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The potential of integrating fire safety in modern building design

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ABSTRACT

Whether explicitly acknowledged or not, modern building design is strongly influenced by fire safety considerations. The building design community, broadly construed, appears to remain surprisingly unaware of the extent to which prescriptive fire safety considerations impact building designs. However, several decades of advances in fire safety science have gradually revealed the potential value of integrating fire safety as one of the many variables that should be optimized during the building design process. This paper presents outcomes from a series of mediated roundtable discussions that occurred during an international seminar aimed at reflecting on the current status of fire safety and fire protection concepts within overall building design processes. An attempt is made to emphasize discrepancies between the perceptions of fire safety considerations, requirements, and drivers exemplified by the various stakeholder participants. A distinction is made between the status of those individuals presently charged with the fire safety design of a building, and the future potential for further integration of fire safety considerations within the building design process. Fundamental changes in support of holistic provision of fire safety in the modern built environment are proposed.

1. Introduction and background

The need for optimization, energy efficiency, sustainability, novel architecture, and creativity are forcing rapid evolution in the use of new construction techniques, innovative materials, and ground-breaking designs in building construction. Ideally, the numerous stakeholders involved in building design, work within a flexible and dynamic environment that supports iterative design processes in an open, knowledge-based, responsive dialogue [1]. However, a compelling case can be made that those charged with the fire safety design of buildings are rarely (and often insufficiently) involved in this iterative process; all too often fire safety practitioners participate only on the periphery of the design process, sometimes with the goal of gaining regulatory approval – thus *constraining* the design to align with prescriptive fire safety measures which are presumed to provide adequate fire safety. The result is a sub-optimal relationship between the overall design and fire safety measures in many buildings.

Since the development of early building codes [2], fire safety design and regulation of buildings has been founded on the concept of 'compliance,' wherein the design of individual building elements is required to comply with 'acceptability' criteria given in building codes to ensure that buildings provide a presumed, however typically unquantified, level of fire safety [3]. This non-integrated prescriptive approach presents fundamental issues for the current and future construction environment; in this context fire safety tends not to be part of the optimization process *involved* in design, but rather an additional set of requirements *imposed* on an otherwise optimized design process. In such a process, fire safety considerations will act as constraints and are likely to be perceived primarily as barriers to one or more other design goals such as material optimization, energy efficiency, sustainability, or architectural expression.

These concerns are not unique to fire safety design; many other participants in building design have reflected in the literature on the current state and potential benefits of more integrated approaches to the design of buildings. For example, structural optimization, lifecycle cost, energy saving, climate control, lightning, acoustics, and various other design disciplines have all made similar claims of a need for integration across all design disciplines (e.g. [1,4,5,6,7]).

The fire safety community (both in research and in practice) has also recognized the need for integration and has reacted to the on-going evolution of buildings and the building design process. During the past few decades global efforts have been made to develop and implement performance-based approaches for fire safety design [8,9,10,11,12]. The use of performance-based fire engineering design approaches is now commonplace in many jurisdictions (e.g. [13]). Furthermore, to deliver *quantifiable* fire safety *performance*, the fire safety research and

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engineering community has invested considerable resources in the development of physics-based tools that have been critical to the design and approval of many building designs ([14,15,16] Despite these efforts, however, many building design professionals (e.g. structural engineers, architects, etc.) still fail to recognize fire safety as an explicit design *variable* [17]. Notwithstanding a small number of particularly enlightened building design firms, fire safety practitioners are rarely considered integral members of the larger design team. This paper reflects on why this might be and asks whether it ought to change.

2. Significance

Many challenges face the introduction of a quantified, explicit performance framework for fire safety in building design [18]. Fire safety is a broad, multi-disciplinary requirement in building design; hence it requires competence (and competency awareness [19] in a wide variety of subjects, including an overall understanding of the building design process and stakeholders [20]. Furthermore, the ways in which fire safety is quantified in buildings are under constant refinement; thus the tools used to quantify fire safety have inherent assumptions and limitations that are not always well understood by all design stakeholders, and they cannot always be used with confidence [21].

Performance-based fire safety design thus requires a dialogue between competent professionals, and vague definitions and/or lack of competence can cause problems when implementing fire safety engineering designs. Many regulatory authorities are slow (or unable) to reach the required level of competence needed to assess new design approaches, thus introducing a 'compliance risk' linked to the inability of regulatory authorities to assess non-prescriptive designs and resulting in refusal to approve engineered designs. Designers and developers may shy away from this compliance risk, and retreat into prescribed rules, even for unconventional buildings where the applicability of the simple rules may be marginal. Indeed, recently implemented performance-based fire safety design codes are in some cases following this trend by moving away from performance-based design and returning to *prescribing* the manner by which *performance* must be demonstrated; e.g. USA [13], United Kingdom [22], and New Zealand [23]. The fire safety community must therefore continue to invest in developing the competence not only of fire safety engineering designers, but also fire safety regulators, standards developers, the fire and rescue services, and academic researchers. After all, "*whilst it is true that it may be sensible to deregulate, one must deregulate into a profession which has competence*" [24].

Changes in legislation that allow the use of performance-based fire safety engineering in design have led approving fire safety authorities to assess and approve performance-based designs (e.g. [22,25,26]). Designers are permitted to generate essentially any design for which an acceptable level of performance can be *demonstrated*. What constitutes 'acceptable' performance remains a grey area in many cases (e.g. [26]), and this is yet another difficulty faced when implementing performance-based fire safety engineering designs. A common approach in practice is to design to assure the same implicit 'level of safety' presumed by delivering the prescriptive solution to the same design problem, thus benchmarking the engineered design to prescribed, and possibly unquantified, performance criteria.

The clear need for an engineered approach in many modern building designs implies that 'design' cannot be implemented in a purely prescriptive manner [27]. Comparison of a performance-based design with a prescribed design cannot therefore be like-for-like. Designing to demonstrate equivalence with a prescribed solution implies that the ultimate goal of performance-based design is to demonstrate that the 'exact' design, optimized by all other professionals, delivers a level of safety equivalent to that prescribed by the fire safety regulations. Thus, even in the most progressive jurisdictions, the individual charged with the fire safety design of a building is rarely empowered to contribute to the potential optimization of the final design, but rather is restricted to a goal of obtaining approval for the pre-determined design with minimum disruption to the overall process (in which they are clearly a non-integrated participant); fire safety becomes a design constraint rather than a design generator, and there is little motivation to introduce fire safety considerations into the building design process. Furthermore, the technical soundness of this 'equivalence' concept is doubtful in most cases (e.g. [28]).

Forty years after the inception of the Fire Safety Engineering programme at The University *of* Edinburgh, this paper assesses and takes stock of some of the above issues, with the primary aim being an examination of the potential value of integrating contemporary fire safety considerations as *variables* within an iterative building design process. First, a brief summary is given of the evolution of fire safety design processes and the role of fire safety considerations in design. Selected views of various key stakeholders in the building design industry are illustrated to paint a picture of their perceptions of the current role of fire safety considerations in building design. The status of fire safety engineering as a discipline is presented through the eyes of these stakeholders so as to establish the factors that are limiting the potential value of better integration of fire safety in the building design process. Finally, the characteristics of the Fire Safety *Designer* – the individual who can truly materialize the full value of integrated fire safety engineering design – is set out, in contrast with the Fire Safety *Code Consultant* or the Fire Safety *Engineer* who are charged primarily with producing and *delivering* fire safe building 'designs'.

3. An international technical seminar in fire safety engineering

In an attempt to better understand the important issues noted above, researchers at The University *of* Edinburgh, with support from The Lloyd's Register Foundation (LRF), organized a five-day international seminar (The Seminar) under the theme of 'integration of fire safety design in the overall design of modern buildings.' The Seminar, held in June 2012 in Gullane, Scotland, gathered selected global experts in disciplines directly and indirectly involved in building design to discuss the current state of fire safety engineering practice. Several of the participants were selected for their backgrounds as leading architects or structural engineers, with a general awareness of fire safety design practice but with little direct knowledge of how it is, or could be, integrated in practice. Presentations were given by participants; these were interspersed with focused, mediated discussions (see Table 1).

4. The evolution of fire safety design in buildings

For centuries, fire safety has played a central role in the building design process. Concepts of fire safety in buildings can be traced back to ancient Rome, when Emperor Augustus created the first fire brigades, the "*Praefectus Vigilum*", who were in charge of vigils for both fire safety and crime prevention. As cities developed throughout history, several disastrous conflagrations occurred, including the Great Fire of London in 1666 [29] and others towards the end of the 19th Century. Fire safety considerations, in the form of building design *rules*, thereafter became influential in dictating the construction materials and methods that could be used in rapidly growing and densifying cities, as well as in influencing urban design and municipal layouts intended to ensure adequate life safety and property protection against fire [21].

During the second half of the Eighteenth Century, coincident with the industrial revolution, *engineering* as emerged as a distinct professional discipline (or rather disciplines) with the aim of finding solutions to the technological problems of the times. The first forays into modern engineering were made by individuals with both scientific and practical knowledge. These individuals were able to rationally account for the necessary factors and give appropriate solutions accounting for a broad set of variables and constraints despite the limited knowledge available