Developing a Fire Robustness Index for the Built Environment

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INTRODUCTION

Over the past decades, the Fire Safety Engineering (FSE) discipline has provided metrics to support a change from prescriptive guidance to a functional fire safety approach in a spectrum that spans from rule based guidance to a more performance-based approach [1], [2]. Amongst those methods, indexing tools have been utilised repeatedly for the assessment of fire risk relative to regulatory acceptable levels.

Fire Risk Indices are heuristic models of fire safety, procedures that provide a practical approach to solving problems. They are also known as scoring, risk ranking, index systems, rating schedules, point schemes, and numerical grading.

A risk index is where a multi-attribute evaluation is used to develop risk assessments that involve the scoring of the causal, and mitigating, fire safety attributes; the results are then aggregated into a single number [3]. The foundation of any Fire Risk Index is therefore a points system. To account for differences in importance, relative weightings can be assigned. A generic structure is shown in Figure 1.

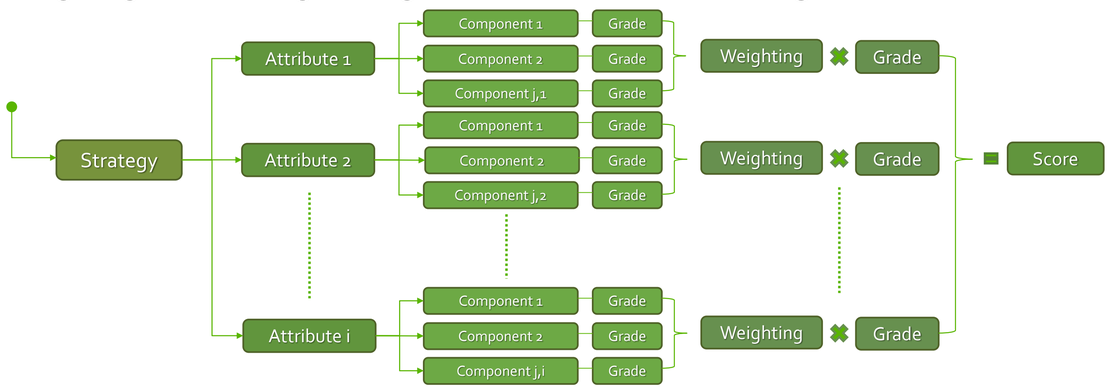

Figure 1. Generic structure of a Fire Risk Index.

A design tool can be developed that facilitates and motivates users to exceed the regulatory minimum – thereby achieving more robust assets, where robustness is defined as the capability of a unit to withstand certain levels of stress without losing its function. Expanding this in FSE, the system should not present major failure, or damage disproportionate to a specific fire event.

HISTORIC OVERVIEW

Various relative methods have been developed globally in the past, aiming to assess Fire Risk depending on the use, occupancy type and typology of construction. These are presented chronologically in the following figure.

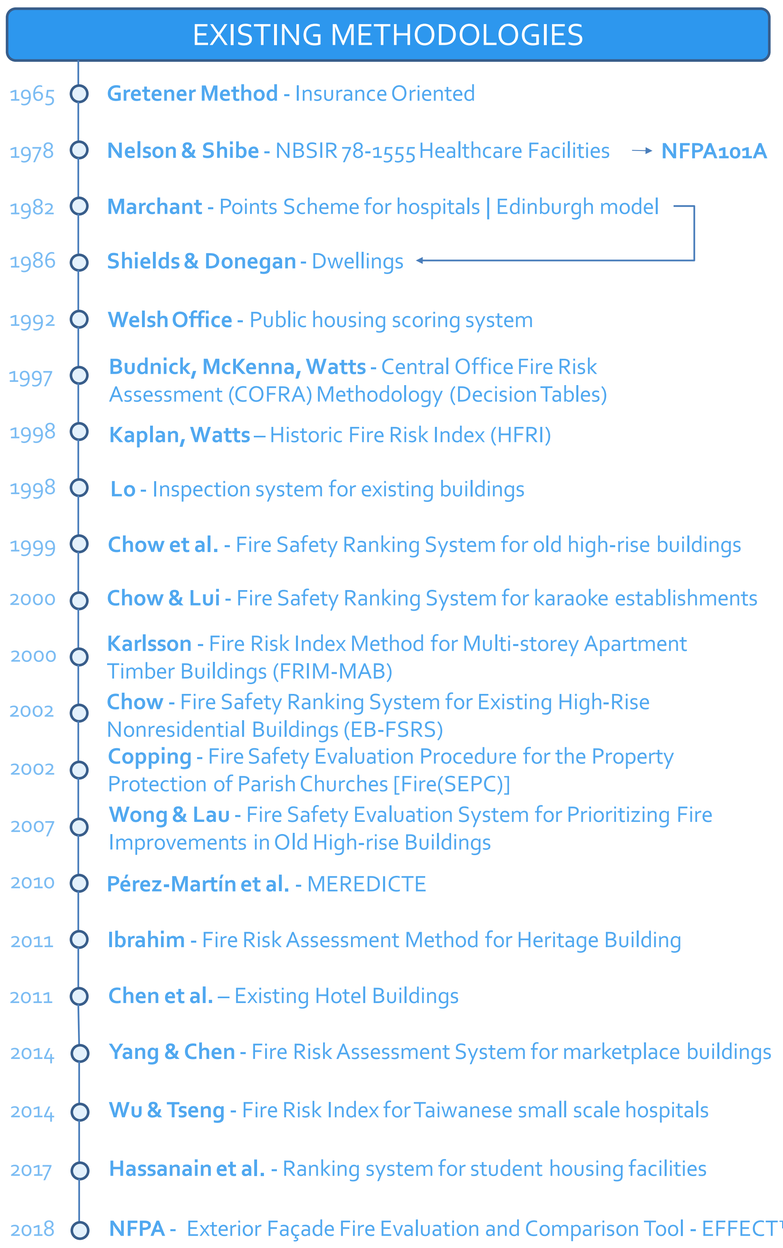

Figure 2. *Chronological list of existing methodologies.*

FINDINGS

In order to obtain a fundamental understanding of how an index is developed, the key aspects that must be included within an indexing method have been analysed [4]. It was found that each method must:

- Identify the parameters to be included within the indexing approach:
  - i. Using professional experience,
  - ii. Using codes, regulations, reports, and previous methods to derive the parameters along with an expert group to refine them;
- Assign weights and values to those parameters employing expert elicitation techniques:
  - Arbitrarily,
  - With multi-attribute evaluation employing an "expert" panel, with various combinations of the Delphi and the Analytic Hierarchy Process technique,
  - Without relative weights but only assigning points with pass/fail criteria;
- Calculate an overall index:
  - a. By comparing customly defined risk factors,
  - b. With multiplication of relative weighting and component grades to compute a final score,
  - c. Through compliance checks and assignment of one point per check.

Table 1 shows how the various methods adopt those different approaches.

Table 1. Overview of methods.

Method	Parameters	Expert elicitation	Calculation
Gretener	[i]	Arbitrarily	[a]
NFPA 101A	[ii]	Delphi (8+21)	[a]
Edinburgh Model	[ii]	Delphi (21)	[b] (0 to 5)
Dwellings (N. Ireland)	[i]	Delphi (30)	[b] (0 to 5)
Dwellings (Wales)	[ii]	Advisory group (6)	[b]
COFRA	[i]	Delphi and AHP (8)	[b] (decision tables)
HFRI	[ii]	Advisory group (2)	[b] (decision tables)
Fire(SEPC)	[i]	Delphi (7)	[a]
Lo	[ii]	AHP (30)	[b]
Chow et al.	[ii]	No weighting	[c]
Wong and Lau	[ii]	Using other methods	[b] (0 to 100)
FRIM-MAB	[ii]	Delphi (20)	[b] (decision tables)
Heritage Buildings	[ii]	AHP	[b] (1 to 10)
Hotel Buildings	[ii]	Delphi and AHP (50)	[b] (1 to 100)
Small scale hospitals	[ii]	Delphi and AHP (10)	[b] (0 to 5)
Student Housing	[ii]	AHP (8)	[b] (1 to 5)
NFPA Facades	[ii]	AHP	Qualitative

CONCLUSIONS AND FUTURE STEPS

To understand the developmental processes involved in Fire Risk Indices, a literature review located a number of notable indexing methodologies in FSE. It was found that all indexing techniques have three common features (1) parameters must be identified; (2) parameters must be weighted and quantified; and (3) the index must be calculated from the weighted values.

The Delphi and AHP are the two expert elicitation techniques most frequently employed to systematically assign weights; yet any assumptions are not always stated, nor is any validation of the results sought.

It is notable that a substantial number of methods are developed as part of a specific project; once their aim is served (or the project is completed) they fall into disuse. This shows that the longevity of a method is limited by the context of its creation and any following technical support for a vital updating process.

Finally, that many method's documentation is not always complete and the basis for decisions not always clear.

The project's next steps will be to map the structure of an indexing method that evaluates the achievement of the Building Act's functional requirements, and explore how theoretical and experimental models can be incorporated in this process.

References:

[1] D. Rasbash, G. Ramachandran, B. Kandola, J. Watts, and M. Law, Evaluation of fire safety. 2004.
[2] H. L. Malhotra, Fire safety in buildings: report of a study for the Fire Research Station on behalf of the Department of the Environment. Borehamwood, England: Building Research Establishment, 1987.
[3] J. M. Watts, 'Chapter 82 - Fire Risk Indexing', in SFPE Handbook of Fire Protection Engineering, Fifth Edition., Springer, New York, NY, 2016, pp. 3158–3185
[4] V. Koutsomarkos, D. Rush, G. Jomaas, and A. Law, 'Comparative Analysis Of Fire Indexing Methodologies', presented at Interlam 2019, Royal Holloway, University of London, UK, 2019, vol. 2, pp. 1647–1659.