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Fire Risk Assessment, Dealing with Complexity. FLAME, A Proposed Method.

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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

• FRAMEworks

• FIRECAM

• F.R.A.M.E.

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.

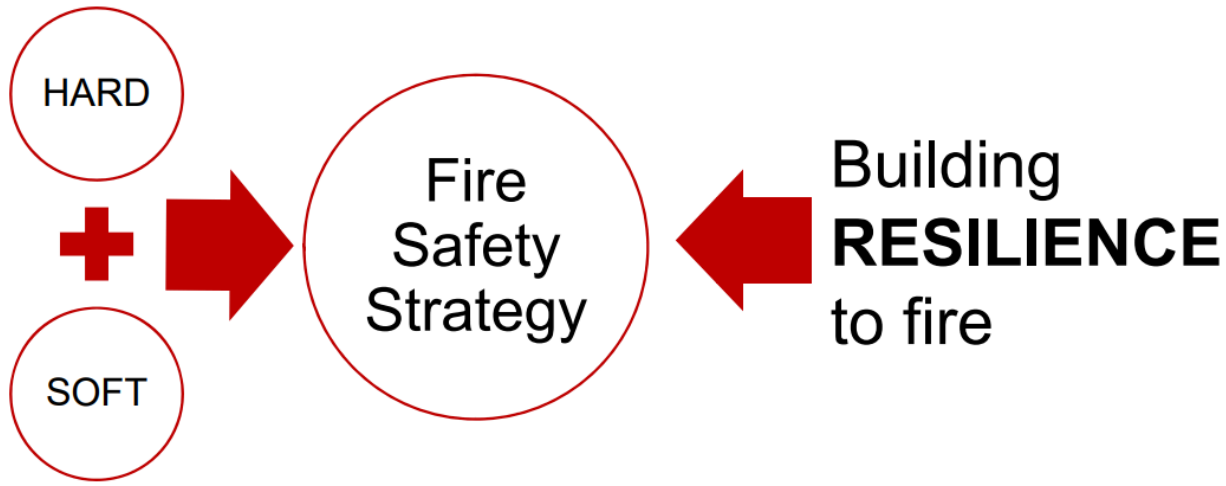


Figure 1

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.

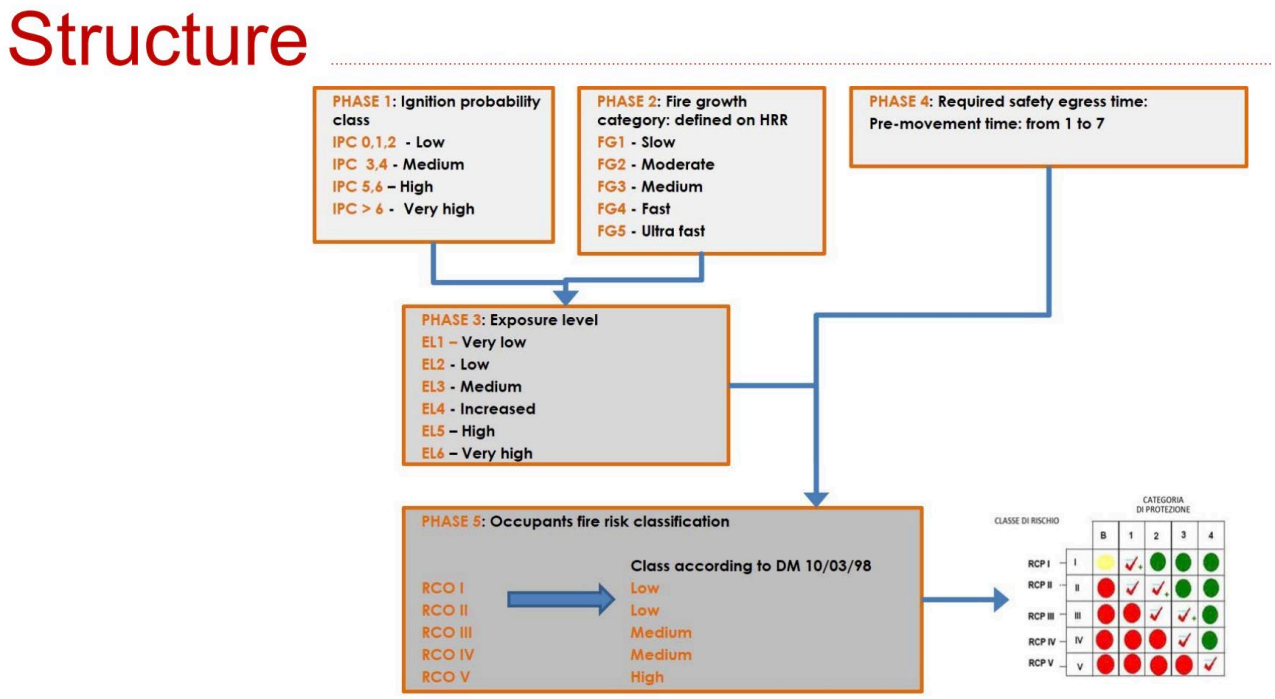


Figure 2

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;

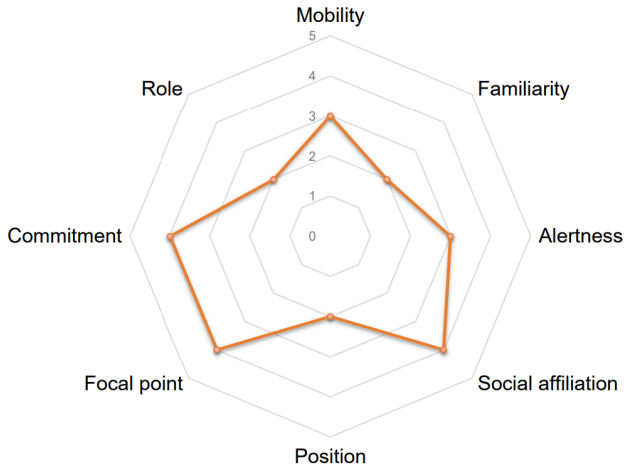
3) The Building Fire Safety Evaluation Method (BFSEM), based on a flow chart structure that make possible to evaluate the likelihood of ignition, fire growth, and the spread of a fire through an existing building or a new building considering occupancy characteristics and protection/prevention measures.

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).



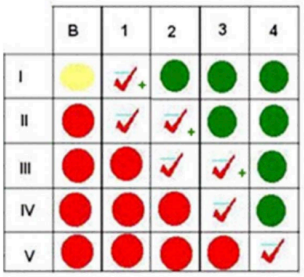
Alert system	Characteristics	Base time (minutes)
A1	None, voice messages from occupants	7
A2	Manual alarm system and bell	5
A3	Pre-recorded messages and cues	3.5
A4	Live emergency evacuation directives	2

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

Figure 4

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 demostrated 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:
https://link.springer.com/article/10.1007/s10694-020-01014

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