} \\ + F_{volunteer\ brigade} + F_{emerg.plan} + F_{evac.plan} \end{pmatrix} \quad (15)$$

The Vulnerability of Contents Coefficient deals with the protection conditions for specific assets or locations which, because of their historic value, require special attention in the event of a fire. The values of the two content vulnerability factors must be determined: the emergency plan factor — $F_{emergency\ plan}$ (according to equation 13 presented earlier) and the contents protection plan factor — $F_{contents\ protection}$ (equation 16). The results must then be used to obtain the content vulnerability coefficient, according to equation 17.

$$F_{content\ protection} = \bar{x}(P52 + P53 + P54 + P55) \quad (16)$$

$$Vulnerability\ of\ Contents\ Coefficient = \bar{x}\left(F_{emerg.plan} + F_{contents\ protection}\right) \quad (17)$$

The Protection Level Coefficient deals with the existence and effectiveness of fire protection measures, even if they are not required by local regulations. The values of the nine factors related to the protection level should be determined: extinguisher factor — $F_{extinguisher}$ (equation 18), alarm factor — F_{alarm} (equation 12), detection factor — $F_{detection}$ (equation 19), fire hydrant factor — $F_{fire\ hydrant}$ (equation 20), sprinklers factor — $F_{sprinklers}$ (equation 21), professional fire brigade factor — $F_{professional\ brigade}$ (tabulated value), urban fire hydrant factor — $F_{urban\ fire\ hydrant}$ (tabulated value), Fire Department factor — $F_{fire\ department}$ (tabulated value) and accessibility factor — $F_{accessibility}$ (equation 22). The results must then be used to calculate the protection level (equation 23).

$$F_{extinguisher} = \bar{x}(P56 + P57 + P58 + P59 + P60 + P61 + P62) \quad (18)$$

$$F_{detection} = \bar{x}(P63 + P64 + P65 + P66 + P67) \quad (19)$$

$$F_{fire\ hydrant} = \bar{x}(P68 + P69 + P70 + P71 + P72 + P73 + P74) \quad (20)$$

$$F_{sprinklers} = \bar{x}(P75 + P76 + P77 + P78 + P79) \quad (21)$$

$$F_{acessibility} = \bar{x}(P83 + P84 + P85) \quad (22)$$

$$Protection\ Level\ Coefficient = \bar{x}\left(\begin{array}{c} F_{extinguisher} + F_{alarm} + F_{detection} + F_{fire\ hydrant} + F_{sprinklers} \\ + F_{professional\ brigade} + F_{urban\ fire\ hydrant} + F_{fire\ department} + F_{acessibility} \end{array}\right) \quad (23)$$

The aim of the method is not to produce a single safety factor value but five values that can be calculated and analysed separately, providing data and input for safety analysis for each aspect to be protected.

For the Initial Hazard and Fire Development coefficients, results in the range between 1.00 and 3.99 indicate that the building has no measures in place to prevent a fire from starting and, if a fire does occur, there are no structural characteristics that could prevent it from developing. Results in the range between 4.00 and 5.99 indicate that the building has some safety measures in its structure but they are poorly dimensioned or not functional enough to provide fire protection. Results above 6.00 indicate that the building has a well-dimensioned structure to prevent fire development, and that the installations that could cause a fire are well planned and maintained. The lower the value, the greater the risk to which the building is exposed.

For the People Vulnerability and Content Vulnerability Coefficients, results in the 1.00 to 3.99 range indicate that the building has no structures or protective measures that can guarantee the evacuation of people or the removal of the building's contents. Results in the range between 4.00 and 5.99 indicate that the building has structures for evacuating people, but that they are poorly dimensioned or not functional enough to guarantee the rapid exit of people or the efficient movement of contents. Results above 6.00 indicate that the building has a well-dimensioned structure to guarantee the evacuation of people, as well as a good level of training for both evacuation and the removal of contents from the building. The lower the value found, the greater the vulnerability of people and contents in a fire situation.

For the Safety Level coefficient, results between 1.00 and 3.99 indicate that the building does not have the basic fire protection systems or, if it does have some of them, they are poorly dimensioned or not maintained, so that they cannot be considered reliable for operation in the event of a fire. Results between 4.00 and 5.99 indicate that the building has some protection systems, which may or may not be well dimensioned, but which are not periodically maintained or do not cover the entire building. These systems may or may not offer some protection but they cannot be considered reliable in the event of a fire. Results above 6.00 indicate that the building has well-dimensioned fire protection systems that can be considered reliable in the event of a fire.

The variation of the coefficient results in the respective value ranges indicates how close the building is to the established limits. Details of the problems encountered and possible solutions can be obtained by analysing the values of each parameter. The change of colours for each score is intended to make it clearer to the analyst how the degree of security evolves as the score gets higher (see Table 2).

4. Case study — Paço de São Cristóvão (National Museum/RJ)

To demonstrate the direct application of the proposed method (CEPI), the analysis was carried out in the São Cristóvão building, located in the city of Rio de Janeiro, Brazil, which housed the National Museum.

Table 2. CEPI Method's result scale: level of safety/hazard.

7	Very Low hazard
6	Low hazard
5	Acceptable hazard
4	Hazard
3	Very hazardous
2	Extremely hazardous
1	Unacceptable

Considering that this building was destroyed by fire in 2018, and that the reconstruction has not yet been carried out, the data used reflect the situation of the building before the fire; according to the information collected in the architectural project (Linhares 2016), the records of the architect responsible for the building (Ferreira 2021), the technical visit carried out by this researcher and the expert fire report that occurred in 2018 (Brasil 2019).

Table 3 shows the values assigned to the parameters of the method, according to the assessment of the characteristics of the building before the fire. The 'parameter' column organises them in the order given by the method; and the 'value' column shows the values assigned to each by the analyst.

Table 4 presents the calculated values for the factors and their respective coefficients, according to the equations of the proposed method. The values presented in the last column are already the final-result of each equation applied to the case study.

The result is presented in five different coefficients. Figure 1 shows the results in comparison with the scale proposed by the method, which organises the hazard/safety levels in ascending order, on a scale from 1 to 7, as previously shown in Table 2.

The building was found to be unsafe in all five attributes, with a medium level of initial hazard and a high-level of hazard in the remaining coefficients.

In the Initial Hazard Coefficient, the higher value of the coefficient (4,00) is because the building structure is made of adobe and stone masonry, which have high fire resistance. The walls with this structure were the ones that resisted the fire that occurred in 2018 and are still standing today, while the rest of the building, including the ceilings and roofs — which were made of solid wood — were consumed by the fire.

The Fire Development Coefficient value (3,33) is due to the fact that there was no internal compartmentation in the building to contain or isolate the fire. The internal spread of the fire was extremely fast, making it impossible for the firefighters to contain the fire.

In the case of Vulnerability of People Coefficient, the low value of the coefficient (1,83) is due to the staircase being made of solid wood, not being protected against flames and smoke, and the distances to be covered to escape being too long. There were no casualties in the 2018 fire because it occurred on a Sunday evening when the building was empty.

For the Vulnerability of Contents Coefficient, the value of the coefficient (1,00) was the lowest that could be obtained in the application of the method. This is owing to not having an emergency plan, no plan to protect the contents and no personnel trained to act in a fire situation. The result was a total loss of all the museum's contents by fire.

At the Protection Level, the coefficient value (2,78) reflects the lack of fire protection systems in the building. The only firefighting equipment available in the building was the fire extinguishers. This is the type of equipment that should be used at the start of a fire, when the fire is still in its early stages and confined to the point of origin. However, the lack of a fire detection system meant that the fire was not detected until it had already consumed the auditorium where it started, and spread to other areas of the building. At this stage, the extinguishers were no longer effective in fighting the flames.

By analysing the results of the proposed method, considering each coefficient and the factors that are

Table 3. Values assigned to the CEPI method parameters in the case study.

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
P01	5	P23	5	P45	-	P67	-
P02	-	P24	6	P46	1	P68	1
P03	1	P25	1	P47	1	P69	-
P04	1	P26	7	P48	-	P70	-
P05	1	P27	1	P49	-	P71	-
P06	6	P28	7	P50	1	P72	-
P07	6	P29	1	P51	-	P73	-
P08	6	P30	1	P52	1	P74	-
P09	-	P31	7	P53	1	P75	1
P10	3	P32	1	P54	1	P76	-
P11	6	P33	-	P55	1	P77	-
P12	1	P34	-	P56	-	P78	-
P13	2	P35	1	P57	7	P79	-
P14	6	P36	-	P58	7	P80	1
P15	1	P37	-	P59	7	P81	1
P16	1	P38	-	P60	-	P82	7
P17	6	P39	-	P61	-	P83	-
P18	1	P40	-	P62	7	P84	3
P19	2	P41	1	P63	1	P85	7
P20	1	P42	-	P64	-		
P21	2	P43	-	P65	-		
P22	2	P44	-	P66	-		

Table 4. Values of the method factors and coefficients.

Factors and coefficients		*Equation*	Calculated value
Initial Hazard	F_{risk}	*table A-1 and A-2*	5,00
electrical factor	$F_{eletric}$	equation 1	1,00
liquefied petroleum gas (LPG) factor	F_{LPG}	equation 2	6,00
Initial Hazard Coefficient		*equation 3*	**4,00**
structural factor	$F_{structural}$	equation 4	3,33
finishing material factor	$F_{finishing\ material}$	equation 5	3,00
compartmentation factor	$F_{compartmentation}$	*table A-7*	1,00
insulation factor	$F_{insulation}$	*table A-8*	6,00
Fire Development Coefficient		equation 6	**3,33**
escape route factor	$F_{escape\ route}$	equation 7	2,50
population factor	$F_{population}$	equation 8	5,00
width factor	F_{width}	equation 9	3,00
lighting factor	$F_{lighting}$	equation 10	1,00
signalling factor	$F_{signalling}$	equation 11	1,00
alarm factor	F_{alarm}	equation 12	1,00
volunteer fire brigade factor	$F_{volunteer\ brigade}$	*table A-17*	1,00
emergency plan factor	$F_{emergency\ plan}$	equation 13	1,00
evacuation plan factor	$F_{evacuation\ plan}$	equation 14	1,00
Vulnerability of People Coefficient		equation 15	**1,83**
emergency plan factor	$F_{emergency\ plan}$	equation 13	1,00
contents protection factor	$F_{content\ protection}$	equation 16	1,00
Vulnerability of Contents Coefficient		equation 17	**1,00**
extinguisher factor	$F_{extinguisher}$	*equation 18*	7,00
alarm factor	F_{alarm}	*equation 12*	1,00
detection factor	$F_{detection}$	*equation 19*	1,00
fire hydrant factor	$F_{fire\ hydrant}$	*equation 20*	1,00
sprinklers factor	$F_{sprinklers}$	*equation 21*	1,00
professional fire brigade factor	$F_{professional\ brigade}$	*table A-25*	1,00
urban fire hydrant factor	$F_{urban\ fire\ hydrant}$	*table A-26*	1,00
Fire Department factor	$F_{fire\ department}$	*table A-27*	7,00
accessibility factor	$F_{acessibility}$	*equation 22*	5,00
Protection Level Coefficient		*equation 23*	**2,78**

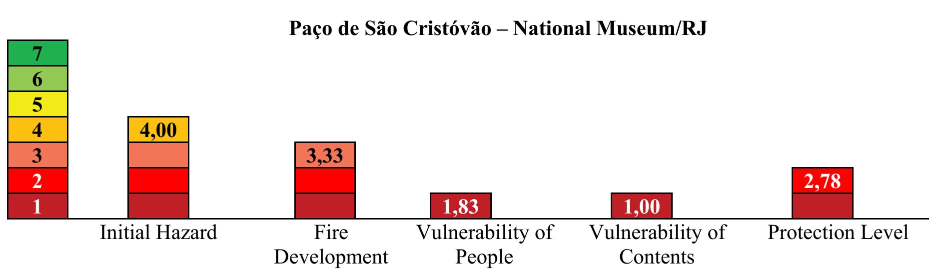

Figure 1. Representative graph of the analysis results.

reflected in its result, it would be possible to determine which aspects are most at risk and, thus, draw up a risk management and reduction plan.

5. Final considerations

The proposed method (CEPI) was tested in buildings of historic value in Brazil, used for schools, museums and large public gatherings.

The objective of proposing a semi-quantitative method is to make it available at no extra cost to fire safety professionals, and to provide a practical and simple tool for measuring fire safety in a building of historic value. Fire safety specialists, already familiar with firefighting projects and systems, must use their technical knowledge to judge the parameters and analyse the results found.

The exemptions provided for in the fire safety legislation have the advantage of guaranteeing the architectural and heritage integrity of these buildings of historic value. Nonetheless, this protection must not endanger the very assets that it is intended to preserve. It is necessary to analyse the boundaries between maintenance and protection, and to reach a consensus that guarantees safety without compromising heritage conservation.

Given the patrimonial value of the building, the minimum protection provided by local legislation is not sufficient, as the asset at risk is irreplaceable.

Therefore, it should be a priority for those in charge of the building to ensure that it reaches the highest level of protection, reflecting greater safety for people and for the existing historic or cultural heritage.

This article is a description of the concepts used in the development of a new fire risk analysis method for buildings of historic value in Brazil, taking into account their effective protection against fire and minimising the risks of any loss of heritage caused by fire.

Disclosure statement

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