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FIRE RISK ASSESSMENT IN OLD URBAN AREAS – COIMBRA OLD TOWN





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ABSTRACT

The fire risk assessment in old urban areas is a matter of concern both for those responsible for civil protection, and also for all inhabitants. These concerns range from the degradation of the old structures, bad electrical facilities, absence of detection systems and fire-fighting systems, lack of access for fire fighters' vehicles, amongst others.
Another major concern is that these urban centers present great heritage and cultural values.
This study is based on a fire risk analysis on the historic old town of Coimbra, which was recently classified as World Heritage by UNESCO.
In this study, fire risk assessment methods as GRETENER and ARICA were used with the purpose of obtaining values of the level of fire safety of buildings. After this analysis and knowing the results of methods, this study also aimed to point out measures to be implemented to improve the fire safety in the studied area.

1 INTRODUCTION

The old urban centers, characterized by their heritage and cultural values, due to their location and typology of building, are vulnerable to fires, as there is a large number of unfavorable factors that facilitate the outbreak of the fire, making it difficult to fight and facilitating its propagation [1, 2]. Several urban fires, which due to their impact on society, are considered historic fires. In Lisbon (Chiado) one of the biggest urban fires occurred in Portugal in 1988. This fire originated in a short circuit that caused the combustion of products in the stores, destroyed 18 buildings, some of them considered emblematic buildings of the city. About 1150 firefighters and 275 vehicles were present

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to combat the fire, in which 73 people were injured and 2 were killed. In this work, the fire risk analysis is performed in the old urban center of Coimbra, more precisely the one designated, Alta de Coimbra. This study analyzes "Alta de Coimbra" through a collection of information which examines the conservation of buildings, building materials and their occupation. The accessibility of these buildings in case of fire is also analyzed. Analyzing the existing buildings in the old town of Coimbra, a set of buildings was selected, taking into account their location and cultural value, to which a more detailed risk analysis methodology was applied, the Gretener Method and the Arica Method, in order to obtain values of fire safety and contribute to the development of a fire risk map for the old town of Coimbra.

2 CASE STUDY – THE OLD TOWN OF COIMBRA

2.1 Delimitation of the studied area

Fig. 1 shows the area considered in the present study, which covers the area of Old Town buildings, the Faculty of Psychology and some monuments, such as the Old Cathedral. In the first phase, surveys were carried out on 25 buildings, and in a second phase, the Gretener and Arica methods were applied and their results analyzed. The delimitation of the studied area is presented below.

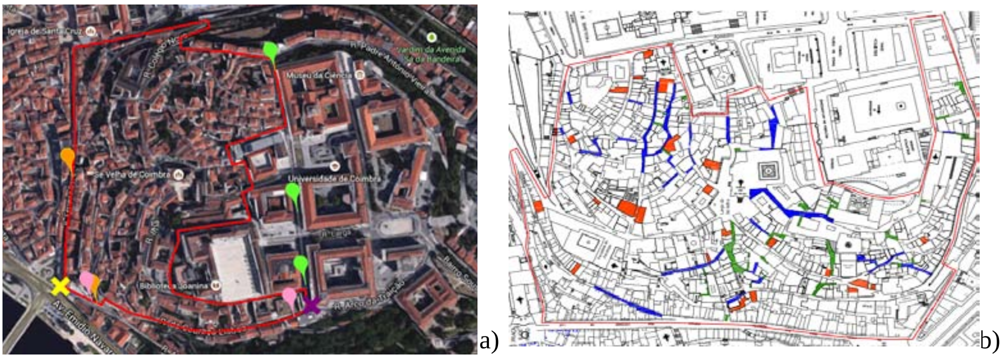

Fig. 1. Delimitation of the study area and its connection points a) top view b) plan

2.2 UNESCO classified area

The "University of Coimbra - Alta and Sofia" has been inscribed on the UNESCO World Heritage List since June 2013, following the unanimous decision of the World Heritage Committee. This property includes 31 buildings of great relevance, in an area of 815000 m^2.

Fig. 2. Historical buildings and routes of the old town of Coimbra

The UNESCO classification considers the buildings of the city and the immaterial dimension, being justified by the University of Coimbra as constructor and disseminator of the Portuguese language and culture. *Fig. 2* references some monuments and buildings that were officially integrated into the UNESCO World Heritage List, as well as their location.

2.3 Characterization of Coimbra Old Town Highlands

The present study area is located in the High zone of Coimbra, which like downtown, are part of the historic center of Coimbra, taking advantage of some special features such as old buildings and buildings of high architectural and historical value. Amongst the several buildings of high historical value, the Chemical Laboratory, the Academic Association of Coimbra, the Department of Physics, Department of chemistry, the Department of mathematics, Faculty of Medicine, the Faculty of Letters, the Paço of schools, General library, the University, the Old Cathedral, New Cathedral and the Botanical Garden. High Coimbra is located on the right bank of the Mondego River. It should be noted that the importance of this zone was immediately recognized by early people who lived there, where it is believed to there have been a castle, whose location was steep and rugged slopes through the side of the River, and by a deep valley from Republic Square to Square 8th May. The area considered for this study covers about 12 hectares and is bounded by the hills that stretched the Conchada to the Botanical Gardens, the North and the East bounded by the Republic Square and the Academic Association of Coimbra and, to the South by the boundaries of the Apostols roas and the door of Almedina. Encompasses approximately of 400 buildings, where residential and non-residential buildings can be found, some abandoned already. The inhabitants of the residential buildings are mostly students and some elderly people. Non-residential buildings are mainly comercial, having a wide variety of trade and services, including a large number for the restoration (mainly bars and cafes).

Fig. 3. Examples of old town building façades of Coimbra

The urban area of this study presents a particular morphology, where the streets and blocks, are the traditional character, with diverse dimensions and geometry, and a wide variety of trade and provision of services, in particular at the level of the ground floor. Being this a strong tourist attraction zone, there are some trade points strongly oriented to tourism. The streets are mostly narrow and curves (*Fig. 4*), allowing pedestrian access and, in some streets, access to transit, noting that the passage of a fire combat truck is very hard or demanding very complex maneuvers. In the situation to find vehicles parked on the street, the vehicle of the fire fighters cannot effect the passage.

Fig. 4. Views of the narrow streets of the old town

It should be noted that in the area of the faculties there are some milestones, which make it even more complicated the access and movement of fire fighter vehicles. There is also the zone called "back-breaker", which is an area mostly consisting of stairs allowing pedestrian access only, getting the limited traffic off at the beginning of this zone. The access for this and some other places is only possible by climbing very steep stairs.

2.4 Risk of propagation of building fires in the studied area

In the present study area, several aspects were found, both internally and externally, that contribute to the outbreak of a fire and to its propagation. At the internal level there are very old and damaged electrical installations, degraded gas installations, gas cylinders in unventilated places and near the stoves, kitchen cloths hung on the stoves and next to the water heater, the water heater hoses outside the walls, as well as heater tubes passing inside cabinets. Moreover, great amount of garbage all over the buildings, specially in the lofts, and also some beams of the roof in a rotten state (*Fig. 5*).

Fig. 5. Examples of fire safety problems found within the old town buildings

At the external level, the most relevant factors were essentially narrow and curved streets, complete stairway areas, the projection of landmarks on the pavements, and abusive parking of cars making it difficult to pass the vehicles (*Fig. 6*).

Fig. 6. Examples of fire safety problems concerning accessibility

3 FIRE RISK ASSESSMENT METHODS APPLIED TO THE PRESENT STUDY

3.1 Gretener method

The Gretener method was created by Eng. Max Gretener in the 1960s in Switzerland, with the main objective of quantifying the risk of fire and fire safety. This method is based on the application of integrated mathematical formulas, using tables and data, allowing to evaluate and compare the fire risk level of different elements of the building, ordering, combining and accumulating applied alternatives until the desired level of safety. It is also assumed that general safety measures are observed, such as safety distances between neighboring buildings, access roads for rescue vehicles, technical facilities in good condition, measures of protection for persons such as egress exits, lighting and safety signs [3].

The methodology followed by Gretener's method is, in a first phase, multiplied by the potential danger factors (fire load, combustibility, smoke and corrosion hazard, fire load, floor level and surface amplitude). In a second stage, protection measures are calculated, which includes normal measures, special measures and construction measures. In the third stage, the values of the danger of activation and the exposure of persons to the hazard (tabulated values) are calculated, then calculating the values of the Risk of Effective Danger and Admissible Risk. In the last phase, fire safety (γ) is determined, comparing the value of the actual fire risk with the admissible fire risk value, allowing the verification of whether the building has the required fire safety conditions, or in other words, the value of γ must be greater than or equal to one so that the building is safe. Otherwise, if the value of γ is less than one, it means that the building does not present fire safety.

3.2 Arica method

The Arica Method has the objective of assessing the fire risk in the old urban centers, considering that the buildings located in these places cannot have a higher fire risk than the most recent buildings, mainly because people living in the centers must not be subject to higher fire hazards. Conditions must be created in order to preserve the buildings located in these places, whose patrimonial and historical value is of great importance. This method is based, initially, on the determination of three global risk factors and a global efficiency factor, which are: global risk factor associated with the onset of fire, global risk factor associated with the development and spread of fire in the building, a global risk factor associated with evacuation of the building and a global factor associated with firefighting. The second phase of this method is based on the calculation of the Fire Risk Factor (FRI), which is compared with the Reference Risk Factor (FRR). In the last phase, the Fire Risk (IR) is determined. If this value exceeds one, the building has fire safety problems, if it is less than or equal to one, the building does not present problems in terms of fire safety, *ie*, it complies with the legislation in force.

3.3 Results of the application of the risk analysis methods

The study included 25 buildings, to which the previously described risk analysis methods were applied. With the application of the Gretener Method to the selected buildings, it was possible to extract the conclusions presented in *Table 1* and *Table 2* [3].

Table 1. Gretener Method – results for 13 buildings

			1	2	3	4	5	6	7	8	9	10	11	12	13
Potential Danger | P	Fire Load	Qm (MJ/m^2)	300	300	300	2100	2100	600	2100	300	300	2500	2500	300	2500
		q	1.10	1.10	1.10	1.70	1.70	1.30	1.70	1.10	1.10	1.70	1.70	1.10	1.70
	Combustibil.	c	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
	Smoke	r	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
	Corrosion	k	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Fire load	i	1.20	1.00	1.20	1.20	1.00	1.20	1.20	1.00	1.20	1.20	1.20	1.00	1.20
	Floor level	e	1.50	1.65	1.65	1.65	1.50	1.65	1.50	1.65	1.30	1.65	1.50	1.50	1.65
	Amp surface	g	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
	P=qcrkieg	**P**	**1.045**	**0.958**	**1.150**	**1.777**	**1.346**	**1.359**	**1.616**	**0.958**	**0.906**	**1.777**	**1.616**	**0.871**	**1.777**
Protection Measures | M	Port. Exting.	n_1	0.90	0.90	0.90	0.90	1.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90	1.00
	Hydrants	n_2	1.00	1.00	1.00	1.00	1.00	1.00	0.80	1.00	1.00	1.00	1.00	1.00	1.00
	Water	n_3	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
	Pipe	n_4	1.00	1.00	1.00	1.00	1.00	1.00	0.90	1.00	1.00	1.00	0.95	1.00	1.00
	Personnel	n_5	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	1.00
	Normal Measures	**N**	**0.468**	**0.468**	**0.468**	**0.468**	**0.520**	**0.468**	**0.337**	**0.468**	**0.468**	**0.468**	**0.445**	**0.468**	**0.650**
	Detection	s_1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Alert	s_2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Firefighters	s_3	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
	Level of int.	s_4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Extintion	s_5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Smoke evac.	s_6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Special Measures	**S**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**
	Structure	f_1	1.00	1.30	1.00	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
	Facade	f_2	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
	Compartment	f_3	1.10	1.30	1.10	1.10	1.30	1.10	1.10	1.30	1.05	1.10	1.10	1.30	1.10
	Windows	f_4	1.00	1.00	1.00	1.00	1.40	1.00	1.10	1.00	1.00	1.00	1.00	1.00	1.00
	Construction Measures	**F**	**1.265**	**1.944**	**1.265**	**1.645**	**2.721**	**1.645**	**1.809**	**1.944**	**1.570**	**1.645**	**1.645**	**1.944**	**1.645**
	M = NSF	**M**	**0.947**	**1.455**	**0.947**	**1.231**	**2.264**	**1.231**	**0.975**	**1.455**	**1.175**	**1.231**	**1.170**	**1.455**	**1.710**
Exposure | B=P/M		B	1.104	0.659	1.214	1.443	0.595	1.104	1.657	0.659	0.771	1.443	1.381	0.599	1.039
Activation Danger		A	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Risk | R=BA		R	1.104	0.659	1.214	1.443	0.595	1.104	1.657	0.659	0.771	1.443	1.381	0.599	1.039
People exposure		PHE	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Risk | R_u=1.3PHE		R_u	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
Fire Safety | $\gamma=R_u/R$		**γ**	**1.178**	**1.974**	**1.071**	**0.901**	**2.186**	**1.178**	**0.785**	**1.974**	**1.687**	**0.901**	**0.941**	**2.172**	**1.251**

Table 2. Gretener Method – results for the other 12 buildings

			14	15	16	17	18	19	20	21	22	23	24	25
Potential Danger | P	Fire Load	Qm (MJ/m^2)	2900	2100	300	2500	2100	2100	2100	2500	2100	600	300	600
		q	1.80	1.70	1.10	1.70	1.70	1.70	1.70	1.70	1.70	1.30	1.10	1.30
	Combustibil.	c	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.40	1.20	1.20	1.20
	Smoke	r	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
	Corrosion	k	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Fire load	i	1.00	1.20	1.20	1.20	1.00	1.20	1.20	1.20	1.20	1.00	1.00	1.20
	Floor level	e	1.50	1.50	1.30	1.65	1.50	1.65	1.65	1.65	1.30	1.50	1.65	1.50
	Amp surface	g	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
	P=qcrkieg	**P**	**1.426**	**1.616**	**0.906**	**1.777**	**1.346**	**1.777**	**1.777**	**1.777**	**2.419**	**1.030**	**0.958**	**1.236**
Protection Measures | M	Port. Exting.	n_1	1.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00
	Hydrants	n_2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Water	n_3	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
	Pipe	n_4	1.00	0.95	1.00	1.00	1.00	1.00	1.00	0.95	1.00	1.00	1.00	1.00
	Personnel	n_5	1.00	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	Normal Measures	**N**	**0.650**	**0.445**	**0.468**	**0.468**	**0.468**	**0.468**	**0.468**	**0.445**	**0.468**	**0.520**	**0.520**	**0.520**
	Detection	s_1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.45	1.45
	Alert	s_2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.10
	Firefighters	s_3	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
	Level of int.	s_4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Extintion	s_5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Smoke evac.	s_6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Special Measures	**S**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**1.600**	**2.320**	**2.552**
	Structure	f_1	1.30	1.00	1.00	1.30	1.30	1.30	1.30	1.30	1.20	1.30	1.30	1.30
	Facade	f_2	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
	Compartment	f_3	1.30	1.10	1.05	1.10	1.30	1.10	1.10	1.10	1.20	1.30	1.30	1.10
	Windows	f_4	1.00	1.00	1.10	1.00	1.10	1.00	1.10	1.00	1.00	1.00	1.00	1.00
	Construction Measures	**F**	**1.944**	**1.265**	**1.328**	**1.645**	**2.138**	**1.645**	**1.645**	**1.645**	**1.656**	**1.944**	**1.944**	**1.645**
	M = NSF	**M**	**2.021**	**0.900**	**0.995**	**1.231**	**1.601**	**1.231**	**1.231**	**1.170**	**1.240**	**1.617**	**2.345**	**2.182**
Exposure | B=P/M		B	1.104	0.659	1.214	1.443	0.595	1.104	1.657	0.659	0.771	1.443	1.381	0.599
Activation Danger		A	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Risk | R=BA		R	1.104	0.659	1.214	1.443	0.595	1.104	1.657	0.659	0.771	1.443	1.381	0.599
People exposure		PHE	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Risk | R_u=1.3PHE		R_u	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
Fire Safety | $\gamma=R_u/R$		**γ**	**1.843**	**0.724**	**1.427**	**0.901**	**1.546**	**0.901**	**0.901**	**0.856**	**0.666**	**2.042**	**3.181**	**2.296**

The application of the Gretener method has led to the conclusion that 60% of traditional constructions (fifteen buildings) presented a fire risk value within the safety values established for this method. The other 40% (ten buildings) did not accomplish the minimum fire safety standards.

The present study also analyzed the buildings, following the methodology defined in the Arica Method [4]. The results obtained with this method are presented in *Table 3* and *Table 4*. By the analysis of the results, it is concluded that, all the twenty-five buildings present values of fire risk higher than one, that is, high fire risk, meaning they are not safe. For all these buildings, measures will need to be implemented in order to improve their fire safety and to obtain fire risk values below one.

Table 3. Arica Method – results for 13 buildings

		1	2	3	4	5	6	7	8	9	10	11	12	13
Global Factor related to beginning of the fire	**FGII**	1.43	1.43	1.33	1.53	1.33	1.10	1.16	1.00	1.00	1.46	1.23	1.43	1.34
Global Factor related to development of the fire	**FGD PI**	1.51	1.24	1.40	1.37	1.29	1.29	1.39	1.32	1.34	1.31	1.36	1.29	1.32
Global Factor related to egress of the building	**FGEE**	1.87	1.95	2.03	2.00	1.79	2.01	1.85	1.84	1.81	1.98	1.83	1.79	1.99
Factor rel. egress paths	FICE	1.40	1.24	1.39	1.34	1.26	1.35	1.36	1.06	1.29	1.30	1.33	1.25	1.31
Factor rel. building	FIE	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Correction factor	FC	1.10	1.20	1.20	1.20	1.10	1.20	1.10	1.20	1.10	1.20	1.10	1.10	1.20
Global Factor related to the fire fighting	**FGCI**	1.65	1.73	1.73	1.73	1.64	1.73	1.73	1.73	1.73	1.82	1.73	1.65	1.73
Factor rel. to the fight of the fire	FECI	1.50	1.75	1.75	1.75	1.50	1.75	1.75	1.75	1.75	2.00	1.75	1.50	1.75
Factor rel. To the fight inside	FICI	1.54	1.45	1.45	1.45	1.43	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.43
Safety teams	FES	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Global Factor Fire Risk Building FRI=(1.2 FGII+1.1FGD PI+1FGEE+1FGCI)/4	**FRI**	1.72	1.69	1.72	1.77	1.61	1.62	1.63	1.55	1.55	1.75	1.63	1.64	1.69
Reference Fire Risk (current buildings) | FRR=0.915+(0.25FC)	**FRR**	1.19	1.22	1.22	1.22	1.19	1.22	1.19	1.22	1.19	1.22	1.19	1.19	1.22
FIRE RISK	**RI**	**1.45**	**1.39**	**1.42**	**1.46**	**1.35**	**1.33**	**1.37**	**1.28**	**1.31**	**1.44**	**1.37**	**1.38**	**1.39**

Table 4. Arica Method – results for the other 12 buildings

		14	15	16	17	18	19	20	21	22	23	24	25
Global Factor related to beginning of the fire	**FGII**	1.06	1.46	1.43	1.33	1.40	1.53	1.46	1.53	1.18	1.08	1.00	1.00
Global Factor related to development of the fire	**FGD PI**	1.25	1.50	1.51	1.37	1.25	1.34	1.34	1.35	1.41	1.28	0.94	1.12
Global Factor related to egress of the building	**FGEE**	1.73	1.88	1.88	1.98	1.80	1.98	1.99	1.98	2.04	1.81	1.55	1.58
Factor rel. egress paths	FICE	1.14	1.42	1.41	1.30	1.27	1.31	1.31	1.30	1.41	1.29	1.14	1.21
Factor rel. building	FIE	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.67	1.67
Correction factor	FC	1.10	1.10	1.10	1.20	1.10	1.20	1.20	1.20	1.20	1.10	1.10	1.10
Global Factor related to the fire fighting	**FGCI**	1.65	1.73	1.65	1.73	1.65	1.82	1.82	1.73	1.82	1.73	1.65	1.57
Factor rel. to the fight of the fire	FECI	1.50	1.75	1.50	1.75	1.50	2.00	2.00	1.75	2.00	1.75	1.75	1.50
Factor rel. To the fight inside	FICI	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.20	1.20
Safety teams	FES	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Global Factor Fire Risk Building FRI=(1.2 FGII+1.1FGD PI+1FGEE+1FGCI)/4	**FRI**	1.51	1.75	1.72	1.70	1.63	1.78	1.76	1.76	1.71	1.56	1.36	1.40
Reference Fire Risk (current buildings) | FRR=0.915+(0.25FC)	**FRR**	1.19	1.19	1.19	1.22	1.19	1.22	1.22	1.22	1.19	1.19	1.19	1.19
FIRE RISK	**RI**	**1.27**	**1.47**	**1.45**	**1.40**	**1.37**	**1.46**	**1.45**	**1.45**	**1.40**	**1.31**	**1.14**	**1.17**

4 PROPOSALS FOR THE FIRE SAFETY MEASURES

After the careful analysis of the studied area, it can be stated that this zone presents great problems of accessibility to the firefighter's vehicles. It is an area in which, as it has been mentioned previously, there is a large number of narrow streets, complete stair access areas, and streets with abusive parking lots of cars. All these factors contribute to an increased difficulty for firefighters to fight a fire.

It is imperative to preserve the buildings of the old historical centers and to improve the conditions of health, safety, hygiene and comfort, and simultaneously preserve the original traces of the facade of building and its surroundings. These measures should achieve not only structural safety but also fire safety for people.

The measures to be implemented, in the buildings and their surroundings, fall mainly in the phases that a fire can experience until its extinction. These measures aim to:

- Reduce the risk of fire deflagration;
- Reduce the risk of fire development and spread;
- Facilitate egress of buildings;
- Facilitate the firefighters intervention and combat of the fire.

In addition to these measures to be taken, safety measures must also be taken in respect of the empty buildings. Here are some measures to implement to reduce the risks of fire.

4.1 Reduce the risk of fire deflagration

- Conduct periodic surveys by specialized technicians for electrical installations and gas installations. These technicians will analyze the facilities and carry out the interventions necessary to guarantee fire safety and should alert the residents to the placement of the gas cylinders in well ventilated places and not near the stove;
- Clean the lofts and make a selective replacement of materials used in construction.

4.2 Reduce the risk of fire development and spread

- Improve the reaction conditions of materials and fire resistance of construction elements;
- Proceed with fireproof coatings of combustible materials;
- Periodically clean all lofts, roofs and poorly accessible spaces;
- Limiting the mobile fire load, especially that found in the escape routes;
- Avoid the use of coating and decoration materials that may contribute to the spread of flames;
- Use non-combustible coverings on floors and ceilings;
- Reduce the fire load in commercial establishments and warehouses, and equip them with detection and alarm systems;
- Installation of fireproof false ceilings;
- Painting of woods with fire protection varnishes;
- Painting of walls and other building materials with intumescent paints;
- Protection of escape routes.

4.3 Facilitate the egress of buildings

- Placing signaling and emergency lighting on the escape routes;
- Conduct drills as a form of training the occupants, to create routines of behavior and improvement of procedures;
- Remove flammable coatings from escape routes;
- Training, for all employees of the exploring entities, in Fire Safety of Buildings.

4.4 Facilitate the firefighters intervention and combat of the fire

- The streets must be free of obstacles and parked cars;

- Know adequately the location of hydrants and their availability of water;
- Conduct hydrant inspections by specialized personnel, in order to know if they have adequate pressure.

4.5 Measures to be applied in vacant buildings

- Cutting off the supply of electricity and gas, whenever these buildings remain unoccupied for a long time;
- Measures to prevent such sites from serving as temporary shelters;
- Removal of all combustible materials stored in them.

5 CONCLUSIONS

The application of the Gretener method allowed to observe that the zone under study presents a risk of fire, but also an accurate intervention/prevention of fire risk is also necessary. The sample used does not cover the entire historical zone, as there may be areas where the fire risk is higher. The Arica Method was much more penalizing than the Gretener, considering all buildings at risk of fire.
The results obtained reflect some particularities of the building and the area where they are located, such as the state of conservation of the electrical installations, the gas installations, the type of existing building materials, the lack of elements of security teams or employees with training in fire safety provided in some spaces, accessibilities conditioned by their characteristics and the assumptions of the technical regulation of fire safety, which vary according to the different uses of the building.
The risk of fire in historical centers is a matter of the present, but its seriousness is still unknown as regards its quantification, since there is still much disagree about the various methods, some more specific and more generic, analysis and calculation of the fire risk of a building.
The City Council and the Civil Protection Service of Coimbra should promote, together with the local fire department, training actions of the resident population aiming at reducing the risk of fire, both in domestic activities and in professional activities.

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