A Word from the Editor

All,

Four months into 2022 and here comes the first opportunity to read a number of interesting articles in our first issue of the year, another opportunity from SFPE to share knowledge among us. This is our eighth year of delivering high quality articles to all of you.

Unfortunately, the ongoing war in Ukraine is casting its shadow on most things these days, SFPE has started some initiatives in order to try to help with the situation, please read about that in the “Message from the SFPE Europe Council Chair”.

In this issue we have a widespread of different topics, some of which I considered “emerging issues” (“Green Buildings” & “Elderly at home”). There are a number of fire related topics that are closely related to climate change, ageing population, and energy. There is a need for us to start to take these topics a lot more into consideration and simply just start to work on them (read plan ahead for them). In future numbers we will always include some of these topics, fire safety is not only advanced engineering solutions to solve problem; it can also be much simpler than that. Just thinking about mass refugee camps (created due to climate change, wars, economy, etc.); when it comes to fire safety for those type of settlements we need to go back to basics to solve problems (distances between “fire loads”, construction materials, alternative escapes...basically a first principles approach), a new advanced detection algorithm for a fire detector won’t solve the problems we encounter for these situations.

SFPE is not only there for our fire safety engineers working on the projects, we need to expand beyond that mindset and also look into where else we can make a difference (SFPE’s mission is to define, develop, and advance the use of engineering best practices; expand the scientific and technical knowledge base; and educate the global fire safety community, in order to reduce fire risk) these “emerging issues” will sooner or later become part of our fire safety engineering projects.

If there are readers out there that feel that you have an important subject that you would like to share with the industry do not hesitate to contact us, we can make that happen.

As always, a great thanks to the people who have put in a lot of time and effort to make this issue a reality. The next issue will come in July.

Yours sincerely,

Jimmy Jönsson, Managing Editor
A Message from the SFPE Europe Council Chair

Dear SFPE Europe members,

everyone was looking forward to the end of the Corona pandemic! All over Europe covid measures are being reduced step by step. In Switzerland, for example, all measures have been dropped since the beginning of April. However, the return to "normal" life was not to be! The war in Ukraine shocked not only us in Europe, but also the rest of the world. At our SFPE Europe General Assembly in early March 2022, our Polish chapter gave us an insight into the situation they are currently experiencing in Poland regarding the war in Ukraine. It was very touching to hear what is happening there and how everyone is trying to help. Since it was clear after a few weeks that this conflict would continue for an extended time, SFPE Europe together with SFPE decided that we could also do something. For this reason, we have set up our own website www.sfpe.org/ukraine where you can find information on how to provide support. We are also in the process of contacting fire safety associations in Ukraine to see if we can help other professionals by finding them jobs in European countries. They deserve our support!

In SFPE Europe itself we had the pleasure of welcoming 2 new European chapters during our General Assembly in March: Finland and Malta. With these two new chapters, we now have a total of 19 chapters and 5 student chapters in Europe.

In November 2021, SFPE Europe applied to become a CEN liaison organization. We were very positively surprised to be able to sign the Agreement of Liaison for the following 3 TCs already in March 2022: TC 127 - Fire Safety / TC 191 - Fixed Firefighting Systems / TC 250 - Eurocodes. The application to join the 4th TC - 156 Smoke Control - is pending.

In March (it was really a very busy month) the virtual 14th SFPE International Performance-Based Codes and Fire Safety Design Methods Conference took place. We had a very good program with many high calibre speakers on a variety of interesting topics. With over 200 participants from more than 30 different countries, the conference was a great success.

Looking ahead to London on 16 May 2022, we will have a great program around the SFPE Europe General Assembly. We will start with a Chapter Leadership Forum, followed by the Ordinary General Assembly Meeting and finish with a very British evening program!

We have also launched an SFPE Europe News Brief. This is a bi-monthly supplement to the SFPE Europe digital magazine, featuring industry news, SFPE updates and activities from SFPE chapters across Europe: https://multibriefs.com/briefs/SFPE-Europe/ Enjoy reading!
Let me conclude where I started: SFPE and SFPE Europe are united with the people of Ukraine. The strength and resilience of the Ukrainian people is an inspiration to others around the world, and our hearts go out to all those affected. The Ukrainian people and all those living in conflict areas need to know: Nobody is forgotten - nothing is forgotten!

Enjoy a peaceful Spring
David Grossmann SFPE Europe Council Chair 2022
Green Buildings: Sustainability Successes Challenge Fire Resiliency

By: Victoria Hutchison, Fire Protection Research Foundation

Over the last decade “going green” has become increasingly mainstream. In an effort to use less energy, save resources, and reduce pollution and waste, we now embrace alternative energy, support energy efficiency, and practice recycling. But it’s important to recognize that going green isn’t just about electric cars, solar panels or battery energy storage, it’s also about buildings, as structures are significant consumers of energy.

While the world’s cities occupy just 3 percent of the Earth’s land, they account for 60-80 percent of energy consumption, 70 percent of global carbon emissions and over 60 percent of resource use, per the UN Environmental Programme Emissions Gap Report. Rapid urbanization is exerting pressure on our supply of global resources, driving the need for buildings to be more sustainable, energy efficient, and resilient to fire and other disasters.

In response to societal objectives, there has been substantial global investment in clean energy and energy efficiency, which drives new innovations, including development of green and sustainable products and systems. As a result of this dramatic investment, these systems and materials are proliferating at an exponential pace. ‘Green’ building materials, systems and features, collectively referred to as the “attributes” of a building, range from interior and exterior materials, systems and facades to alternative energy sources or electrification of infrastructure on-site. A recent study by the Fire Protection Research Foundation (FPRF) on the fire safety challenges of green buildings and attributes identified over 100 ‘green’ attributes that are being incorporated into modern building designs or sites.

‘Green’ building designs are fundamentally rooted in environmental, economic, and social sustainability, but aren’t necessarily focused on fire resiliency. The FPRF study found that while fire hazards and risks of ‘green’ buildings and attributes have been addressed in many regards, fire safety is still considered relatively late in the design process. If it is considered, these efforts don’t always carry through to the operational phase of a building. And there are clear fire safety implications, as a result.

Over the last decade, there have been several major fire events, which involved ‘green’ building features or technologies, notably the Grenfell Tower fire in London (combustible insulation), the Dietz & Watson cold storage warehouse in Delanco, New Jersey (photovoltaic panels, combustible insulation), and a plethora of fires in buildings under construction using lightweight timber framing.
These fire incidents indicate that the adoption of such systems can sometimes have unexpected consequences when safety considerations are not considered early in the development phase or where unexpected combinations of materials are used to create and install systems outside of the original specifications. Having fire safety take a back seat to other performance parameters in buildings is nothing new—fire safety often seems to be playing catch-up with developments occurring in the construction industry. Even when fire safety professionals are aware of a potential problem, a catastrophic incident often occurs before the issue starts to be addressed holistically. But this is no longer acceptable. Fire safety must move in lockstep with sustainability and be given due diligence up-front in the design process to avoid potential roadblocks in sustainable building.

Key fire safety challenges with emerging ‘green’ building trends are summarized below.

**Structural Materials & Systems**

In the 1980’s, the concept of lightweight construction materials was introduced as a green alternative to traditional building materials and a way to reduce consumption of raw materials. Since then, a vast array of materials and engineered solutions have been introduced, such as lightweight engineered lumber, fiber-reinforced polymer (RFP) elements, plastic lumber, bio-polymer lumber, bamboo, mass timber (e.g., cross laminated timber), among others. However, in comparison to traditional building materials, they present a heightened fire risk. They can contribute to the fuel load, burn readily once ignited, and increase the heat release rate. These lightweight structural materials and systems also introduce the potential for reduced time to failure, along with concerns of stability, flame spread, and adequate fire department access. Further, materials such as mass timber, e.g., CLT, can delaminate, further contributing to the fuel load and structural integrity issues. Additive manufacturing/3D printing technology has been applied to building applications where it is hoped that savings may be made in manufacturing costs or in building construction sustainability by reducing waste and material production emissions and life-safety at construction sites. However, it presents performance trade-offs when compared to traditional building materials, as it can fail more quickly, present stability issues and challenge egress and fire service response. For most of these materials and systems, utilizing approved or listed materials and incorporating fire resistive barriers where appropriate are significant steps in the direction of safety.

**Exterior materials, systems, and façade features.**
To facilitate energy conservation, green buildings often include interior or exterior insulation. Various types exist, such as fiber-reinforced polymer (FRP), rigid foam, spray-applied foam, structural integrated panels (SIP), or exterior insulation and finish systems (EIFS). These insulating materials are attractive from an energy conservation perspective as they are lightweight and composed of recycled plastics and have a high thermal resistance. However, if non-approved materials are used, adequate protection and barriers are not in place, or if the insulation materials are not properly constructed, some insulation materials can present a high fire risk if left unmitigated. This can result in fast fire spread, increased burn intensity and the generation of toxic products of combustion.

On February 9, 2009, a fire at China Central Television headquarters in Beijing demonstrated how nonapproved extruded plastic insulation panels behind curtain walls could fuel and quickly spread the blaze through the entire building. Data also shows that some metal class materials (MCM) used for exterior cladding has contributed to reduced fire safety in some cases, fueling the fire. The Grenfell tower fire in 2017 brought concern of combustible exterior walls and cladding systems to the forefront, as it prevented the egress of over 70 people.

It should also be noted that while the well-insulated nature of these structures is a clear attribute for energy efficiency, under fire conditions these structures also retain the heat from the fire, accelerating the time to reach flashover, further challenging fire service response. Standardized fire tests and adoption and enforcement of codes and standards can play an important role in helping ensure the use of appropriate materials and proper installation and arrangement of these systems.

**Alternative Energy Systems**

**Photovoltaic (PV) systems** are a commonly used green technology to generate electrical power, where the PV module can generate direct current from the sun’s energy and convert it into alternating current. However, PV systems can contribute to the fuel load, present an ignition and shock hazard. Research indicates some indication that for roof-mounted solar panels, the space between the roof and the installation can create flue-like conditions accelerating the spread of flame. In this case, the size of the space and angle of incline are important parameters to identify the fire risk.

**Battery Energy Storage Systems (ESS)** are another critical element of today’s dramatic push for sustainable and renewable electrical energy, as they provide a means of storing energy produced via other renewable energy sources. Since 2018, there have been over 40 incidents in large-scale lithium-ion battery energy storage sites,
globally, that involved some failure resulting in fire or explosion. Incidents in 2021 impacted a combined capacity of over 1.7 GWh. While a variety of battery technologies are used, lithium-ion is a dominant technology at this time, which presents unique challenges from a fire and explosion perspective. While substantial research on-going, there are still many unknowns and challenges with respect to li-ion battery ESS. From controlling or stopping thermal runaway, to finding an effective suppression solution and mitigating the explosion hazard, to establishing proper fire fighter response tactics to ESS incidents, to decommissioning and dealing with the stranded energy hazards.

At the site. Increasing density is one approach to sustainable development. But with increased densification comes the need for alternative modes of transport for city mobility, such as car-sharing, dockless electric bikes and electric scooters. For these alternative options, ownership of the transport vehicle no longer belongs to the user, thus, dockless e-bikes or e-scooters can be available anywhere in a city and are dropped off at the user’s destination. As a result, the presence and charging lithium-ion batteries for electric mobility (e.g., electric vehicles, electric bikes, and electric scooters) become an increasingly present hazard at residential and commercial sites. For example, e-scooters and e-bikes sparked 330 fires in the U.S. from 2015 to 2018, causing more than $9 million in property damage, according to the Consumer Products Safety Commission (CPSC). In 2020, New York City had 44 scooter fires that resulted in 23 injuries; the number of fires doubled in 2021.

Another serious concern is if local restrictions or conditions, such as a drought, restrict the available water supply at the site or facility. This may present a high hazard with respect to not having an adequate water supply for fire suppression activities. To mitigate this potential hazard prior to an unforeseeable incident, emergency response planning with the local jurisdiction should be conducted. The impacts of climate change and limited water supplies on fire protection systems is currently being studied by the SFPE Foundation.

Conclusion
With these representative challenges in mind, risk and performance considerations should be included in overall assessments of whether structures meet design criteria across all societal dimensions so that ‘safer’ solutions for buildings, fire service personnel, and the community are ultimately achieved. To attain our desired future of safe and sustainable buildings, we must focus on how to obtain our sustainability objectives with fire resilient strategies.

References

<table>
<thead>
<tr>
<th>Site</th>
<th>Reduced Water Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permeable concrete systems</td>
<td>Hydrogen infrastructure</td>
</tr>
<tr>
<td>Permeable asphalt paving/pavers</td>
<td>Community changing stations</td>
</tr>
<tr>
<td>Extent (area) of lawn</td>
<td>EES fuel loads/hazards</td>
</tr>
<tr>
<td>Water catchment / features</td>
<td>EV fuel load/hazards/chargers</td>
</tr>
<tr>
<td>Vegetation for shading</td>
<td>Propane vehicle hazards</td>
</tr>
<tr>
<td>Building orientation</td>
<td>Fuel-cell vehicle hazards</td>
</tr>
<tr>
<td>Increased building density</td>
<td>Bicycle storage impact exits</td>
</tr>
<tr>
<td>Localized energy production</td>
<td>Reduced FD apparatus access</td>
</tr>
<tr>
<td>Localized water treatment</td>
<td>Densification / fire spread</td>
</tr>
<tr>
<td>Localized waste treatment</td>
<td>EV chargers on building exterior</td>
</tr>
</tbody>
</table>
Egressibility – Accessible Fire Evacuation for All

By: Erik Smedberg\textsuperscript{a}, Enrico Ronchi\textsuperscript{a}, Gunilla Carlsson\textsuperscript{b}, Giedre Gefenaite\textsuperscript{b}, Steven M. Schmidt\textsuperscript{b}, Björn Slaug\textsuperscript{b}

\textsuperscript{a}Division of Fire Safety Engineering, Lund University, Sweden
\textsuperscript{b}Department of Health Sciences, Lund University, Sweden

Most evacuation strategies rely on the abilities of occupants to self-evacuate. Decreasing functional capacity, which often overlaps with older age, leads to decreased ability to self-evacuate in case of fire. That is unless the building is designed to accommodate the needs of people with lower functional capacity. Functional capacity refers to the abilities to perform fundamental everyday activities such as seeing, hearing, moving around, etc., while a decrease in functional capacity is referred to as a functional limitation.

Through the years, accessibility to the built environment has increased, and accessibility is now seen as an integral part of building design. Increased accessibility means that now more than ever, the functional capacity of the people occupying and using public buildings worldwide has become much more diverse. Furthermore, globally the population is ageing, inevitably leading to higher prevalence of people living with functional limitations.

Research on fire safety and accessibility has often focused primarily on challenges related to the needs of people who use wheelchairs [1]. However, functional capacity can be limited across many other domains of human functioning, such as cognition, vision, and hearing. Moreover, functional limitations can be viewed as a continuum [2], meaning that people with a specific functional limitation may experience very diverse challenges.

To highlight the specific challenges for evacuation design related to people with functional limitations, the term ‘egressibility’ has been proposed [3]. The term in itself mirrors the term of accessibility but puts the emphasis on the environments and activities relevant for evacuation. It is argued that egressibility should not only focus on measuring the evacuation capabilities of people with functional limitations but should also (or primarily) focus on making the design of the environment usable and safe for people with diverse abilities. In accessibility research, a useful model to understand issues of accessibility is the person-environment fit model [4]. This model can be applied to egressibility as well. The model describes the interaction between functional capacity and the demands from the environment. In general terms, higher functional capacity means that you can withstand higher environmental demands, whereas people with lower functional capacity might have issues to self-evacuate when the environmental demands are high. For example, a stair poses
demands on people for them to make use of it. In some cases, the functional capacity is too low to manage the demands. If a person uses a wheelchair, the stair is referred to as an environmental barrier in that the demands set forward are too high to overcome. A schematic representation of the interaction between functional capacity and environmental demands is presented in Figure 1. These concepts have been used to systematically link functional limitations and the activities needed for evacuation using the International Classification of Functioning, Disability and Health by the World Health Organization [5].

![Figure 1: Schematic representation of egressibility for persons with mobility limitation. This includes the interaction between the personal and environmental components. The red area indicates when there is a mismatch between functional capacity and environmental demands, meaning that self-evacuation is difficult.](image)

Recently, a new European standard (EN-17210:2021, *Accessibility and usability of the built environment - Functional requirements*) was published which incorporates fire safety as a part of accessibility. The standard highlights already known important aspects related to egressibility, but knowledge relating to accessible evacuation for all is still lacking.

A necessary step to improve egressibility involves investigating the perspectives of people with functional limitations on egressibility. In a recent study [6] interviews were conducted with older people with functional limitations in Sweden to develop an understanding of their perspectives on evacuation opportunities and related aspects of accessibility. Although the study participants did not have first-hand experiences of evacuation situations (or at least not at their current functional capacity), parallels to accessibility were often drawn. Experiences of inaccessibility may very well influence how a person with functional limitations conceives an evacuation situation. Prior to the interviews, the participants were asked to fill in a questionnaire regarding functional limitations. Among the participants, hearing impairments and functional limitations related to movement were most common.

The interview covered topics such as accessibility, egressibility, evacuation, assistance from other, and risk perception. Using a qualitative analysis method, three themes representing patterned meaning were generated from the interview answers.

**Theme 1: Other people’s difficulties in understanding**
While most of us recognize that others may have different functional capacities, it can be difficult to understand the challenges that others face. In several interviews, we found that people with functional limitations described situations where others may have tried to help but did not know how. One example was given by an older gentleman in a wheelchair, where others sometimes tried to hold doors or gates open for him, but instead blocked his passage so that he could not get through. The same man also told that he perceived that others showed more consideration towards him when he used his wheelchair compared to when he used a cane. It can be concluded that in evacuation situations, people sometimes rely on assistance from others. In those cases, it is imperative to know who might need assistance, and also how assistance is best afforded.

**Theme 2: Strategies to cope with the limitation**

People with functional limitations regularly face challenges while interacting with the environment, and they develop and use coping strategies to better navigate such interactions. Some strategies include making use of other senses if one is impaired. For example, people with hearing impairments stated that they may look at others to be informed of an emergency. A person who was blind said that he regularly used sounds and smells to orient himself. In the uncertain event of an evacuation however, many participants stated that they may have an ability to ‘push through’ or go beyond their normal abilities in order to evacuate. This could for example mean that a person in a wheelchair may decide to try to crawl down a staircase, or that a person who experiences pain in walking longer distances could do so if it was urgently necessary. It is however important to recognize that ‘pushing through’ is not always possible and may in some cases lead to serious adverse effects.

**Theme 3: Uncertainty of evacuation**

Most participants had never experienced an evacuation, especially not at their current functional capacity. This of course leads to a lot of uncertainty for people with functional limitations regarding how an evacuation situation may look, possible reactions, and how others will react. Many participants stated that they did not worry about evacuation, stating that they were not the kind of person being worried in general. Despite this, many participants saw themselves as more vulnerable to fires due to their age and functional limitations. Nonetheless, many participants were uncertain whether or not people around them would provide assistance during an evacuation, and that it may be difficult for them to evacuate if needed.

**Conclusions**

In summary, the results from the interview study showed that older people with functional limitations may be uncertain about whether the built environment and people around them would be supportive in case of evacuation. Instead, many would rely on their own ability to overcome challenges during an emergency. These findings highlight two important aspects to consider in fire evacuation design. Firstly, the design of the built environment should accommodate the evacuation needs of our increasingly diverse population to the extent that people can have confidence in their possibilities to self-evacuate, regardless of functional limitations. This paradigm shift is needed to ensure equal access to egress in public buildings, as merely relying on assisted evacuation procedures is not in line with current accessibility policies aimed at participation, regardless of functional limitations. Secondly, the strategies adopted by people with functional limitations to overcome daily challenges should be identified, considered, and incorporated in fire evacuation design. The current over-generalization concerning the needs of people with functional limitations should be substituted by a careful scrutiny of the individual challenges linked to the type of functional limitation(s) and an assessment of the associated consequences on fire evacuation.
Further information can be found in the Fire Safety Journal scientific article presenting the results of this interview study [6].

References
Elderly at Home and Fire Safety: The Spanish Case

By: María Fernández-Vigil, School of Architecture, University of Navarra, Spain
Juan B. Echeverría Trueva, School of Architecture, University of Navarra, Spain

This is a short version of the article published in Fire Technology “Elderly at Home: A Case for the Systematic Collection and Analysis of Fire Statistics in Spain”

The use of a homogeneous and regulated system for the collection of fire data has demonstrated to be an essential tool to understand the fire problem and the identification of the key risk factors underlying major accidents. Several countries, such as the US, UK, New Zealand, Australia or Japan, have already developed a systematic collection of fire incident data [1–5].

In Spain, 77% of fatal fires from 2010 to 2016 were residential fires, and 60.1% of fatal victims were people over 65 years old [6–11]. Unfortunately, there is not a comprehensive national fire incident which allows the identification of the risk factors for residential fires in dwellings occupied by elderly people, and previous research is sparse and incomplete.

Therefore, the first step for the characterization of the fire problem, and specifically residential fires involving elderly people, is necessarily the creation and assessment of a fire database.

1. Current Situation in Spain

At the present time, there is no nation-wide, systematic approach to collecting, analyzing and presenting fire loss data in Spain. The statistic treatment of the fire departments interventions in Spain is poorly regulated, and it does not have homogeneity: since 1994, official statistics have not been published. Currently in Spain, the only existent documents about fire victims are those annually published by Mapfre Foundation in collaboration with “Asociación Profesional de Técnicos de Bomberos”1 (APTB) since 2010 [6–12]. These reports show information about fatal victims in structural fires and are developed from data detailed by fire departments, who voluntarily fill out a form answering some questions.

---

1 Asociación Profesional de Técnicos de Bomberos, APTB, could be translated as “Professional Association of Firefighters”
However, researchers do not have access to the original database used for the development of the reports, which prevent the analysis of the key risk factors for specific population groups. Through a new database, it will be possible to collect incident data of all residential fire incidents, injured victims and deaths and to link the collected parameters and the age of the victim.

2. Justification of the research

The focus on the elderly population is necessary considering the Spanish demographic predictions: the Spanish National Statistical Office (Instituto Nacional de Estadística, INE) estimates that by 2064 adults aged 65 or older will comprise 38.7 percent of Spain; that is, they will be more than the third part of the Spanish population.

In addition, previous analysis of fire data indicated that there are certain groups, such as the elderly, that have a higher risk of mortality per residential fire [13]. The reasons why elderly people are more vulnerable in a fire than the general population have been investigated in different countries [14–21], and are related to several factors such as: the decline in physical health [3, 14, 22–24]; the onset of some mental illness [15]; their vulnerability to burn injuries [16]; the prevalence of a low socio-economic status and pre-existing diseases; the use of old and under-standard electric appliances [18]; the social isolation; or the necessity of heating the household for more hours per day [25].

The combination of all these circumstances makes the elderly people a vulnerable group in case of fire.

3. Methodology

As first steps to overcome the lack of a nationally populated and managed fire incident database, a methodology for collecting fire data based on information extracted from the media was developed. For the development of the database, the tool MyNews Hemeroteca [26] was used, and the search was done with two keywords: “Fire, dwelling”. The collected data included variables about fire incidents, injured victims and fatal victims in residential fires in Spain in 2016. The results of the statistical analysis were used to assess fire risk to the elderly population living in their dwellings.

4. Results and discussion

4.1. Overall trends

Home fires cause more than three out of four fire deaths in that type of accidents [7–12]. This means that dwellings are the most common place where fatal fires happen, far away from the next one, exterior fires, which account for 12% of deaths.

Residential fires are also the main scenario where casualties occur in other countries, such as the US, the UK, China, New Zealand or Sweden [4, 25, 27–31]. However, these events are not distributed evenly through society, but there are certain sectors that experience disproportionate numbers of incidents.
Fire death rates per million population (pmp) have fallen 48% since 1980. However, this descending trend suffered a turning point in 2013, and since then the number of fatalities has increased by 61% (Figure 1). The first quarter of 2019 closed as the worst since Fundación Mapfre prepares these reports [32].

4.2 Age and gender

In 2016, home fires killed 80 people 65 or older. While this age group accounted for only 18.9% of the general population [33], they accounted for 60.6% of fire deaths. This means that adults 65 and over were 3.2 times as likely as the general population to die in fires and for those individuals aged 85 or older, the risk was 8.5 times as high.

Males have a higher risk of fire death and injury in home structure fires, in all age groups. Although Spanish Statistics Office (INE) figures show that 51% of the population is female [33], 58% of fatal home fire victims in 2016 were male.

Therefore, as it happens in other countries, the group that experiences the highest risk of fatal fire is men over 65 years-old, and it increases with age [14, 15, 37–40, 16, 19, 29–31, 34–36].

4.3 Fatal Fire Profile: Average Income in the location, age of the building, month, and leading causes

Almost 60% of injuries and 70% of deaths were in locations where the gross income was lower than the national average. In 2016, the risk was multiplied by 2.7 for people living in locations with the lowest incomes in Spain.

That year, homes built in the last 5 years had a low risk of being the origin of a fire with victims, and those with more than 45 years had higher risk of both deaths and injuries (Figure 2).
Figure 2: Relative Risk of home fire deaths by the antiquity of the building, 2016. Sources: Media database and INE [33].

Figure 3 shows that winter is the season with the highest percentage of deaths, while there is an important decrease of victims during summer, especially fatalities.

During 2016, the main cause of home fire deaths was heating equipment (fixed or portable space heaters). The second leading cause was electrical distribution and lighting equipment, followed by smoking materials and, in the fourth position, fireplaces (Figure 4). It could be affirmed that the risk of fire death or injury in the event of fire varies considerably by fire cause.

More than one-third (39%) of the older adult victims died in fires started by heating equipment, and they accounted for 71% of fatal victims in this type of fires.
The influence that lower incomes have in the risk of home fire has been widely studied [3, 4, 42–45, 15, 22, 25, 29, 30, 35, 38, 41]. Deprivation in basic needs, as well as living on fixed income –a typical situation among elderly people- usually lead to a bad state of the dwelling, especially if it is old, since the necessary home arrangements cannot be afforded. In addition, some studies suggests that poverty may be related to a low educational level [14, 25], which can interfere with an older adult’s ability to understand the details regarding fire prevention and safety.

During the coldest months, the influence of low incomes and the antiquity of the building create a typical scenario of fatal home fires in Spain: if the central heating source of the dwelling does not work properly, the occupants cannot afford the cost of it or even it does not exist; people use to rely on temporary sources of heat, such as portable space heaters or fireplaces, to keep their homes warm. This situation makes heating systems the first cause of home fire deaths in Spain, representing an elevated fire danger to older adults.

However, in other countries such as the US, Sweden, Australia, or the UK the first cause are smoking materials [14, 16, 19, 25, 29, 34, 36, 38, 43].

### 4.4 Victim’s factor

During 2016, being asleep was a factor in, at least, 28% of the home fire deaths. More than one out of four of those killed had a physical or mental disability, 85% of them were over 65 years-old. The most frequent disability was low mobility: two thirds of fatal elderly victims were mobility impaired. 48% of the fatal victims were vulnerable people (elderly, children or disabled) who were unattended or unsupervised when the fire started, and almost one half were alone at home.
Results about the role played by disabilities in the fatality of a fire are consistent with different studies [14, 15, 46, 16, 19, 22, 29–31, 34, 35]. In fact, the presence of people with disabilities may affect the evacuation dynamics of the building [24] and it is expected that total evacuation times will increase as populations age [23], since they will be more likely to experiment physical or cognitive changes that can reduce their abilities to prevent, detect, or respond to fires.

Moreover, many older adults suffer mobility impairments, which make their ability to successfully escape from fires more difficult, particularly when combined with living alone. Some studies demonstrate that substance-induced impairments, such as those caused by the side effects of prescription medication, can result in a wide range of impairments that increase older adults’ risks of fire, fire fatality, and fire injury [14, 34].

The combination of all these factors is very frequent in elderly people living in their own dwelling, making them a frail group in case of fire, without appropriate safety or evacuation measures.

5. Conclusions

This research is focused on the identification of the key risk factors for fires in dwellings occupied by elderly people. Most fatal fires have their origin in residential buildings; with elderly people being the most vulnerable group. Although the death and injuries rates per million population in Spain is much lower than the rates in other countries [47], the number of fire fatalities among the elderly is not decreasing, it is even increasing for those adults over 85 years-old [6–11]. In addition, this group is also increasing day by day [33], so we can expect that the number of fires continue growing in Spain.

The present research confirms, as several studies did before [14, 34], that elderly fatalities differ from general population fatalities in fire. These differences may suggest that preventive strategies for the elderly population require a different emphasis from those for younger people [16, 34, 37]. In addition, there are some factors that are different in Spain than in other countries which have more experience in the fire statistical work. Both reasons support the importance of fire data collection and analysis, as an essential task to understand how home fire incidents are and the consequent development of efficient fire safety measures and Building Codes and Regulations, which will lead the reduction of casualties.

6. References

32. Fundación Mapfre; APTB (2019) Estudio de víctimas de incendios en España en 2018
Review of the literature. Fire Technology 35:7–34


46. Ahrens M (2014) Physical Disability as a factor in home fire deaths. Quincy, MA

By: Dennis Pau and Matthew Hughes, University of Canterbury, New Zealand

**Introduction**

Cultural heritage buildings have great significance to a society as these buildings convey invaluable culture and historic information to the communities [1]. The current building design and construction practice typically focuses on delivering buildings with optimized functionality, cost and aesthetic [2]. However, for cultural heritage buildings, the aesthetic will often have greater importance over the functionality and cost, as the building fabrics, which is inherent to the building’s cultural heritage status need to be retained. The challenge in fire safety engineering design of cultural heritage buildings is to retain these intrinsic building fabrics while also achieving a societally acceptable level of fire safety. Typically, the minimums include (1) ensuring life safety, (2) protecting neighboring properties and (3) facilitating firefighting operations. The unconventional or traditional constructions frequently manifested throughout cultural heritage buildings present some challenging considerations for designers. In place of modern non-combustible linings, such as steel, concrete and plasterboard systems, cultural heritage buildings contain exposed timber, arts, and crafts, which are combustible, and could cover an extensive portion of the walls and underside of floors. The fire performance of these combustibles is often unknown, and fire-retardant treatments which do not interfere with the cultural heritage values of the materials are also limited. Cultural heritage buildings could also contain unique geometries, which reduce the effectiveness of fire protection systems, e.g., large concealed attic spaces, steep sloped ceiling or roof, etc.

Recently, a number of high-profile cultural heritage fires on the global stage provide a timely reminder of the significance of these buildings, and also the necessity to ensure these are protected feasibly to prevent unwanted losses. In 2019, Notre-Dame de Paris suffered a fire, which destroyed the spire and ‘forest’ oak roof beams supporting the lead roof [3]. National Museum of Brazil suffered a fire in 2018, which resulted in damages to 90 % of the artifacts housed within the building, totaling 18 million items which include Ancient Egypt, Mediterranean Cultures and a number of indigenous archaeologies [4]. These fires not only damaged the buildings and contents but also caused environmental contamination, e.g., due to lead in the case of Notre-Dame de Paris, and emotional trauma to the global community. Fire Protection Engineering magazine, #92 released in Q4 of 2021 [5], presented a number of good discussions around the subject of fire safety design, fire protection, and refurbishment of cultural heritage buildings. The separate authors, Kilby, Millar, Esposito and Ivison highlighted the wide range of fire risks relating to historic buildings with mixed uses or changing use over time, which must be considered adequately in conjunction with the
building itself. It is also vital for fire safety design of cultural heritage buildings to achieve a societally accepted balance between fire safety, heritage aesthetic and building functionality. The authors, particularly Millar, discussed the development of cultural heritage fire safety design through (1) gathering knowledge on the building through detailed inspections, (2) uncovering and addressing design incompatibilities via a collective design team effort, (3) application of design strategies beyond the building code minimum, and utilizing expert knowledge to manage the fire risks from design – construction – end users, including having indepth understanding of the design intent, and (4) consideration of the longevity and serviceability of the implemented fire protection systems.

A similar philosophy is also adopted when developing research involving the fire safety of cultural heritage buildings, (1) comprehend the cultural heritage significance through consultation with the stakeholders involved, (2) clearly review the fire risks and the risk tolerance in relation to the buildings, and (3) develop tailored research objectives and strategies accordingly. This short article provides some background on cultural heritage buildings unique to New Zealand (NZ), and the research opportunities to enhance cultural heritage fire safety. The aforementioned challenges posed by cultural heritage buildings including fire performance and effectiveness of fire protection systems, show the necessity to continue educating the wider public and to utilize cutting-edge research to progress the current fire safety knowledge frontier.

**Past Cultural Heritage Fires in New Zealand**

Cultural heritage buildings in NZ comprise English architectures, e.g., Jacobean, Georgian, Victorian and Edwardian or fusion with other European architectures, and the traditional or modern Māori architectures such as found on marae. Marae are complexes of buildings and open areas that are the traditional center of Māori social life, and are ritually performative spaces that host multiple cultural and religious activities including pōwhiri (welcome ceremonies), community meetings to discuss tribal and political issues, dining, sleeping, crafts, education, and tangihanga (funeral rites) [6]. In terms of structures, the most important building is the wharenui (meeting house – literally "big house"), also known as the tipuna whare (ancestral house), a marae focal point in which most of the aforementioned activities occur. For many traditional wharenui, the building structure is representative of the body of a founding ancestor of the tribe or subtribe, and is therefore imbued with deep spiritual significance. The consumption of food is forbidden in the wharenui, and preparation and consumption of meals occurs in a separate dining hall (whare kai). The whare kai is another essential structure, as sharing of food is deemed vital to concluding ritual activities that occur within the wharenui. Many rural and urban marae, since the 19th century and through the 20th century, have incorporated buildings with English architectures. Over the last century, especially in rural areas, marae have experienced underinvestment in structural upkeep and infrastructure services [7]. Although in recent years, investment has resulted in some wharenui, whare kai and other structures to be built with traditional architectural elements, utilizing modern materials. Currently, there are approximately 800 tribal marae throughout NZ, with a mix of traditional and English architectures.

This section presents some unwanted fires suffered by NZ cultural heritage buildings in the past, which resulted in significant or irreparable property loss. Note that these are some recent examples only, and is not an exhaustive list.

**Exemplar fires involving European architectures:**

- Antonio Hall [8] built between 1904 and 1909 as seen in Figure 1(a), became derelict after the 2011 Christchurch Earthquake. The building suffered two arson fires in 2019 and 2021, refer to Figure 1(b), and likely to be irreparable [9].
• Recognized as one of world’s largest timber houses, located in Christchurch, McLean’s Mansion [10] was constructed in 1900. The unoccupied building suffered a suspicious fire in 2020 which was successfully contained and suppressed due to fire service intervention [11].
• Unlike the two prior examples, Te Kiteroa homestead [12] in Waimate also known as ‘The Grand Ol’Lady On The Hill’ was built in 1913 and cared for throughout its life. The building was destroyed by an electrical fire in 2021.
• Similarly, St. Andrew’s Church [13] located in Whareama, was completed around 1904. In 2021 while still actively being use for religious activities, the free-access building suffered a fire resulting in complete loss.

Exemplar fires involving traditional Māori architectures:
• Taumata o Te Rā Marae [14] in Halcombe suffered a fire in 2011, which damaged the kitchen and dining hall of the marae [15]. It was reported that the firefighting operation also faced challenges due to limited water supply [16].
• Mana Ariki Marae [17] with strong spiritual connection to Taumarunui community, suffered two separate fires in 2014 [18] and 2017 [19], which destroyed a few buildings on site.
• Mōkai Marae [20] in Taupo suffered a complete loss to its dining hall during a tangi (traditional funeral rite) due to fire in 2015 [21]. Similar to the marae in Halcombe, the firefighting operation faced challenges due to lack of water supply.
• More recently, in 2019, heritage listed Tapu Te Ranga Marae [22] located in Wellington, suffered a complete loss as a result of accidental fire, refer to Figure 2. The fire was started by ember from a brazier located 15 m away from the building [23].

Overall, the examples provided here highlight the increased fire risks associated with derelict, frequently unoccupied or low security, free-access cultural heritage buildings. These fires also reflect the importance of timely and effective fire service intervention to limit property damage, which has
been particularly detrimental to maraes located in areas with limited firefighting water resources. Lastly, some of the examples were equipped with detection systems to provide early warning for occupants, but all were lacking sprinkler protection which is capable of limiting the extent of property damage.

Opportunities for Cultural Heritage Fire Safety Research

The fire protection of NZ European architectures needs to remain sympathetic to the building’s heritage fabrics, and some modern fire protection strategies adopted globally have achieved that. Some examples include accommodating the exposed heritage timber and utilising recessed or concealed sprinkler heads across heritage feature ceiling. Similarly, for Māori architectures, sympathetic consideration of the cultural fabrics is the impetus. Knowledge about the cultural heritage significance of the local iwi (tribe) and also adjustment to modern fire protection strategies will be necessary, to achieve this objective. Both global and local challenges on cultural heritage fire safety have presented a few research opportunities to prevent and mitigate unreasonable fire losses. First of all, a strong understanding of the cultural heritage significance established through meaningful community engagement, along with literature review, survey and statistical analysis, is paramount to ensure research outcomes will benefit the cultural heritage buildings and communities. Co-creative research on seismic retrofitting of wharenui provides an example of providing methods and solutions that integrate traditional architectures and modern safety features [25].

Cultural heritage fabrics such as exposed timber, arts, and crafts manifest the uniqueness of the buildings but also tend to exacerbate the spread and severity of fires. Naturally, experimental investigation is needed to form a good understanding of the combustion behavior of the expected fuels and the subsequent compartment fire dynamics. Previously, Duncan et al. have conducted small- and full-scale experiments to investigate the burning behavior of Māori cultural fabrics [26]. Multi-scale experimental investigation as such could help in the development of sympathetic fire protection strategies for the cultural heritage fabrics. These strategies include fire retardant treatments or fire breaks incorporated within feature walls or ceiling to limit fire spread, or specially designed fire suppression systems to enhance life safety and owner’s property protection where firefighting water supply is scarce. The application of numerical fire models supported by these experimental findings could also be a cost-effective means of assessing the feasibility of different fire safety solutions on larger building-scale scenarios. The feasibility of integrating or retrofitting these strategies into traditional marae structures will need to be explored in co-creative, collaborative engagement with individual communities so as to not compromise the spiritual integrity of building elements. However, for new constructions, collaborative design among Māori communities, architects and engineers may present opportunities to implement state-of-the-art fire protection systems within buildings while retaining traditional architectural features.

Due to varying design objectives and differences in cultural heritage significance, future research into the implementation of artificial intelligence (AI) recommender systems could streamline the design options, resulting in an enhanced design framework suited to cultural heritage buildings. A recommender system informed by architectural and engineering expertise along with culturally-informed design criteria could rank the effectiveness of different fire protection strategies, and recommend the optimal solution based on the required level of fire safety, the cultural heritage aesthetics, the building uses, the practicality of construction, and the serviceability of fire protection features. In conclusion, cultural heritage buildings are worth protecting for future generations to use and appreciate, and the research avenues highlighted here will hopefully contribute to the fire safety improvements.
References


[20] Mōkai, Māori Maps (2022), [https://maorimaps.com/marae/m%C5%8Dkai](https://maorimaps.com/marae/m%C5%8Dkai), 7 March 2022.


Fire in the Sky: A Look Back at the Montreux Casino Fire

By: Michael Spearpoint and Jamie Clark, OFR Consultants, Manchester, UK

Introduction

Anyone who is a fan of hard rock will know of the song ‘Smoke on the Water’ and its iconic guitar riff. The song was released by Deep Purple 50 years ago, inspired by real events that occurred on 4 December 1971. This article\(^1\) recounts the fire that was the inspiration to the song. Although accounts differ\(^2\) on some details there are some striking similarities to other well-known fire incidents such as The Station Nightclub, and the Dupont Plaza Casino.

The Building

The Kursaal, as it was then known as, was originally opened in 1881 as a casino and included a restaurant, winter garden and theatre [1]. The casino was first modified around 1900-1901 (Figure 1).

\(^1\) A more thorough version of this article can be found at 10.13140/RG.2.2.12192.25608/2

\(^2\) Original articles not published in (or not already translated to) English have been translated with the help of Google Translate followed by a review by the second author of this article who is proficient in French.
A terrace facing the lake (Figure 2) was added between 1905 and 1918. The first dance hall, called the Lido, later replaced the old winter garden. The swimming pool was opened in 1957 at which point the casino was known as the Casino de Montreux. In 1962 a new Lido and expanded terrace were opened, with further renovations completed in spring 1964 and the Hourglass (le Sablier) dance hall opened in 1969.
In 2015 Schröder et al. [2] released a virtual representation of the Hourglass auditorium. The stage is shown at the top-left in Figure 3(a), with the circular recessed ceiling visible above, and the hourglass emblem is shown by the two pyramids. Figure 3(b) shows a visualisation towards the stage with the emblem and a distinctive ‘spiderweb’ ceiling arrangement.

The ceiling of the auditorium was reportedly made from wood “with tropical island décors” [3]. Other reports say the ceiling also included curtains, papier-mâché Christmas decorations, and was covered with rattan. The Lido contained armchairs, curtains and a considerable amount of wood. There was apparently little plastic in the Hourglass but most of the construction was described as ‘natural’. However, Schröder et al. [2] maintain that the hourglass emblem was filled with “…tens of thousands of liters of paraffin”.

The Concert

The Montreux Jazz Festival was originally founded in 1967 in part by Claude Nobs. In 1971 the festival included a concert by Frank Zappa and The Mothers of Invention. The Deep Purple band members were in Montreux and decided to attend the concert.

Some sources say [1] there were 2 000 people in the audience. Zappa said, “There were between twenty-five hundred and three thousand kids packed into the room – well over capacity” [4]. Elsewhere [5] the audience was said to number as many as 4 000.
Peter Schneider [6] recalls that the chairs that were normally in the auditorium had been removed. Similarly, Alain Rieder says [7] “...there were no chairs, it was not yet the fashion of standing concerts, and so the audience sat on the floor [...]”

Schneider noted that the event started around 2 pm. The venue had security staff, volunteers from the Montreux Tourist Office and four fire-fighters on hand during the concert. Figure 4 shows the band on stage in which the recessed part of the ceiling can be seen and although there are curtains across the back it is possible that are also windows in the vicinity. Figure 4 does not show any decorations on the ceiling, and other than the ceiling appearing to be of some form of timber construction, it is not obvious that any rattan / bamboo is present.
The Fire

The fire started somewhere between 16:15 and 16:20. A Deep Purple band member is quoted as saying that “Toward the end of the concert, someone behind us shot off a flare that soared into the rafters. The heat from the phosphorous light ignited a fire” [3]. An eyewitness reported [8] that a young man near her had fired a small pistol at the start of the concert and later fired it again which started the fire in the ceiling. This version of events is disputed by Schneider who thought a boy was throwing lighted matches up towards the low-level ceiling. However, elsewhere it was reported [9] that “Witnesses saw the fire start in an electric canvas pendant lamp near a bamboo ceiling [...] suggesting a short circuit.”

Regardless of the way in which the fire started, the consensus is that it initially involved the ceiling. Rieder [7] recalls “At first, the fire is very small, I think it will be extinguished quickly and the concert will continue.” Schneider [6] says “I remember looking behind me and seeing a large ball of flame. Because I was very stoned it looked beautiful [...] I actually thought that the fire was part of the show!!”. These descriptions are reminiscent of The Station Nightclub fire, where some of the audience initially thought the flames on the stage walls were part of the act [10]. Figure 5 shows two different photographs of the ceiling fire with what look to be some form of decoration hanging below the ceiling.

In an interview recorded for French TV, Zappa says “…this guy runs up […] with a fire extinguisher” and when he used it “fire came out of the ceiling and this part of the roof fell down” [11]. It also appears that attempts were made to use a hose reel. One commentator recalls “Claude [Nobs] had already handled a ‘fire hose’ [...] the jet barely reached 2 m in height... the pressure had been reduced to prevent the coffee machine from exploding !!!!”. One of the on-duty firefighters also tried unsuccessfully to use a hose reel [8].
The fire rapidly spread through the Hourglass (Figure 6) and then the rest of the building. A witness recalled “The dense smoke had filled the room and stopped at a level about three feet from the floor; below that the air was just sort of gray, but you could still see a bit.”

At its height, the fire was described by an eyewitness [1] as “…a gigantic torch and emits a black smoke that can be seen for dozens of kilometres around.” Pictures of the casino during the fire show extensive scaffolding due to ongoing renovations, which “burnt like torches” [9].
Evacuation

Soon after becoming aware of the fire, Zappa is heard to tell the audience “Fire! If you’d kindly move calmly toward the exit, ladies and gentlemen. Calmly.” According to Schneider [6] the absence of chairs and the time of day allowed the audience to easily move towards the exits. He recalls “I seem to remember somebody at the microphone saying, ‘Don’t panic’. In fact nobody did panic because nearly everybody was so stoned that fear didn’t kick in and the audience exited in a more or less orderly fashion.” A similar quote recounts “I remember there was very little panic getting out, because it didn’t seem like much of a fire at first” [12].

One eyewitness stated, “All the emergency exits are open, thanks to the quick action of the security staff and the younger staff members of the hotel and casino.” However, Zappa declared [11] “…one of the problems was they got to the exit and it was locked, they had to bang that down.” Zappa later said [4] “Since more kids were outside, trying to get in, the organizers had cleverly chained the doors shut.”

Not everyone used the exits, as Schneider [6] says, the rapid fire spread had trapped the people at the front. Rieder [7] states “…people opened the curtains that hid floor-to-ceiling windows on either side of the stage. Some grabbed chairs to break the windows.” Zappa later said [4] “As the room was filling with smoke, one of our roadies took an equipment case and smashed the big window.” Nobs is quoted as saying “We had big windows in the concert hall overlooking the swimming pool. Frank Zappa took his guitar […] and he smashed the big window down”. This version of events is repeated elsewhere [3], although it appears Zappa never made such a claim. Whether Zappa broke the windows or not, he saw that smoke was already filling the room [4] and was able to leave through a back exit.

Schneider recalls that he and others were saved by a firefighter breaking the windows with an axe. People were able to jump down to ground level which was around 10-15 ft [6]. Rieder was one of those who used the window, saying [7] “…the ground must be about three metres away, there is a ledge from which I hang and I let myself fall into the grass…” Another witness said, “Before jumping, I retraced my steps to rescue my belongings which were exactly where I had put them.” Using windows as exits again is reminiscent of The Station Nightclub fire [10], and also the Dupont Plaza fire [13] in which people reportedly had to jump 5 m.

Schneider remembers that before the glass was broken, he was beginning to struggle to breathe. Once the windows were broken then the fire accelerated, spreading across the ceiling. Zappa [11] said “…our roadies were the last ones coming out of there and they were blown out there by an explosion […] from the heating system”.

Outside people were seen taking photographs, and one iconic image shows Claude Nobs pulling a fire hose (Figure 7). Michel Ferla [5], speaking of Nobs and the team, said ”We crawled through the burning building on all fours, at that time a lot of marijuana was smoked. We wanted to be sure that no one had fallen asleep.”
Notwithstanding potentially locked exits, people needing to escape through broken windows, and efforts required to rescue some of the audience, the Montreux Tourist Office declared “...everyone was able to be evacuated safe and sound in three and a half minutes”. Nobs is quoted “...within about five minutes, the 2,000 kids were out.” Figure 8 shows people leaving (and possibly trying to enter) through what appears to be the main door of the old Kursaal building.
Fire brigade response

The Montreux fire brigade received an alarm at 16:22 [8] and the first fire appliances arrived after 3½ minutes at the same time the last of the audience left the building through the main door. Around 80 firefighters initially arrived (Figure 9) from surrounding areas. One of the senior firefighters later reported [1] that “...the water system was empty after two hours, before water was taken from the lake.” The firefighters managed to stop the fire spreading to a garage adjoining the casino. Attempts were also made to prevent the fire spreading to the theatre, but these were ultimately unsuccessful [1].

![Firefighters at the incident](www.rts.ch/info/galeries-photos/7824393-lincendie-de-casino-de-montreux-en-images.html)

Aftermath

The incident resulted in no deaths, and Zappa said [11] “...there was very little injuries, there was three people who went to hospital” of which one was one of the roadies caught up in the explosion. Figure 10 shows the severe damage to the casino in which the remains of the Kursaal building that formed part of the façade (Figure 1) can be seen. Also clearly visible is the distinctive ‘spiderweb’ remains of the Hourglass. The then estimated cost of the property loss was 12 to 15 million francs [1], [9]. The person supposedly identified as firing the flare gun fled the scene [12] and was never apprehended by the Swiss police.

A tribunal took place in 1972 to investigate the circumstances surrounding the fire. It had a range of issues to examine regarding; the materials used to decorate the Hourglass, and the ‘hydraulic clock’ which would appear to be the emblem previously mentioned by Schröder et al. [2]. One claim was that the clock contained 4 500 litres of liquid paraffin, although the casino’s lawyer stated it was 3 000 litres of mineral oil. Whether these contents contributed to the severity of the fire is unclear.
Conclusion

The Montreux Casino fire is an iconic event in music history. Examining multiple sources published on the web leads to some conflicting statements and the promulgation of what appear to be myths. However, there appears to be sufficient evidence that there were no seats at the time of the concert and that the audience evacuated calmly with no indication of any ‘panic’. It is evident that people used broken windows to escape by jumping to ground level. It is also very clear that Claude Nobs and his associates made exceptional efforts. What is less clear is how the fire started (although the consensus is that it was due to a pyrotechnic device) and whether any of the exits were blocked.

References


By: Luca Fiorentini – TECSA S.r.l.

A fire risk assessment has always been a challenging task especially considering the need to face new fire risks, new perspectives and general complexity of technical and socio-technical systems that present fire threats. Risk-based approaches and new probabilistic approaches require an underlying sound fire risk assessment to define performance targets and fire safety objectives for different vulnerabilities (occupants, environment, assets and business continuity). Also company enterprise risk management frameworks requires for the fire risk being managed to guarantee business resilience and disruption avoidance: often it is requested to adopt a single framework (as the workflow proposed by ISO 31000 standard) to deal with different risks.

Furthermore performance-based approaches to fire engineering have shown that risk-based decisions and fire scenarios are fundamental elements that must be considered in fire safety strategies design. A correct assessment of the fire risk allows all the involved stakeholders to identify a specific strategy from among a variety of possibilities. A fire risk assessment is the best tool to identify comparable fire protection strategies and to measure the reduction in fire risk that can be obtained with each specific prevention and protection measure, i.e., by means of different fire safety strategies.

Setting up the fire strategies to manage the fire risk in performance-based approach requires specific method in order to identify a specific strategy from among a variety of possibilities.

The FLAME method (Fire Risk Assessment Method for Enterprises) provides a simple index-based technique to assess the fire risk. This method has been based on the general approach to fire safety objectives provided by the fundamental NFPA 550 standard with the Fire Safety Concepts Tree.

At the beginnings of the fire risk assessment methods, in the seventies, the components of a fire protection strategy were treated as being independent of one another, leading to useless duplication of protection systems (overdesign) or gaps in protection/lack of desired redundancy. Several methods, applying to industrial or civilian buildings, to comply with standards or adopt methods enforced by local laws or regulations, have been developed such as:

- GRETENER
- Fire Safety Evaluation System
- Building Fire Safety Evaluation Method
- Vaughan-Beck model
The relevant features of these earlier methodologies included the concept of relative risk and acceptability of the risk level, the inclusion of management procedures as a means of achieving acceptability, the use of probability to describe the mean performance of fire safety and the adoption of an event tree structure, which was used to define connections between the components of a system and to compare their performance.

Purposes and motivations of FLAME method can be identified in:

• Lack in methodologies about fundamentals of fire dynamics and concept of fire risk;
• address both probability of occurrence and consequences on exposed humans, structures, assets;
• identifying the specific objectives for each vulnerable targets, an acceptability threshold;
• suitable to face nowadays challenges (posed for example by new construction materials, complex geometries filled buildings, etc.);
• measure risk reduction associated to different fire strategies.

FLAME has been conceived as a combination of:

• weighed check-lists;
• risk Matrix;
• simplified algorithms.

FLAME approach is the combination of both hard and soft factors (Figure 1), negative and positive to describe the risk level. Beside the key elements describing fire danger also fire protection (active and passive measures) can be assigned values in a predefined range and at the end specific issues related to fire safety management aspects can be evaluated against specific indexes to reduce or confirm negative performances.

Figure 1

In FLAME method, the risk is measured with a semi-quantitative way, using a scoring approach with ordinal scales: this allow a risk ranking to be drawn up against a common criterion, and they permit a range of factors
that have an impact on the level of risk to be condensed into a single numerical score of the level of risk. Inputs are derived from the analysis of the context (description of the system), considering various parameters in order to overcome the limitations of qualitative judgements.

FLAME general structure is given in Figure 2.

**Figure 2**

The FLAME model has the aim of guaranteeing an understanding of the relationship between changes in the design and changes in the resulting fire risk, where any changes may be associated with technical and/or management issues.

Main advantage of index method like FLAME is to avoid the complete qualitative approach to risk assessment such as HAZID, Bow-Tie, etc. which may not be able to offer a preliminary estimation and/or an initial assessment of the risk reduction associated with different measures selected as part of the overall fire safety strategy, or the risk reduction of a preferred strategy versus alternative ones.

Dealing with fire risk indexing make this approach feasible and effective both for staff members with the responsibilities of risk management and for people who are not used to fire safety concepts.

FLAME methodology was developed considering the key elements from the following methodologies:

1) the Gretener Method, developed to calculate the fire risk of industrial building;

2) The Fire Risk Assessment Method for Engineering (FRAME), developed in 1988 and derived from the Gretener method. This method make it possible to define an adequate fire strategy from balance between the fire threat, fire protection and fire exposure;

3) The Building Fire Safety Evaluation Method (BFSEM), based on a flow chart structure that make possible to evaluate the likelihood of ignition, fire growth, and the spread of a fire through an existing building or a new building considering occupancy characteristics and protection/prevention measures.
4) The Fire Safety Evaluation System, developed to verify compliance with NFPA 101 with a method which could be used to determine fire safety measures that provide an equivalent level of fire safety to that provided by the NFPA 101 itself.

5) The Dow Fire and Explosion Index, developed in 1964 by the Dow Company. It can be used to quickly examine and identify which sections of plants constitute a significant fire and/or explosion hazard.

FLAME allows the differentiation between risk indexes associated with occupants and assets. The final fire risk level (with fire risk ranking) is then obtained from the combination of the factors that increase fire severity and the elements that contribute to mitigating fire hazards.

Apart from the key elements that describe a fire hazard, scores are assigned to fire protection (active and passive) measures so that fire safety management aspects can be evaluated against specific indices to reduce or confirm negative performances, as well as occupants’ characteristics that define pre-movement time, combined with the alert systems in place (Figure 3).

<table>
<thead>
<tr>
<th>Alert system</th>
<th>Characteristics</th>
<th>Base time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>None, voice messages from occupants</td>
<td>7</td>
</tr>
<tr>
<td>A2</td>
<td>Manual alarm system and bell</td>
<td>5</td>
</tr>
<tr>
<td>A3</td>
<td>Pre-recorded messages and cues</td>
<td>3.5</td>
</tr>
<tr>
<td>A4</td>
<td>Live emergency evacuation directives</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 3

In the logical and systematic structure of FLAME the main fire elements and issues can be defined through several parameters, classified (according to the intensity level of the parameter) and combined in order to obtain a more specific and effective evaluation of the required safety level for the safeguarding of people and for the tenability of structures.

Resulting fire risk is verified against fire risk management in place (Figure 4) that takes into account a number of specific management factors (including housekeeping) and described by five categories of quality (from B, basic to 4 complete and advanced management system in place). Any non-conformity or failure concerning the other aspects acts as a downgrading score on the acquired level.
Protection Category Concept: Definition of Acceptability of Risk with respect to Protection Level

- Technical protection measures
- The emergency procedures planning
- The fire safety management system
- The housekeeping and cleaning procedures
- The maintenance and inspection level of firefighting means

This allows the FLAME simplified approach also to be used for fire safety audit sessions in order to analyse existing fire compartments, and to investigate whether the protection measures in force are efficient or not, or for new buildings, to optimise their fire safety protection measures with a proper balance among hard and soft preventive and protective measures.

Moreover, it has been demonstrated that FLAME approach is coherent with the current standards focused on the definition of the occupant' risk.

The method could be extremely flexible and adaptable to different actual realities. The parametric structure considered by FLAME includes not only fire-basic indexes (as fire load or growth) but also those dealing with the vulnerability of occupants and structures, even in the fire safety management system for the emergency procedures and plans.

The user could, with respect to the previously identified level of risk, determine the Protection Category which measure the resilience of the compartment to fire, or to different fire scenarios envisaged. Once the evaluation is performed, the user could come back to verify, if any changes to the end-use or asset of the compartment whether the Protection Category is modified adequately or could no longer withstand the severity of the fire.

Protection Categories represent, within the method, the application of the concept of acceptability of risk, since this latter is obtained as a combination of the risk level and the category defined: the final matrix gives the “acceptability” of the compartment protection measures opposing to fire. The dual nature of the evaluation performed with FLAME, considering with different parameters occupants or assets vulnerabilities, allows analysts to obtain also a score for the “property risk”, which could be regarded as a measure of the balance between the economic losses of structures against the costs due to the implementation of fire protection systems.

Full article is available, together with case studies and validation data, in open access format, online at the URL:


References


