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# EBRAFire: Fire Safety Assessment and Classification of Buildings

Fernando José da Silva*, Luís Carlos Ferreira Moreira**,
João Carlos Gonçalves Lanzinha***, Paulo Gustavo von Krüger*
*(Doctor Professor of Department of Technology of Design, Architecture and Urbanism, Federal University of Minas Gerais, Belo Horizonte, Brazil, Email: fernandojsilva@ufmg.br, paulovonkruger@gmail.com)
** (Mastering of Civil Engineering Program of UBI – University of Beira Interior, Portugal. Email: luis_moreira92@hotmail.com)
*** (Doctor Professor of Department of Civil Engineering and Architecture, UBI – University of Beira Interior, Portugal. Email: joao.lanzinha@ubi.pt)

**ABSTRACT**
Due to the increase of rehabilitation works and the knowledge that the majority of the existing buildings was not objected of a fire safety project because there was no regulation at the time of construction, it is necessary to create technical assessment tools suitable to buildings or built sets, especially in more sensitive areas. This work proposes the model and operating procedures for an assessment method called EBRAFire. It assigns a rating to the buildings analyzed, based on fundamental parameters, observed in technical and regulatory standards, and also in empirical events resulting from experience in preventing and fighting fires. The model provides a detailed analysis of the parameters connected to the building's fire safety, with results that are easy to understand, can be useful for creating records for the Geographic Information Systems (GIS), and can also be a fundamental collaborative work tool for all civil protection agents. Considering that one can act in particular on a factor that has a significant risk contribution, it is possible to carry out localized rehabilitation projects for existing buildings, providing more accurate budget estimates and with lower costs, with the ultimate goal of always be ensuring the best response capacity in case of fire.
***Keywords -*** Assessment, Existing Buildings, Fire Risk, Fire Safety.

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## I. INTRODUCTION

Considering the importance of instruments in rehabilitation in recent years, it is clear that rehabilitating buildings, restoring abandoned urban centers, ensuring the safety of users of buildings and keep assets that can be considered valuable Heritage is a fundamental activity.

Nowadays, it is common to carry out projects for new buildings in which one of the specialties to be mandatorily elaborated and studied is Fire Safety. The technical requirements required for the project are given based on a set of elements that are described in the existing regulations and made available in the legislation. International safety standards present requirements and models related to building, regarding construction and security against fire [1, 2]. In Portugal, the competent entity to ensure compliance with the fire safety regime in buildings is the National Emergency and Civil Protection Authority, ANEPC [3], and in Brazil this entity is systematized by the National Civil Defense, organized in several sectoral bodies, among them Fire Department, Civil Police, Military Police, Armed Forces, Social Assistance Secretariat, among others, which define rules, regulations, and ordinances normally presented and individualized by different Brazilian states. Another national normative body is the ABNT Brazilian Association of Technical Standards [4], which also has several rules regarding fire prevention and fighting in public and private sectors [5], including having a work group called the Brazilian Fire Safety Committee (ABNT / CB-024). These regulations and decrees are only valid for the buildings to be constructed.

Due to the scarcity of elements that underlie in-depth analyzes for the application of Fire Safety requirements in constructed buildings, it is considered essential to envisage the creation of a fire risk assessment model applicable to this kind of buildings.

## II. THE NEED TO ASSESS THE FIRE RISK

In a set of protection measures for a society, which can be called Civil Protection, the main objective is to protect people and property in housing; the need arose in 1990 to create in Portugal the first regulation regarding protection against fire risks in residential buildings [6], while in Brazil, the National Civil Defense System (SINDEC) was created in 1988, reorganized in August 1993, and updated through Decree nº 7.257 in 2010 [7].

Although the regulations have been applied in Portugal since 1990, of the 3.5 million buildings existing in the country in 2011 [8], more than 70% had been built until the date the regulations started to be applied. For that reason, they did not comply with the minimum safety requirements, most of the time due to compartmentalization, means of escape, the materials used and their degradation, lack of maintenance, change in activity, conditions of the building envelope, use of the equipment and risky facilities, among others. This situation is certainly similar to that which occurs in other countries and other areas of the planet.

The fire risk assessment in existing buildings should consider combining these and other factors to determine quantitatively the conditions to which a given construction is subject. As such an assessment requires a visual inspection of the target buildings, it is intended that the survey and, mainly, the treatment of the data are done by technicians with knowledge in the scope of structural fires and/or in the civil protection (Firefighters, Protection Technicians Civil, Civil Engineers or Architects) with the support of a fire risk assessment model. Some authors such as Santana et al. [9], Iringová and Idunk [10], Zahmatkesh and Memari [11] and Lo [12], among others [13, 14], have already carried out works and publications on this subject, showing the importance of carrying out a careful observation in this field, including analysis in specific software in this area [15].

The proposed risk assessment model, called EBRAFire: Existing Building's Risk Assessment for Fire [16] allows an automatic procedure, facilitated by using an Excel© spreadsheet, which the simplified assessment of an existing building regarding its fire safety.

This procedure deals with a set of data that can be taken from the observation of one or more existing buildings in a given location [17]. Thus, it will be possible to assess the level of comfort and safety in terms of occasional structural fires.

The importance of implementing an analysis of this kind is justified by the degraded state of the existing buildings, in which the analyzes must be sensitive to their age and state of conservation, since in large urban centers (and even in rural areas) it is very conventional to find old buildings that, since its construction, have never been intervened in terms of fire protection measures, evacuation plans, or even the application of materials with greater fire resistance.

## III. SECURITY REQUIREMENTS AND THE IMPORTANCE OF AN ASSESSMENT MODEL

There are currently a set of regulatory standards considered in new building design, which contain various topics on fire safety compliance. In Portugal, for the preparation of projects and for the fulfillment of these requirements, there must be based in the Legal Regime for Fire Safety in Buildings (RJSCIE, *Regime Jurídico de Segurança Contra Incêndio em Edifícios*), established by Decree-Law No. 220/2008 of 11 November [18], and amended by Law No. 123 / 2019 of October 18 (3rd amendment) [19] as well as in the Technical Regulation on Fire Safety in Buildings (RTSCIE, *Regulamento Técnico de Segurança Contra Incêndio em Edifícios*), established in Ordinance No. 1532/2008 of 29 December [20].

In the topics required by the RJSCIE, the type of construction of the building, its use, thermal load of the content, self-protection measures, classification of various materials in terms of fire resistance, ventilation, or water tightness should be highlighted.

Analyzing in-depth the ordinances and decree-laws in force in Portugal, it can be seen that the regulations applicable to buildings already in place are very restricted and vague. Thus, for the reasons invoked, it is of utmost importance to create a fire risk assessment model applicable to existing buildings, especially to buildings constructed before implementing fire safety regulations.

## IV. HOW TO ESTIMATE EVALUATION PARAMETERS AND RISKS

The parameters used in the assessment method must be based on factors considered in the other national regulations, studies, research, and articles (theoretical), such as the regulations, RGEU [21], Decree-Law 64/1990 [6], RTSCIE: Ordinance No. 1532 / 2008 [20], Law No. 123/2019 [19], mentioned above, including civil protection policies, coordinated by the National Emergency and Civil Protection Authority (ANEPC) [22], amendment to

decree law 220 [23] and also factors observed in several case studies of structural fires (empirical factors). In addition to these nominees, knowledge was also acquired in the field of structural fires from a group of entities that participate in the implementation of safety procedures, namely:
- Sapadores Firefighters (Coimbra, Portugal).
- Volunteer Firefighters (Fundão, Covilhã, Castelo Branco and Proença-a-Nova Counties, Portugal).
- National Fire School (Portugal).

In the research carried out, the following factors were highlighted as fundamental characteristics of analysis:

a) Fire duration,

b) Fire Propagation Speed,

c) Severity of Fire,

d) Susceptible Compartments,

e) Available means of combat,

f) Firefighting efficiency,

g) Efficiency - Severity Combination Factor,

h) Probability of Ignition Occurrence,

i) Escape conditioning factor,

j) Individual Exposure Level - Risk for Users,

k) Surroundings and Security,

l) Exceptional risk,

m) Class of protection characteristic of the building,

n) Class of protection characteristic of the surroundings,

o) Class of protection characteristic of the activity/exception.

## V. EBRAFire: MODEL PROPOSAL FOR FIRE RISK ASSESSMENT APPLICABLE TO EXISTING BUILDINGS

The creation of the model was based on a survey of the factors mentioned and described in the previous chapter. The sequence of parameters, the simplified interface and language, and the quantification of each item assume that this assessment can be easily interpreted by users with no experience in fire safety, thus being able to guarantee that the sharing of information is successful.

Although it is necessary to survey various information for each building, data input is simple which allows for several classifications per day, which will, in turn, surveys to be stored in the future in GIS type information (Geographic Information System), such as fire safety records in buildings in a given location, using five characteristic colors corresponding to each risk class, which allows a view of the gradient of sensitive urban areas, with the possibility of, in the future, act in terms of rehabilitation and the application of corrective and self-protection measures.

The model creation process was based on the quantification by risk levels of the various parameters influencing safety in the building and the users. Some of these parameters are even the result of the correlation of several other factors through the same quantification process. The results of each parameter will vary according to the data entered, by direct and automatic relation in the application of the EBRAFire model.

### 5.1 MODEL ORGANIZATION

The final result of the fire safety classification is the analytical comparison organized into four subchapters. The evaluation of a set of parameters will result in the assignment of a certain security class for each of these subchapters.

Subchapter A analyzes fire safety from the building's physical characteristics, layout, materials, and content.

Subchapter B studies the factors contributing to users' safety, such as behaviors, activities, and availability of means of combat.

Subchapter C examines the function of the space around the building and its contribution to fire and ignition safety, such as forestry and adjacent buildings, as well as access.

Finally, subchapter D looks at the security applied to activities occur by exception, as are the examples of fairs and cultural festivals, which reuse existing housing to change its main function. This last subchapter will be included in the global security value if there is a need for its analysis; otherwise, the global fire safety value of the building will be the result of only subchapters A, B, and C.

The summary table that the EBRAFire application will show as a global result assigns the value to each subchapter according to the data entered to obtain the final classification (Fig.1).

Each subchapter will enter the final classification in the admissible percentage about the importance it represents for the overall security of the building; this percentage is not equivalent to the four subchapters.


Figure 1: Final Classification: Subchapter D Inactive

Assuming that there will be a need to consider the parameters included in subchapter D, it must be activated by changing the data "Does the Exception apply?" to the value "YES", and consequently all input fields will be unlocked. This factor will then enter into the calculation of the Global Classification (Fig.2).

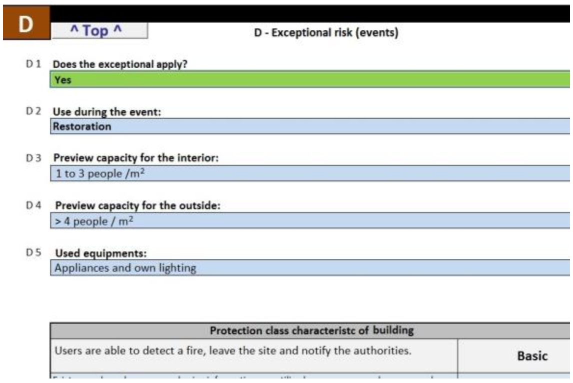


Figure 2: Subchapter D Active

### 5.2 Final Fire Safety Classification

Five levels of classification are proposed for the sub-chapters and consequent final classification: Insufficient, Minimum, Necessary, Recommended, and Superior. This denomination can be translated as follows:

- Fire safety (FS) of the building is **Insufficient** - this result presupposes corrective action about the chapter in question or the generality of the building;
- The FS of the building is **Minimum** - although there are some beneficial characteristics, they are not necessary to guarantee the security of the building. Corrective and rehabilitation measures must be taken to increase the level of classification;
- The FS of the building is the (minimum) **Necessary** - the chapter/building has fire safety characteristics that are concluded to be beneficial for its classification. Although the minimum conditions are necessary, it is recommended that case, a study of the chapter is carried out to ascertain which of the parameters introduced in that chapter influences the result obtained;
- The building's FS is the **Recommended** one - this classification indicates that there are few or no needs for intervention in terms of fire safety in the building;
- The FS of the building is **Superior** - This classification is the one that you always aim to achieve. The necessary actions in the building are practically null, and maintenance, equipment updating, and personnel training must be considered to remain valid for longer periods;

In the final Classification, although it may have a level of classification "Necessary" or "Recommended", the subchapters should always be checked in an analysis in which it is determined whether there is one of them with a classification below the necessary and that, if so, it should always consider corrective actions.

The EBRAFire assessment procedure also provides a graph that outlines the contribution that each chapter has to the building's security. Observing this graph allows you to have a visual idea of the corrections that may eventually be implemented (Fig.3).

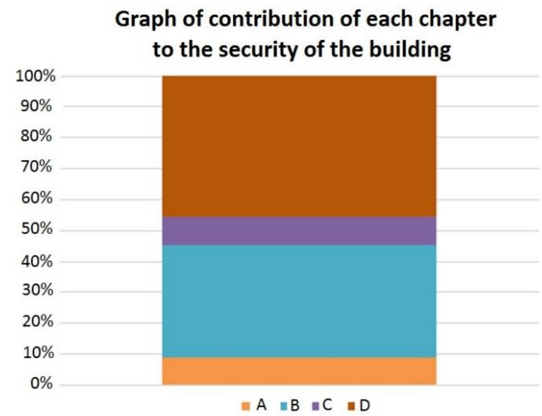


Figure 3: Balance graph between chapters

## VI. Procedures to be followed in risk assessment using the EBRAFire model (data collection and treatment)

The Fire Safety assessment procedure using the EBRAFire model has three distinct phases: collecting data about a specific building, entering data into the program, and finally analyzing the results with their export.

### 6.1 Data Collection

In the data collection phase of the building being studied, the EBRAFire program provides a “Checklist” form (Fig.4) and allows it to be printed and taken to the site, to be filled out.

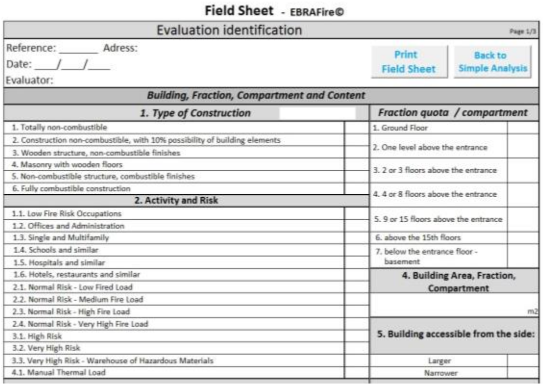


Figure 4: Field Sheet extracted from EBRAFire

### 6.2 Data Input

The EBRAFire assessment procedure contains the data input section (Fig.5), called EBRAFire Simple, to find the four subchapters. In each of them, there are fields to choose from among the various options that the model allows, and it is up to the user to select the one that corresponds to the constant in the field sheets or in another reliable data source.

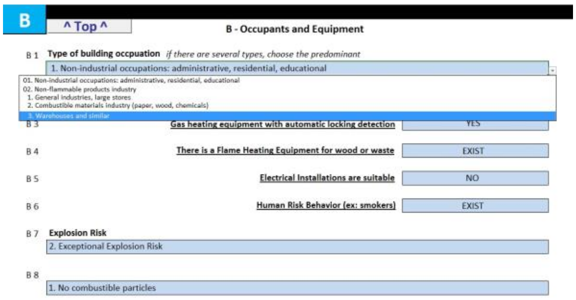


Figure 5: Example of EBRAFire Simple Layout – in Subchapter B

### 6.3 Results Analysis

After the user of the procedure enters and reviews the data contained in EBRAFire Simple, the assessment model will automatically perform the calculations, demonstrating the results in a practical and intuitive way. The results will appear in summary in the EBRAFire layout, where it is possible to analyze in real-time and know the final fire safety class of the building.

The purpose of this analysis is to subsequently be able to locate in detail where it will be possible to intervene in a given building to raise the fire safety rating, either through the implementation of equipment and self-protection plans, as well as the rehabilitation of the building itself.

A well-done detailed analysis allows for a more accurate budget estimate and intervention project, closer to the real one, to satisfy the security needs and, of course, the requirements of the owners, owners or municipalities, avoiding unnecessary expenses or unmeasured interventions.

### 6.4 Export Results

The procedure allows a final form to be provided, exported from the assessment model, and generated automatically, where the results of the analysis of a building can be observed.

It is objectively intended that any non-technical individual in the area of fire safety, engineering, or civil protection will be able to view this exported sheet and recognize the failures or contributions to that classification.

The information should be transmitted to the competent entities, which will carry out the proper intervention study in a given location with a higher risk.

The following is an example (Fig.6) of the final result after assessing several buildings. In this specific case, it is a cluster of houses located in the old part of a historic village, where you can see several buildings that need attention, highlight in red.

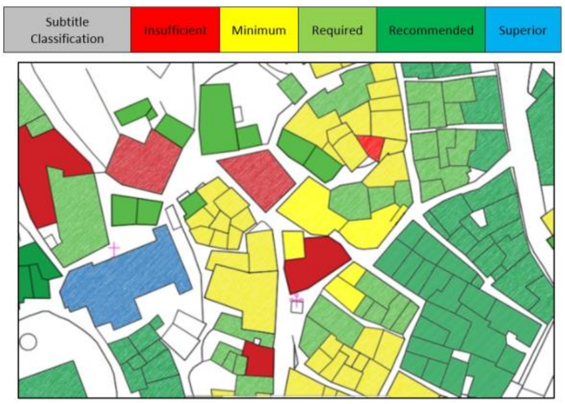


Figure 6: Application example: final results made with EBRAFire

## VII. APPLICATIONS

The EBRAFire method has already been used in two cities, one in Alpedrinha (Portugal) and the other in Ouro Preto (Brazil).

The first experience of using the EBRAFire model was in the historic area of Alpedrinha,


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belonging to the municipality of Fundão, located in Beira Interior, Portugal. Its built historical set presents a spatial typology of narrow and irregular streets from the medieval period with few changes to the present days (Fig. 7); in its buildings, two and three floors prevail, with narrow windows, and railings on the balconies, and decorative elements. They are located very close to the street, even with non-existent sidewalks. Among its historical constructions, four churches and chapels stand out, such as the Romanesque Mother Church (12th - 13th Century), in addition to the 17th Century Town Hall, Picadeiro Palace, regional Baroque construction from the 18th century, and the Pillory of the century XVII, in addition to significant museological spaces, with objects related to family activities and handicrafts from the Serra da Gardunha region. It also has a theater founded in 1839, the oldest in the Castelo Branco district, and the Museum of Music, with a vast set of instruments and scores for philharmonic bands and religious and cultural events in the village. Thus, a high historical patrimonial value is observed in this locality, of importance observed in other works [24, 25].

Figure 7: Medieval layout of streets in Alpedrinha (Source: google.maps)

Approximately 490 buildings were evaluated for fire risk, in this case, in an exceptional context, that is, they evaluated not only the general conditions of the building in terms of fire safety but also the conditions that occasional festival provides for these rooms, since most of them are changed in terms of use, equipment, electrical connections and even in terms of the number of users. As a result, there were a large number of buildings with insufficient or minimal evaluation, as shown in Fig.8.

In the survey, it can be observed that only 1.6% obtained a Higher level, 4.5% Recommended level, 43.3% Required level, 31.8% Minimum level, and 18.7% Insufficient level, with emphasis on the historic center that presented in its street considered as the main axis, almost all buildings obtaining the two lowest and most worrying concepts about fire safety.


Figure 8: Assessment Alpedrinha with EBRAFire

After the survey, in partnership with municipal authorities of the Municipality of Fundão and with the municipality's Voluntary Fire Brigade, interventions were carried out on the site that enabled a significant increase in security for the following festival and which remained with residents throughout the year:

- Active surveillance throughout the festival with a constant presence of intervention teams prepared for forest and structural fires, pre-hospital assistance, among others.
- Reinforcement of supply networks and landmarks/fire hydrants, with review and repair of inoperative branches;
- Content review of some houses in the context of the festival;
- Review of improvised electrical installations in the context the festival;
- Instruction to a group of people to operate in the case of fire (operation with extinguishing agents);

The other city to which EBRAFire was used, Ouro Preto, located in the central region of Minas Gerais state, brings together the largest and most important collection of architecture and art from the colonial period across Brazil. Due to its size and conservation, Ouro Preto was one of the first cities chosen by the United Nations Educational, Scientific, and Cultural Organization (Unesco) to be a World Heritage Site in 1980 [26].

Until now, EBRAFire has been used in the Historic Center of the city (Fig. 9), the block between Tiradentes square, street Senador Rocha

Lagoa, little street Cônego Camilo Veloso and street Conde de Bobadela (Fig. 10). However, it is intended to complete the assessment of the entire Historical Center as a continuation of this research.

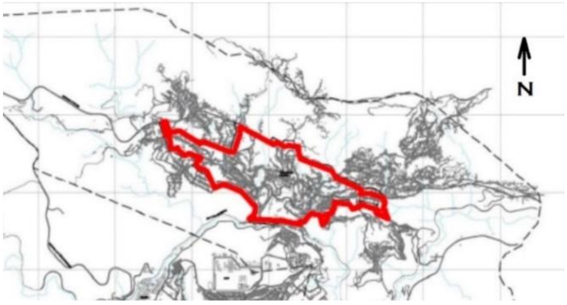


Figure 9: Ouro Preto Historical Center (highlighted in red). Source: MINAS GERAIS [26]

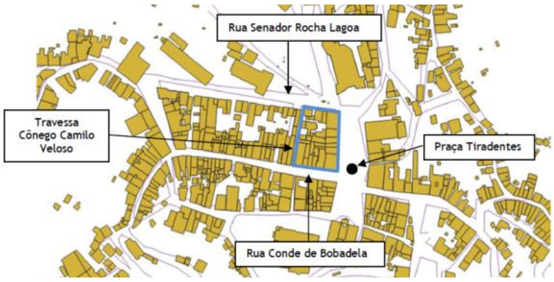


Figure 10: Area chosen for the study (highlighted in blue), inside the Historical Center of Ouro Preto. Source: Geoprocessing Laboratory of the School of Architecture of the Federal University of Minas Gerais.

The Figure 11 shows the results of the assessment using EBRAFire in Ouro Preto.


Figure 11: Fire risk assessment using EBRAFire. (Source: Fire Science and Technology Research Group – IGNIS)

It can be seen in the Fig.11 that all the buildings on the assessed city block were classified as Insufficient about fire safety. Therefore, this area has a high degree of fire risk, thus requiring urgent actions to reduce it.

## VIII. CONCLUSION

Considering the growing importance of the instruments in the rehabilitation of the buildings in recent years, it is clear that the improvement of fire safety conditions in existing housing buildings, in their various contexts, and especially in older urban areas or with a heritage character, is fundamental.

The main reason for proposing the creation and application of the EBRAFire assessment model is the lack of simple methods for calculating Fire Safety. Its application in the context of urban rehabilitation processes is even more noticeable when it is verified that the processing of data, in the process of analyzing buildings, which allows us to act proactively to effectively ensure the necessary fire safety of the built set.

The current legislation presents a set of regulatory norms for new construction buildings. With the study of these laws, it is concluded that the regulation in terms of rehabilitation, or improvement of safety in existing buildings, is very vague, contributing to this the building's geometry and implantation factors that preclude changes that condition safety in case of ignition.

In the development of the procedure for calculating the fire safety classification of an old or existing building, parameters were established that were considered fundamental for the analysis described based on technical, regulatory, and empirical factors. In each of the parameters, a set of characteristics common to several old/existing buildings was considered, to which a quantitative nature was attributed that allows automatic but rigorous calculations. Combining a certain set of factors contributes to the final grade so that the building's security can be wholly analyzed.

An intuitive layout was created, called EBRAFire Simple, where data can be entered simply, through the choice of an item among several options, in a certain parameter. The assessment model also allows the printing of a Field Sheet in the form of a Checklist that is prepared so that data can be quickly collected in the building site, and even several during the day. After data input, EBRAFire allows a detailed analysis of the parameters and presentation of the assessment results to understand their contribution to the building's safety. There is also the possibility to extract a global information sheet where some characteristics of the building are observed, the parameter classifications, and the final results, and it may be attached to a safety report issued by a competent entity.

The treatment of these results is intuitive and easy to understand and can be useful eventually for the creation of registrations at the GIS level, or, more simply, in digital plant format, and collaborates with civil protection agents to understand the sensitive points of a specific building, location or event, providing ways of acting in the event of a fire, and even promoting preventive actions, through simple visual identification information created by colors assigned to the classifications, and the gradient when surveying several buildings.

Another function of the analysis of the final results will be to identify determining factors that are contributing or not to the security of the building, and, once detected, they can be corrected. Knowing that one can act in particular on a factor that has a significant risk contribution, it is possible to carry out localized rehabilitation projects, providing for more accurate budget estimates and with fewer costs to the owners, with the ultimate goal of ensuring the ability to respond in case of ignition.

In the future, and with its development, it is believed that EBRAFire is geared even for lay people in the context of fire safety since its nature and simple language allows concrete conclusions to be drawn about possible security breaches. For now, it is recommended that this whole process be carried out by a professional, be it a technician specialized in fire safety, a civil engineer, or a firefighter, since the surveys carried out in the field lack knowledge of the scope of the study and due to the specificity that requires the decision to correct, prevent and rehabilitate a certain founded failure.

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