Fire risk assessment of historical areas: the case of Montemor-o-Velho

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Abstract

Historic constructions are different from contemporary ones for reasons associated with the old conception of villages or towns, and with the types of materials and constructive solutions used. Those characteristics make it difficult to adopt common fire risk assessment methods in the old areas of towns. In Portugal, fire risk analyses became more important after the 1988 fire in Chiado, in the historical area of Lisbon. The features of the area and the absence of any fire detection and suppression facilities led to the destruction of 18 buildings. This fire motivated the development of new fire safety regulations and more careful fire risk analysis countrywide.

This paper first describes the characteristics of the historical areas of Portuguese towns/cities in terms of their buildings, streets, the existing means of first intervention, the characteristics of the fire brigades and other aspects.

Then the methods of fire risk assessment normally used in these areas are summarized and compared, showing their strengths and weaknesses.

Finally, the fire risk analyses carried out on Montemor-o-Velho, an old town in the centre of Portugal, are presented. The different methods used, the results obtained and the fire protection solutions adopted for the different areas and buildings are described.

Keywords: fire, risk, evaluation, heritage, protection.

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1 Characteristics of historic areas of Portuguese towns/cities

Historic areas in contemporary urban centres may be important for many reasons: cultural heritage, architecture styles, and special sites within them or social histories. But they may well contain buildings without any special features and even contemporary constructions. The definition of town and city has changed over history, along with their characteristics and concepts. This makes historic zones quite different from contemporary ones in many ways. The streets, the ways of constructing buildings and the types of buildings, society's needs have all evolved, and all present problems that need to be understood and addressed in this paper. The problems may be different in these areas, and common solutions must be adapted before they can be used and in some cases completely new solutions must be created.

How this can be done is described in Câmara Municipal de Guimarães [1], Coelho [2] and Gonçalves [3], with special emphasis on fire safety. The historic areas of Portuguese towns and cities have a number of problems to be solved, or at least to be thought about:

- Narrow, winding streets raise difficulties for vehicles, particularly for Fire Department vehicles carrying the equipment and the water to help extinguish the fire (fig. 1);
- Adjacent buildings with shared separating walls. Fire can thus start and propagate easily through the contact between roofs (fig. 1);
- Buildings in historic areas are residential or small businesses, such as grocery and craft shops. Dwellings are usually too small to justify some measures, but are exposed to fire risk in the same way. Shops often had another use originally, and no changes were made to adjust them to fire safety needs;

Figure 1: Narrow, winding streets, facades face to face, adjacent roofs at the same height, decrepit and contemporary buildings in the same neighbourhood. (Personal Archive.)

- Some buildings have been abandoned or/and are in a poor state of repair with combustible materials inside like wood and old furniture, and there are no plans to restore them. The chance of fire starting accidentally is quite low and there are no people to evacuate, but on the other hand, if a fire spreads to these buildings the material and dust inside can increase the fire.
- Load-bearing structures and facades with very high fire resistance, but inside the horizontal and vertical separation is combustible, which means that in a fire all the building will be exposed to it and it will not be possible to confine the fire just to one or a few compartments;
- There are too many more or less abandoned attics and basements whose access is intricate. Fire can begin very quickly and people will take time to notice it, reach the site and start to tackle the blaze;
- The buildings often have large openings. In the event of a fire with big flames, it will propagate to the upper floors via the windows and also by radiation to other buildings in front of the windows;
- Buildings' electric and gas systems often are old and have not been properly maintained. Short circuits and gas leaks may cause fires.
- As a rule there are not enough fire hydrants to tackle fires, or else they are in disrepair and the water supply sometimes has insufficient pressure;
- There are often no fire alarm or detection systems in these zones, which delays calling the fire brigade and tackling the blaze;
- The population of these areas is mostly elderly, and as such they are not prepared to react rapidly to any type of danger, including fire.
- People have no idea how to store and look after combustible materials in places without adequate access that are not cleaned. Dust encourages the spread of fire.

2 Fire risk assessment in historic areas

Risk analysis is developing all the time, especially in the context of associating high and new technology with mathematics. Risk Analysis is used in many areas and has a real potential for development.

Risk concerns the probable loss in a determined, undesired situation, the likelihood of the situation occurring and all its consequences. Fire risk analysis should therefore focus on the minimization of the risk of fire breaking out, and, if a fire does occur, the minimization of its consequences. It should consider the rapid evacuation of people from dangerous places and extinguishing the fire to prevent it propagating to other rooms and other buildings.

Although big and destructive fires dot the landscape of history fire risk analysis is particularly recent. Even so, there are now several approaches to fire risk analysis of buildings depending largely on the used methods. Towns'

historic centres are obviously their oldest zones, but fire safety measures and analysis have not been applied to them, and it is sometimes not really reasonable to apply them considering all the situations listed above that may be involved.

Check lists for the observance of regulations generally have faults and omissions relative to the fire safety measures established to protect buildings in historic areas. The regulations cannot cover every situation in these zones and even so the regulations are not always properly enforced.

Fire risk analysis methods for historic centres tend to be adaptations of the usual methods, but this does not necessarily mean that the method is suitable for the above specificities of historic centres.

Fire risk analysis may be used for construction units with more than one building. This type of concept is acceptable to historic areas, because the buildings are very close each other, without a separation wall with enough fire resistance and the adjacent roofs are with the same height. The propagation of the fire between buildings is easy.

The ranking analysis methods are used to order the situations before and after the implementation of some protective measures, comparing them with a reference value that represents the acceptable fire safety level. Constant values are attributed, to multiply each factor according its importance to the building protection or to the fire outbreak hazard and to its propagation. The parameters in these methods have to be chosen carefully, because if they are not well considered, some errors may be introduced in the calculation process. These errors are not always clear for the designer and the final result may be not correct. In case of historic areas the set of parameters to be considered is so big and complex, that this type of errors has more probability to occur [4].

Dobbernack [5] presents some fire risk ranking assessments, which indicate that the ranking methods most applicable to fire risk analysis in historic areas are:

- Risk Value Matrix Method: is the NFPA historic centre risk assessment method. This method just shows relative numbers, without any absolute result, which means that hazard and risk values within each assessment are compared. The likelihood of the event occurring and its consequences are considered. The risk takes the value of the product of fire risk value and fire hazard value. The hazard is defined for five coordinated descriptions, the fire risk for another five descriptions and these, organized into a matrix, can take 25 different values. They are compared one by one to support the decision on which combination is best, for the prevailing conditions.

- SIA 81 – the Gretener Method: is a Swiss assessment method created by Max Gretener to assess industrial buildings for insurance companies. It has been revised several times, and adapted to new situations, always focusing on the interests of the property and the insurance companies. For this reason it does not consider the need to evacuate the occupants or to protect and guarantee the activities in there. For historic centres, despite this method being widely used, buildings are generally small or partitioned and residential, so there are many factors missing from these zones that the

method normally assumes. Furthermore there are many risks attached to these buildings that are not found in large industrial buildings and which the method does not consider.

- Fire Risk Assessment Method for Engineering (F.R.A.M.E) was developed from the Gretener Method to address its failings. It can be applied to planned or existing buildings, taking into account the property protection, the people's safety and the interruption of labour activities. Like the Gretener Method, the FRAME method considers some factors that are not directly applicable to historic centres and miss others that would be important, prejudicing the buildings' risk assessment. The FRAME is more favourable to the safety of the people than the Gretener method
- Hierarchical method is a Delphi method developed by Edinburgh University. An expert group is always required to select the policy, the objectives, the strategies, the parameters and the survey items and rank them according the situation, discussing all the steps and with everybody in the group agreeing the same solutions. Each member of the Delphi group must agree with all choices.

Quantifying methods like the events tree or the faults tree are more accurate and also harder to use. They list all occurrences and all their possibilities until the fire is extinguished, either by human action or because it burns itself out. The events tree goes from the beginning of the fire until the end, looking for the stages of development and the fault tree does the opposite: if the undesired event happened which step was at fault in terms of protection? It is thus possible to evaluate many ways the fire may develop, choosing the events or faults and putting them in order.

To organise the possibilities and sequences of events/faults from some initial point, the events/faults tree takes human behaviour and the reliability of the protection systems' installation into account. This kind of assessment requires specific and accurate information, only possible with research and a database on similar situations.

To build the decision trees, a general engineering project is created to choose a solution for the fire safety objectives, proving that all objectives have been met. Essentially, this requires seven steps: choosing the initial event; identifying the fire safety sources; building the tree; ranking the consequences; estimating each possibility/probability; quantifying and ranking the consequences according to the previous step, and finally evaluating the results.

The fire risk analysis in historic centres requires the definition of a lot of details, some of them difficult to obtain, because private buildings have to be examined in the public interest. The owners must be made aware of the studies and their importance if they are going to permit the visits.

Historic centres need at least two methods to give an adequate assessment in order to make the most of the potentialities of each one and nullify their faults. If it is possible to understand how and why fires do or do not occur, a more realistic analysis can be made to back a decision on what measures should be used to protect individual buildings and the entire zone.

3 The case of Montemor-o-Velho – defining scene

To better observe and understand fire risk analysis in the historic areas of the Portugal's cities, the historic zone of Montemor-o-Velho, a town in the centre of Portugal, was chosen as a case study. Montemor-o-Velho has been developed under tourist revitalization plans, and this involves better town planning. Natural elements and historic places will gain from tourism and foster local growth. Fire risk analysis can improve the plans by introducing the notion of fire safety locally, to safeguard historic buildings and their surroundings.

The area of interest is the slope of a hill on which the town's pre-medieval castle stands. The castle is the most important tourist point of the city. Of the characteristics of Portuguese historical centres listed earlier, this hill has a difficult slope, there is a difference of over 40 meters between the top and foot, representing about 4 bars, difference in the water pressure available for fire suppression, with serious implications for fire safety.

Montemor-o-Velho's historic centre has a population of about 500, most of who were born there. They are mainly elderly people. This and other social characteristics of the population of this zone must be considered, so as to propose some preventive measures against the possibility of fire in the assessments applied, especially because some measures relate to how ready the population is to act in terms of fire prevention and suppression.

A number of businesses and facilities are located in the lower zone, along the main street. These include schools and the local health centre. Further up the hill, we find more private houses, although some businesses and dwellings were paid more attention because they might represent an extra hazard in view of the factors of difficult access, lower water pressure and more chance of any fire that occurs spreading.

The zone in question has hydrants connected to the mains water system, and in the most problematic area there are not enough hydrants to cater for a fire risk, and the diameter of the water pipes is not large enough. The mains water system was remodelled a few years ago to deactivate the castle's tank. Two hydrants from the old network are still in operation, but all the others were moved to closer points in the new system. The problem here is that neither the residents nor even some firemen do not know which hydrants are working, and which are not. The hydrants are not checked or maintained regularly, and there is no guarantee that the hydrant that is needed will work well in the event of fire.

The district's fire fighting and safety is under the responsibility of the Montemor-o-Velho Volunteer Fire Brigade, and is housed outside the perimeter of the historic centre, but only about one kilometre from any part of this zone. The Fire Department has one computerised communication centre and a 24 hour alarm system. It has four large and medium water capacity vehicles, one ladder-vehicle with a 30 meter reach for rescues, two ambulances and 2 small water capacity vehicles. These may be good resources, but since only the last two can reach most of the zone, and neither can reach some parts, this does not mean a great deal. The other vehicles can only cover the main road and the main street of the historic centre, where the water supply for fire fighting is not a problem. The

principal problem for the rescue vehicles, in most of the areas of the historic part, is the narrow streets that sometimes become narrower because some private vehicles park on them.

The zone has another big problem related to the storage of the domestic gas bottles. The area doesn't have piping gas systems and quite all houses and shops have gas bottles not safely stored. The shops do not have fire detection or alarm systems: they are old buildings that are not covered by the law either because are too small or because they are not inspected for law enforcement purposes.

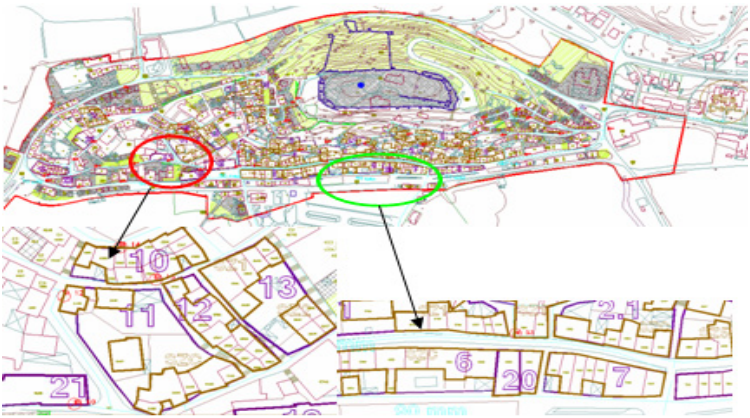

Figure 2: Montemor-o-Velho: general view with the study zones. The most critical zone marked in red and the most favourable zone marked in green.

4 The case of Montemor-o-Velho – assessments apply

The fire risk assessment methods chosen to be applied in the case of Montemor-o-Velho were the Gretener and the FRAME methods. Although these two methods are very similar with respect to their main features, this choice was intended to delimit the boundary that separates them, identifying their common and individual good and bad points, as well as trying to achieve similar solutions.

First, 21 regions were pinpointed in the historic zone, selected according to the buildings' proximity, to create uniform groups that could be dangerous perimeters in case of fire (fig. 2). Six isolated buildings were also selected, because of their size and uses. Appling the two methods to these initial assumptions revealed that the problem was more complicated. Even the more sophisticated measures for the regions could not satisfy the Gretener Method, it was worse for FRAME method. All the features of the historical centre referred above and the large areas encompassed by these perimeters made it impossible to assess some regions as safe, even if all possible measures were applied. It was therefore necessary to observe the regions more closely, one by one. They were divided into sub-regions capable of ensuring safety according to both methods,

using reasonable measures. This subdivision is a first measure to be guaranteed by having structural barriers between the buildings studied. In some regions the buildings were analysed almost individually.

The fire hazards considered by Gretener and FRAME methods depend on the content in terms of goods and the construction solutions of the building. As the buildings don't have a separation between floors, with enough fire resistance, because they are made of old timber, very dry, and there isn't a staircase, the total fire load is the summation of the fire loads of all floors related to the ground-floor. When a division between floors exists, the fire load to be considered is the one of the floor with a highest value.

In the Gretener method, the combustibility, smoke and toxicity factors were defined by the most dangerous of all uses-type/goods inside the building, occupying at least 10% of the area. If there is a use-type that occupies less than 10% of the area, but has a high fire hazard in terms of the above-mentioned parameters, the value considered for, was the medium of the values suggested in the method [6].

In FRAME method the openings area considered was 5% of the perimeter.

In terms of normal protection measures, the alternatives considered to be available are, first, people training, and then the adequate portable extinguishing systems. The interior hydrants were considered unnecessary in most cases because they are very expensive and wouldn't be used to protect more than one building. This solution was only considered in specific situations. The water transport conduits needed are always shorter than the 70 meter standard length considered by the Gretener method.

Where the mains water pipes were less than 90 mm diameter, two alternatives were assessed: changing the pipes to a 120 mm diameter set, or doubling the present system by adding another 90 mm diameter set. The second option is cheaper and achieves better safety values in both methods.

The special measures initially adopted concern the fire brigade and its action delay time. In what concerns to the fire brigade, it was considered a department with all necessary equipment and at least one 1200L water capability vehicle, at least 20 trained men in the brigade who can always be contacted by phone, and with 4 men always on duty, ready to act in relation to fires and gas leak protection, and able to leave at 5 minutes notice. The fire department of Montemor-o-Velho easily verified these exigencies.

As the entire zone is less than one kilometre in diameter the delay time for the fire department to act was always held to be less than 15 minutes. Additional special measures were only considered in some special cases and only fire detection and alarm measures can be justified in the cases studied.

The sole structural measure considered reasonable in some situations was the horizontal division of floors by elements having at least 60 or 120 minutes fire resistance.

The ignition hazard was considered generally normal, except in abandoned houses where it was considered low, and one electronics shop and a disco where it was high. People's exposure to hazard was standard, except when it was possible to have more than 30 people inside the critical compartment.

Case by case, using all measures under different combinations, it was possible to reach the property safety according both methods applied. In what concerns to the people's safety, the Gretener solutions, when using the FRAME method, were not enough to obtain the desired safety level.

The extra measures to reach the necessary safety level were applied to the zone as a whole, considering a big building and all existent buildings as compartments. Some of the measures were applied to the buildings itself (such as energy sources like lighting, heating and gas) and the others to the zone (such as hydrants, emergency signs, safety routes and safety plans).

5 Conclusions

The Gretener method is sensitive to changes in water supply and compartment conditions. Accurate information about water pressure, pipe diameter and water tank size can make difference to using this method. Another important factor in this method is whether the integrity of the compartmention can be guaranteed by means of 30 or 60 minute fire resistance elements. The Gretener method is not sensitive to the changing of the area, for certain relations between the length and the width of the fire compartment.

The FRAME method is sensitive to area changes that benefit small buildings.

In addition FRAME method can evaluate sites' continuity of activities, a point not considered here.

The properties of interior goods, in the FRAME method, are considered quantitatively, using a critical temperature, combustible dimension and combustibility rate with numerical values, contrary to Gretener method which classifies not only combustibility but also smoke and toxicity using qualitative concepts as low, medium or high, and then assumes factor values for them.

The changes in compartmention conditions with respect to structural fire resistance are not visible in the FRAME method.

To achieve people's safety in the FRAME method, at least half of all normal and safety route measures must be adopted.

Both the methods applied show a lot of deficiencies and faults for the analysis of historic centres, but they also show how important it is that some analysis is undertaken. They expose the faults that can be seen easily but need some support if they are to be remedied and also less obvious faults that are equally dangerous. The Gretener and FRAME methods complement one another for isolated buildings and small regions; for a zone the application of both is still not enough to analyse all questions involved in historic centre assessment, but if extra measures are taken, known from expertise to establish the situation as a "small region", the methods meet all expectations.

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