Paul Bryant M.Sc.

A SEMI-QUANTITATIVE METHOD FOR THE EVALUATION OF HOLISTIC FIRE STRATEGIES FOR NON-STANDARD PUBLIC BUILDINGS

PhD Thesis

Abstract

PhD Tutor: dr hab. inż. Dorota Brzezińska

Lodz 2021

The Thesis titled "A semi-quantitative method for the evaluation of holistic fire strategies for non-standard public buildings" reflects the 30 years of the Author's experience in the field of fire safety and protection engineering in the UK, Europe, and internationally. It presents key elements of his research and describes a novel semi-quantitative method for the evaluation of holistic fire strategies for non-standard public buildings. This would incorporate an assessment of fire strategy elements, namely, building management, passive fire protection, fire detection, active fire protection systems, and fire-fighting arrangements. The methodology would be applicable to the design process of both new build projects and existing buildings. It can guide the building process from the concept stages through to the construction phase. It provides a proposal for a uniform global solution for both fire strategy formulation and evaluation. The Thesis is written over seven chapters:

Chapter 1 presents an introduction and asserts that the formulation and verification of fire strategies for buildings in different countries do not follow a consistent approach. Even for a single risk building profile, the output strategy can vary considerably. This belief became the Author's motivation for instigating the research presented in this Thesis. The chapter introduces the subject of fire engineering and the concept of fire strategies and provides a state-of-the-art review. It illustrates how fire engineering is unique as a discipline, although its subject matter is, in fact, a combination of many aspects of engineering, management, technical and social sciences, including civil engineering, chemical engineering, environmental engineering, mechanical engineering, and finally safety science and management science.

Chapter 2 examines the development of fire (safety) regulations over time and demonstrates how contemporary "performance-based" fire engineering solutions are increasingly used in preference to the more traditional prescriptive rules. This is particularly the case for more complex building arrangements such as non-standard public buildings. The chapter introduces the term "fire strategy" and how this has been used and understood in the context of national and international fire standards and regulations. One of the objectives behind this Thesis is to develop a methodology that is global rather than nationally based. An analysis of the national fire regulation requirements for seven countries was undertaken to find out if there were commonalities over a number of areas of fire safety specification. It was found that, in many aspects, there was an implicit agreement, whilst in other areas, there were still noticeable variations in the national approach to fire safety.

Chapter 3 introduces the concept of holistic fire strategies and presents a detailed description. The emphasis of the approach is to improve the consistency of both preparation and evaluation of fire strategies. It also discusses the primary objectives as life safety, property protection, business protection & continuity, and environmental protection. Each of these objectives is further divided into four sub-objectives. This idea and the associated diagram is unique in the field of fire engineering and was originally developed by the Author of this Thesis. It is proposed that every fire strategy should consider all 16 sub-objectives for every building project rather than the one or two objectives currently assessed in many countries. This chapter describes how the novel method enables assessment in terms of the suitability to a specific building protection purpose. Furthermore, the topical issues of sustainability and the increasing use of building information modelling (BIM) are considered as related to the assurance of building fire safety.

Chapter 4 introduces the concept of fire scenario determination and provides an overview of existing methods used for fire safety and fire risk assessment. A new fire risk assessment method for the adopted fire scenario is proposed here. It is based on an enhanced and novel analysis method of the probability of fire ignition and fire growth. The result of the analysis, and the determination of a Scenario Fire Risk Value, allows the selection of the most adverse fire scenarios for any building profile, which will then be used as a basis for further analysis and evaluation of the fire strategy.

Chapter 5 describes the Author's semi-quantitative index method for fire strategy evaluation. It allows for the detailed scoring of eight separate fire safety measures incorporated into every fire strategy. It is a comparative method, allowing the evaluation of solutions proposed for a building's actual fire strategy risk index ($FSRI_{actual}$), with the expected fire risk index given in a baseline fire strategy ($FSRI_{baseline}$). The presented method of assessing the fire strategy was inspired by the UK fire strategies fundamentals developed by the Author in British Standard PAS 911:2007 in combination with the *Max Gretener* risk assessment index method. The evaluation makes use of a seven-stage process:

1. description of the building,
2. analysis of possible fire scenarios and prediction of the worst case scenario,
3. specification of the baseline fire strategy,
4. preliminary analyses for the assessment of the actual fire strategy,
5. evaluation of the actual fire strategy,
6. presentation of the baseline and actual fire strategies on a fire strategy value grid,
7. calculation and analysis of the actual fire strategy risk indices.

The presented method divides the analysis of eight fire safety factors, covering (1) fire prevention and fire spread limitation - organisation and management; (2) control of ignition sources and combustible materials; (3) fire and smoke spread limitation - passive systems; (4) detection and alarm communication; (5) fire suppression; (6) smoke control and evacuation; (7) maintenance of fire precautions and systems; and (8) fire service intervention.

A questionnaire is utilised to allow a detailed understanding of how each of the factors is relevant to the overall fire strategy. This uses a scoring system with a range from 0 to 25 points for each factor. The actual fire strategy is based upon a detailed consideration of those elements currently provided for the building in question. The baseline strategy can be based upon, for example, local/national fire regulations or, alternatively, make use of the Author's table of default values assigned to individual building's risk profiles (as described in a UK standard BS 9999:2018). A detailed summary of the default baseline values for fire strategies based on building risk profiles is given in Annex D.

Additionally, this chapter presents the Author's self-developed default values of weighting factors for baseline fire strategies, relevant to the risk profiles of the building. A mathematical relationship has been devised to allow the calculation of the fire strategy risk index and to make a final assessment of whether the fire protection measures applied in the assessed building provide the required level of fire protection. The results would help determine whether a fire strategy is fit for purpose or further control measures are required. The proposed methodology allows for a comparison of different fire strategies for a singular building or, alternatively, of similar strategies for different buildings.

Chapter 6 presents a trial of the methodology for three public buildings. The chosen publicly used buildings have all been developed from their original designated use. In the case of the Polish buildings, these evaluations were used, together with the fire expert reports, for obtaining permits to use non-standard solutions in relation to the requirements of the local regulations. The buildings were:

a) The City of Culture EC1 in Łódź (Poland) - originally an industrial facility (a power plant), converted in 2015-19 into a cultural and entertainment centre (ZLIII public building) with non-standard complex architecture, and a multi-storey atrium;

b) Hotel Castle in Ryn (Poland) - originally a teutonic castle (14th century), rebuilt in the 1990s into a hotel building (public building ZLV) of a non-standard architecture, with a vast covered courtyard intended for use by large groups of people;

c) Chelsea Hospital in London (UK) - originally a shopping centre building, rebuilt into a hospital building in 1992 (ZLII public building), with a non-standard architectural layout due to the multi-storey central parts, open passages (formerly shopping arcades).

For each of the above examples, the seven stage process as described in the presented methodology, was undertaken. It included the selection of the most adverse fire scenario for further analysis (described in Chapter 4) and the calculation of the fire strategy risk index (FSRI) for the baseline and actual conditions (Chapter 5). This chapter also provides the results of the supportive analysis, including CFD simulations of fire development and smoke spread. In each case, the actual and expected fire strategy risk index was calculated.

In the case of the EC1 Centre, the analysis showed that the first approach to the fire strategy was acceptable. However, in the case of the Hotel in Ryn and the Chelsea Hospital, the first evaluation showed the need for adjustments to the actual strategy. Once these had been made, the revised results led to a positive conclusion. Annexes A, B, and C present detailed data for all three buildings.

Chapter 7 provides the summary and conclusions. It is concluded that the proposed technique of a fire scenario risk analysis, and the development of a new, semi-quantitative method for determination of the fire strategy risk index was proved to be a useful tool for the formulation of holistic fire strategies and their subsequent evaluation.

As well as annexes A to C, annex D provides a summary of the score ratings developed to create baseline fire strategies based upon a building's risk profiles. Annex E presents the details of a computer programme created by the Author for the development of fire strategies in accordance with the proposed methodology. The programme is currently available in Polish because it had been used for evaluation by Polish industry. In the future, it is planned to provide the programme in multiple languages.