Fire safety regulation

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FIRE SAFETY REGULATION: PRESCRIPTION, PERFORMANCE, AND PROFESSIONALISM.

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ABSTRACT

Fire safety regulation is changing as adherence to prescriptive requirements is being replaced or complemented by an approach based on performance based design (PBD). However, this shift in regulatory practice raises important issues concerning the ability of regulators to provide competent oversight of fire safety engineering. This stems from the inevitable 'expertise asymmetry' that exists between regulators and those who are regulated, and means that regulators must rely on, and trust, data and analysis that is produced by industry. This dilemma could logically be resolved if fire safety engineering was accorded the status of a self-regulating profession whose competence and ethics were trusted by regulators. However, there are two main barriers to this: doubts about whether fire safety engineering is yet sufficiently mature as a profession; and concerns about whether the probabilistic nature of fire risks make fire safety engineering unsuitable for self-regulation.

INTRODUCTION

Regulation has long been a feature of fire safety engineering, and one that is widely acknowledged to have greatly reduced fire casualties during the twentieth century. Initially implementation of this regulation was driven by major fires with common-sense interpretation of the factors involved leading to prescriptive requirements for new buildings. For example, following the Great Fire of London of 1666 regulations were introduced affecting the width of roads, the use of materials (brick or stone, not wood), the width of party walls, etc. [1] This type of prescriptive regulation was augmented during the mid twentieth century by knowledge gained from standard testing, particularly as regards the fire resistance of materials and building elements. The main US standard furnace test, ASTM (American Society for Testing and Materials) E119, introduced in 1918, and the similar British Standard 476 test standards first promulgated in 1932, specify time-temperature curves according to which structural elements such as beams and columns are exposed under defined conditions in a furnace. [2] These standardised tests provided a mechanism by which crude measures of fire resistance, such as party walls needing to be two bricks thick (as set out in the regulations that resulted from the Great Fire of London), could be quantified into more comparable measures such as, say, 60 minutes fire resistance. Prescriptive regulation thus became underpinned by exhaustive schedules listing the required fire resistance of building elements. [3]

It was always recognised that such standard testing provided comparability rather than an accurate representation of real fires, and post-war research (for example, at the Fire Research Station in the UK) sought better understanding of the fundamentals of fire and smoke phenomena and of the structural responses of buildings. This better understanding made it possible to argue that fire safety knowledge was sufficiently advanced for bespoke engineering solutions to present a viable alternative to prescriptive regulation. Moreover, practical application of this knowledge in modelling tools became attractive with the greater computer power that became readily available in the late twentieth century. Rather than any particular type of building being required to incorporate the prescriptive 'one-size-fits-all' fire safety features, buildings could then have fire safety solutions designed individually through a Performance Based Design (PBD) approach. [4] Such PBD fire safety engineering was seen as desirable because it could enable the use of innovative building designs and materials, allow the use of constrained or usually shaped sites that would otherwise be inhibited if strict compliance with prescriptive rules was required, enable fire risks to be addressed rationally, and in some cases be less costly than prescriptive solutions that for many buildings include large margins of safety.

However, this shift to PBD fire engineering has raised concerns about the regulation of fire safety solutions. In a PBD approach, who decides (and on what basis) what constitutes a sufficient level of fire safety? [5] Does the use of PBD mean that acceptable levels of safety become a matter for engineers' design choices rather than being societally mandated in regulatory requirements? [6] More specifically, if fire safety solutions are implemented and justified through the use of state-of-the-art knowledge and modelling tools, can regulators have sufficient expertise to understand what they are being asked to approve?

This paper addresses these concerns through comparison with regulatory practices in other industries (aviation and pharmaceuticals). The key challenge for regulation of complex technologies lies in the 'expertise asymmetry' between regulators and those that are regulated. Unless regulators are heavily funded to enable them to maintain high levels of technical competence this expertise asymmetry inevitably means that regulators must rely on data and analysis provided by those they are regulating. This means in practice that many industries in effect self-regulate to some extent, and raises the question of whether such a practice should be formalised for fire safety. One mechanism for doing this would be through the acceptance by regulators that professional accreditation of fire engineers provides sufficient assurance of effective fire safety solutions, and the potential for such an approach is considered through a comparison with regulation of structural engineering.

REGULATION OF TECHNOLOGY

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Advances in technology can produce many benefits, but typically there are negative consequences too, and the classic societal response has been to attempt to maximise the benefits while mitigating any harmful consequences through regulation. Regulatory effectiveness depends on there being sufficient understanding of how these impacts occur and how regulations would ameliorate harmful consequences while sustaining technology's benefits. Regulators thus need to know about the performance of technology. To what extent does a drug cause side-effects relative to its benefits? [7] Are planes safe enough to carry passengers? [8] Do genetically modified crops risk contamination of natural species? [9] Or, are building sufficiently safe as regards fire risks?

However, the extent to which regulators need to understand the performance of technology varies according to the type of regulation. Three approaches are typically used, with regulation focused on: (1) achieving certain measurable outcomes (e.g. a level of pollution in industrial effluent); (2) policing the use of prescribed techniques (e.g. the use of 'best available technology' for a particular industrial process); or (3) being able to assess prospective performance as satisfactory (e.g. will an aircraft design be reliable enough that each safety critical system will suffer no more than one failure in every billion hours of flight). The first of these regulatory approaches measures actual outcomes retrospectively and does not require the regulator to have in-depth knowledge of the processes being regulated. However, such an approach requires some tolerance of unsatisfactory outcomes. Whereas it may provide a suitable approach for regulation of effluent from paper mills or breweries (most of whose discharges are only harmful to ecosystems in excessive concentrations), such an approach has not been seen as suitable for the regulation of airliner reliability, drug safety, or indeed fire safety. Although individuals or organisations that are held responsible for fire casualties or damage can be prosecuted, fire safety regulation has not been predicated on retrospective measurement of fire outcomes.

Instead fire safety regulation has traditionally sought to attain satisfactory outcomes through prescriptive regulation that requires the use of specific approaches for any given type of building. Prescriptive fire safety regulations thus specify required building characteristics such as the fire resistance of structures (as rated in furnace tests), enclosed stairways of particular sizes, maximum travel distances to stairs, whether sprinklers should be used, and so on. Effective though these prescriptive regulations appear to have been, they have come to be seen as increasingly onerous and often irrational. In particular, because the prescriptive approach specifies particular solutions it can limit innovation in architectural design and use of new materials, and present insuperable barriers to developments in constrained sites. For example, Norman Foster's innovative design of Stansted airport envisaged a large, high-ceilinged space that would not have been allowed by the traditional prescriptive approach, instead requiring first principles fire safety engineering to convince regulators that the building was safe (see below).

In recent decades this prescriptive approach to fire safety regulation has been supplanted or complemented by a regulatory approach based on assessment of prospective performance in what is widely known as Performance Based Design (PBD). The introduction of PBD as a regulatory option addresses the dissatisfaction with the 'one-size-fits-all' approach of prescriptive regulation, and has been made possible by the belief that fundamental fire safety knowledge has progressed sufficiently to enable bespoke fire engineering solutions to be designed and assessed.

An important advantage of regulation focussed on prospective performance is that it facilitates innovation. Rather than strict prescriptive rules that have to be followed, the regulatory requirements are expressed in terms of overall performance. For example, in aviation regulation the Federal Aviation Administration (FAA) makes it clear that its regulatory approach seeks to ensure aircraft reliability without specifying particular technological approaches: 'As much as possible, regulations do not constrain designers a priori by specifying details such as material properties or the design of individual structures. Instead, designers are given a free hand to incorporate new materials, structural concepts, etc., so long as they accept the responsibility for showing that systems with innovative design features meet the FAA's stringent reliability requirements.' [10]

However, the challenge of this type of regulation is for the regulator to have sufficient competence to understand the proposed approaches sufficiently well to provide the desired oversight. While technologies are generally getting more complex, and reliant on more specialised knowledge, there is a contrasting reduction in the willingness of many governments to pay for regulatory oversight. There is thus an 'expertise asymmetry' in which regulators will inevitably have less understanding of the technology than those whose work is being regulated. Given the trend towards deregulation (certainly in the USA and UK), there seems little prospect that regulatory authorities will have their funding increased in order to reduce this expertise asymmetry. In the UK fire deaths have fallen significantly in recent year, making it impossible to argue in the face of competing demands on resources that government should spend more on fire safety regulation. [11]

Of course, it is likely that some fire disasters may still occur even with the very best regulation of prospective performance. The extent to which fire risks can be eliminated through the appropriate use of such knowledge may depend on the nature of the technology. Where technologies involve complex, tightly-coupled systems such as nuclear power stations, Perrow argues that 'normal accidents' are inevitable (though rare). [12] Perrow's argument is that minor variations in technological performance and practice will occasionally align in a sequence of events leading to disaster because, as summarised by Downer, 'trivial but irrepressible irregularities – the background static of normal technological practice - when taken together have inherent catastrophic potential.' [13]

It is an intriguing question (beyond the scope of this paper) as to how many fires can be seen as 'normal accidents', and whether the move to PBD makes such systemic failure more likely. Advocates of PBD would argue that first principles fire safety engineering enables elegant solutions that can reduce complexity. However, in practice many applications of PBD appear to be 'sticking plaster' solutions applied to achieve regulatory compliance for a building design driven by other considerations – possibly the artistic vision of the architect, more likely the commercial desire for greater saleable or rentable floor space. This latter form of 'remedial' fire safety engineering often relies on the use of active systems such as smoke control or fire shutters, and thus adds complexity that may produce technological systems more prone to normal accidents. It is therefore conceivable that some fire risks are not amenable to regulatory control based on rational analysis of prospective performance. However, for the purposes of this paper it is assumed that for the majority of buildings the better regulators understand the performance of the technology, the better they can ensure its safety.

In that case, the expertise asymmetry constitutes a crucial challenge for regulation because of the difficulty of assessing prospective performance. Whereas checking conformance with prescriptive regulations is in principle a straightforward 'box-ticking' exercise (although in practice prescriptive regulations are typically so complex that adjudication is often necessary to decide when a rule applies or even what a rule means), assessing the adequacy of prospective performance requires in-depth fire safety knowledge. But many regulators (e.g. in building control and in the fire services) will not have the same level of knowledge as that used by fire engineers in state-of-the-art implementations of PBD.

PBD fire safety engineering can simply involve straightforward hand calculations to demonstrate an inherent safety feature of a building. A classic early example was the way that Margaret Law of Arup Fire used 'an analytical and scientific rather than a conventional approach to fire safety' to demonstrate the safety of the architect's vision for the new Stansted airport building because the high ceiling design would act as a smoke reservoir, 'allowing plenty of time for the building to be evacuated before the fumes reached floor level'. [14] However, many instances of PBD now draw on the latest research findings with fire safety solutions derived through the use of modeling of fire and smoke dynamics, structural responses, and human behaviour.

Moreover, this increasing use of modeling tools (for example, the use of Computational Fluid Dynamics to demonstrate smoke control has become commonplace in some jurisdictions) in PBD can mean that some knowledge claims are in effect 'black-boxed', and thus opaque to many engineers as well as regulators. As Beard notes 'the user must be knowledgeable about the limitations and conditions of applicability of the model' because of 'the possibility of misuse of the model and methodology, or misinterpretation of results.' [15] Increasingly sophisticated graphical outputs for such modeling tools add to the risk that some regulators might be unaware of how little they understand. While regulators can, and often do, augment their own expertise through the use of outside review, decisions about approval ultimately rest with the regulator and depend on how well they understand the claims made about the efficacy of PBD solutions.

EXPERTISE ASYMMETRY AND DELEGATED REGULATION

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The issues raised by expertise asymmetry can be explored by brief analysis of regulation in two other industries: pharmaceuticals and aviation. In both these industries regulators seeks to understand performance before the technologies are approved for use in order to protect the public. In the case of new drugs, this assessment of prospective performance hinges on cost/benefit type judgments as to whether efficacy relative to existing treatments is sufficiently great to outweigh any side-effects. In aviation, the assessment is purported to assess whether a required level of reliability has been attained, with the US FAA having a goal of each safety-critical system having no more than one failure in every billion hours of flight. [16]

Testing is central to both pharmaceutical and aviation regulation. In pharmaceuticals, satisfactory results in animal tests can lead to the approval of human trials and the results of these are interpreted to decide whether a new drug is both safe and effective. In the US, drug regulation is carried out by the Food and Drug Administration (FDA) and its experts assess the available data to decide whether a new drug should be approved, and at what doses. Similarly, US aviation regulation is carried out by the FAA (in conjunction with its European counterpart) and relies heavily on test data provided by manufacturers such as Boeing and Airbus.

The problem facing these regulators is that they rely on industry to provide not just virtually all the data that they use for assessing performance, but also much of the analysis of that data. In the case of drug trials, data can be presented selectively, and trials that do not provide the desired results can simply be suppressed and not made available to the FDA (as of course is the case for furnace testing done by manufacturers to demonstrate fire resistance). Moreover, approval decisions often hinge on complex judgment calls about efficacy relative to existing treatments, potential side-effects, and the severity of the illness. Where these judgments are finely balanced, further expert advice may be sought, but these experts are rarely independent from the drug industry as their very expertise stems from their work in the same field, and they will most likely be in receipt of industry funding to do this research (and many may also have more direct connections with industry through consultancy work, as well as being share holders).

In essence, therefore, although the FDA is in principle the regulator of new drugs approval in the USA, its reliance on data and expert advice from industry (or industry-influenced) sources means that in practice the industry plays a significant role in regulating itself. In UK drug regulation even some of the regulators themselves have ‘direct and indirect financial interests in pharmaceutical companies’, resulting in what Abraham and Davis call ‘permissive regulation’. [17] This form of ‘regulatory capture’ raises serious concerns about whether the right balance has been struck between commercial interests and public safety.

Whereas the expertise asymmetry problem is unacknowledged in pharmaceutical regulation it has long been recognized as an issue for aviation, where it was realized that government regulators could not hope to stay sufficiently abreast of the wide variety of complex technologies involved. Instead, the FAA has sought to mitigate the expertise asymmetry by coopting senior engineers from the aviation industry to help with reliability assessments. The FAA’s approach recognizes that only those involved in the development of aviation technologies have sufficient knowledge to judge what is safe or not. Thus, the industry largely self-regulates because the FAA delegates much of the task to these Designated Engineering Representatives. [18]

Aviation regulation is generally thought to work well in that air travel is relatively safe (certainly compared to other means of transport). Two aspects of the airliner innovation system explain why in this industry self-regulation works in maintaining public safety. First, the commercial interests of airliner manufacturers are strongly aligned with safety because of the reputational damage that can result from a major accident. The very visible nature of aircraft disasters in which the name of the manufacturer is likely to be reported, along with the high numbers of fatalities that often result from one accident, mean that any hint of wrong-doing could greatly impact on commercial performance. Second, airliner innovation is incremental in nature and thus past performance is generally a good guide to future performance (disasters such as those in the 1950s caused by metal fatigue in the Comet – the first jet airliner – have made the industry reluctant to introduce radical innovations). As Downer [19] notes:

> Reliability assessments of new civil aircraft lean very heavily on inferences from the – statistically well-established – data from earlier, different, aircraft designs. This is viable because the architects of new aircraft are highly conservative when developing new models. Large civil aircraft change only very incrementally between generations. Innovations are extremely modest, with new technologies being withheld until their reliability has been well-established in other contexts (in military aircraft, for instance).

DELEGATION TO PROFESSIONALS

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When regulation requires close scrutiny of the prospective performance of complex technology, the expertise asymmetry means that some level of delegation is unavoidable. Those who develop the technology will best know how to judge its performance, but at the same time will also be susceptible to aligning their judgements with their organisational and commercial interests. In aviation this has not proved problematic because of the incremental nature of innovation in airliner technology and the great reputational damage that could be done to the commercial success of longstanding companies such as Boeing and Airbus.

Aviation regulators trust the industry to act responsibly and provide accurate and honest appraisals of technical performance. Downer [20] thus argues in the case of aviation that 'high-technology regulators contend with an intractable technical problem by turning it into a more tractable social problem, such that, despite appearances to the contrary, the FAA quietly assess the people who build aeroplanes in lieu of assessing actual aeroplanes'. Other industries, where innovation does not follow such a gradual incremental path and where there are more companies with lower public profiles, may be more susceptible to a form of regulatory capture in which the 'expertise asymmetry' renders regulators unable to assure public safety. While there are large engineering companies that take great care to maintain their reputations, fire safety design is also carried out by many small operations for which the longevity of the business is likely to be much shorter than that of the buildings they design. Not only might such small operators be tempted by short-term economic gains, but also they may lack the full range of expertise to carry out competent PBD.

However, an alternative model for self-regulation, in which people rather than technology are assessed, relies not on the alignment of the commercial interests of companies with the public good, but rather on the alignment of the behaviour of individual professionals working for those companies. The essence of a profession such as medicine or law is not just that the individual professionals are competent in a particular type of knowledge-based expertise, but also that they adhere to a particular code of conduct.

Structural engineering provides a model for how fire engineering self-regulation could operate, clearly analogous to fire safety regulation because both aim to assure safety in the built environment. The work of structural engineers is typically not subject to detailed examination by regulators; rather structural engineers are trusted to be competent professionals. It is thus the people, and not their work that is regulated, and this regulation takes the form of effective self-regulation based around the accreditation of structural engineering as a profession Although the specifics vary between jurisdictions, this accreditation of structural engineering typically involves two components: education and experience. If a structural engineer has completed the requisite educational qualifications and accrued sufficient relevant experience then they are deemed competent by virtue of the resulting accreditation, and this means that they can practise their profession in that jurisdiction.

Regulators may provide some oversight of the work of structural engineers, for example in England and Wales noting whether Approved Document A has been used. However, regulators will not normally seek to analyse or second-guess a structural engineer's calculations. In some jurisdictions the reliance on engineers' professionalism can be almost total. Thus, for example, the Building (Scotland) Act 2003 offers the option that 'experienced, competent and responsible professionals can certify compliance with the Building Regulations without any further check by local authorities, provided that they are employed by reputable companies operating proper checking procedures.' [21]

Many would like to see fire safety engineers accorded the same status as competent, trust-worthy professionals. A significant step towards this came in 1996 when the Institution of Fire Engineers (IFE) was licensed by the Engineering Council to register members with the appropriate professional status according to their educational and experiential standing. However, this accreditation operates as a weak guarantor of professional behaviour in the UK because it is not a necessary requirement to operate as a fire safety engineer. This is in contrast to jurisdictions such as the USA that have a strong form of accreditation whereby only registered/licensed engineers are able to sign off designs.

In any case, even in the USA regulators scrutinise fire safety designs in detail. A number of factors may explain why regulation continues to be focussed on the quality of fire safety projects rather than on the quality of the engineers responsible for them. In particular, there are two ways in which fire safety engineering can be argued to differ from structural engineering. First, fire safety failures are highly probabilistic in nature, and sometimes many different factors need to interact to produce disastrous outcomes. Even when the causes of structural failure are probabilistic, for example due to earthquakes, the structural responses can largely be understood in terms of deterministic processes. The key aspect of fire safety engineering was summarised by Bullock and Monaghan [22]:

> It is also crucial to recognise that the thing that sets Fire Engineering apart from the majority of other engineering disciplines in the built environment is that fire is an accidental loading condition (ie there is a significant probabilistic aspect to its application), whereas other areas of design such as structural, acoustic and thermal performance are all 'normal' day-to-day service conditions.
>
> Failure to design and construct a building properly in terms of 'normal' service conditions tends to lead to a situation where resulting problems manifest themselves pretty quickly in terms of customer dissatisfaction. This is in marked contrast to defects in relation to fire safety that may not become apparent until there is a significant fire, (in itself, a probabilistic event).

This difference may explain why there is less explicit learning from incidences where fire safety engineering is done badly. Unless a particular set of circumstance coincide many potential fire safety engineering failures may lie dormant throughout the whole lifetime of a building, and thus provide no feedback both as regards identifying the individuals responsible and informing the profession as a whole. Even when they do occur, major fires are rare and often poorly interrogated to gain useful engineering feedback. In contrast, structural engineering failures are usually highly visible, and learning from disasters is prioritised. For example, the Institution of Structural Engineers has an Earthquake Engineering Field Investigation Team (EEFIT) that is a funded group of structural engineers who go to major earthquake sites globally and study building performance. [23] There is no such 'FEFIT' group to investigate major fire engineering failures, and proposals to create one have so far have been ignored.

The disparate and probabilistic nature of fire safety failures is also reflected in the heterogeneous nature of fire safety engineering as a profession. Not only is fire safety engineering very new as a profession compared to structural engineering, but it is also heterogeneous both as regards the disciplines involved (fire and smoke dynamics, structural response, and human behaviour) and the backgrounds of many involved. As Ben Bradford, chairman of the Fire Industry Association Fire Risk Assessment Councils Professional Standards Working Group, notes 'the fire safety profession is in its infancy and the constituent base is very fragmented.' [24]

Apart from anything else, this fragmented constituency raises issues about accreditation through peer review. In principle, peer review should uphold a coherent set of standards as regards competency and ethics, but the issue for fire safety engineering is whether the profession as it is currently composed is sufficiently homogenous to have this coherence. Many of the new generation of fire safety engineers have high levels of education (often to PhD level) but little experience, whereas the 'old guard' may have less education, but decades of experience (albeit in a prescriptive regulatory environment). It may simply require some time before the balance between education and experience held by those who are considered professional fire safety engineers reaches a state that would be considered ideal for a profession.

In addition, any lack of coherence in the expertise required to be a fire safety professional would raise concerns about the way that society arbitrates unsatisfactory professional performance through litigation. Again, comparison with structural engineering is instructive. The case of the Abbeystead Pumping Station, where a methane explosion caused 16 deaths and 22 injuries in 1984, provides a precedent for how professional performance is assessed under the law. Ultimately, the consulting engineers, Binnie and Partners, were found liable for negligence, but the judge, Lord Justice Bingham, summed up the argument for professional liability thus [25]:

> a professional man [sic] should command the corpus of knowledge which forms part of the professional equipment of the ordinary member of the profession. He should not lag behind

> other ordinarily assiduous and intelligent members of his profession in knowledge of new advances, discoveries or developments in his field. He should have such awareness as an ordinarily competent practitioner would have of the deficiencies in his knowledge and the limitations on his skill. He should be alert to the hazards and risks inherent in any professional task he undertakes to the extent that other ordinarily competent members of the profession would be alert. He must bring to any professional task he undertakes no less expertise, skill and care than other ordinarily competent members of his profession would bring, but need not bring more.

Thus, if we apply this same standard to fire safety then it is clear that professional liability hinges on a coherent view as to what comprises an ‘ordinarily competent practitioner’. Fire safety engineering can therefore only be accorded the self-regulating privilege of a mature profession when it is clear that there is a level of knowledge and expertise (including awareness of the limitations of this expertise) that all accredited fire safety engineers would be expected to hold.

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DISCUSSION

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Traditional prescriptive regulation of fire safety is unlikely to disappear any time soon. For many types of buildings the prescriptive guidelines provide fire safety features that are straightforward to implement and approve. However, we do not know how these prescriptive approaches perform, except in so far as to note that fire deaths in the UK, for example, are lower than in living memory. Dissatisfaction with the prescriptive approach is thus not due to poor outcomes, but rather to its limiting effect on innovation, along with its imposition in some cases of what are thought to be overly restrictive, irrational, and costly requirements. As a result, the use of PBD is becoming increasingly common (in some places more than others), and this raises serious issues for regulatory oversight.

A key challenge is that fire engineered PBD solutions rely on knowledge claims about a wide range of phenomena encompassing fire and smoke dynamics, structural responses and human behaviour, and there will almost inevitably be an ‘expertise asymmetry’ between the regulators and those they regulate. Regulators are now faced with seeking to adjudicate on fire safety knowledge claims made in PBD proposals, just as they have traditionally adjudicated on code compliance when working to prescriptive guidelines. However, whereas the regulators may have the upper hand when it comes to knowledge of the codes and their application, the opposite is likely to be true when it comes to knowledge of fundamental fire safety knowledge and its application.

Given limited funding for regulation, the introduction of PBD as a fire safety engineering option thus means that regulators must increasingly rely on the fire safety profession to provide relevant data and analysis, leading to some degree of *de facto* self-regulation. An alternative to this approach would be to make self-regulation explicit by shifting regulatory oversight away from individual projects and on to individual professionals. If fire safety engineers were accorded the same status given to structural engineers as a self-regulating profession then the accreditation of individual fire safety engineers could be taken as a guarantee of their competence and ethical behaviour. However, there are two potential barriers to this. First, fire safety engineering is a relatively new discipline and its practitioners come from a wide range of backgrounds, with disparate levels of education and experience. It may simply take some time, along with active management of accreditation requirements, before fire safety engineering is sufficiently coherent as a discipline to be accorded full self-regulating professional status. Second, and perhaps more fundamental, the ability of fire safety engineers to ensure adequate safety depends on the reliability of their knowledge about fire risks and the techniques used to counter them, but fires are rare, typically involve many probabilistic factors, and are often poorly interrogated.

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REFERENCES

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1. Charles II 1666 declaration is in the UK National Archives in file SP 9/171.
2. See V. Babrauskas, R. B. Williamson, The Historical Basis of Fire Resistance Testing – Part I, Fire Technology, Vol. 14, Issue 3, (1978), 184-194: V. Babrauska, R. B. Williamson, The Historical Basis of Fire Resistance Testing – Part II, Fire Technology, Vol. 14, Issue 4, (1978), 304-316.
3. In the UK this work resulted first in the post-war Fire Grading of Buildings: Part I General Principles and Structural Performance (HMSO, 1946) and Fire Grading of Buildings: Part II Fire Fighting Equipment; Part III Personal Safety; Part IV Chimneys and Flues (HMSO, 1952), and then in national building regulations in Scotland and then England & Wales in the 1960s.
4. B. J. Meacham, The Evolution of Performance-Based Codes and Fire Safety Design Methods, NIST-GCR-98-761 (National Institute of Standards and Technology, US Department of Commerce, 1998).
5. See, for example, V. Babrauskas, Performance-Based Building Codes: What will happen to the Levels of Safety? 1999, Fire Science and Technology Inc, 9000-300th Place SE, Issaquah WA 98027, USA.
6. V. M. Brannigan, Fire Scenarios or Scenario Fires? Can Fire Safety Science Provide the Critical Inputs for Performance Based Fire Safety Analyses?, Fire Safety Science – Proceedings of the Sixth International Symposium, 1999, 207-218.
7. J. Abraham, J. Sheppard, Complacent and Conflicting Scientific Expertise in British and American Drug Regulation: Clinical Risk Assessment of Trizolam, Social Studies of Science, Vol. 26, No. 9 (1999), 803-843.
8. J. Downer, Trust and Technology: The Social Foundations of Aviation Regulation, The British Journal of Sociology, Vol. 61, Issue 1, (2010), 83-106; J. Downer, On Audits and Airplanes: Redundancy and Reliability-assessment in High Technologies, Accounting, Organizations and Society, Vol. 36, (2011), 269-283.
9. L. Levidow, Precautionary Uncertainty: Regulating GM Crops in Europe, Social Studies of Science, Vol. 31, No. 6, (2001), 842-74.
10. National Research Council, Improving the Continued Airworthiness of Civil Aircraft (National Academy Press, 1998), 12.
11. Interview with UK regulator, 25 November 2014. Annual fire deaths in England have dropped from over 700 in 1981-82 to 275 in 2013-2014. See Department for Communities and Local Government, Fire Statistics Monitor: England April 2013 to March 2014, 2 July 2014. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/325696/Fire_Statistics_Monitor_April_2013_to_March_2014_final__3_.pdf
12. C. Perrow, Normal Accidents: Living with High-Risk Technologies (New York, Basic Books: 1984).
13. J. Downer,"737-Cabriolet": The Limits of Knowledge and the Sociology of Inevitable Failure, American Journal of Sociology, 117(3), (2011), 725-762, at 733.
14. C. Davies How it was built, The Architectural Review (21 April 1991).
15. A. Beard, Fire Models and Design, Fire Safety Journal, Vol. 28, (1997), 117-138, at 131-132.
16. National Research Council, Improving the Continued Airworthiness of Civil Aircraft (National Academy Press, 1998), 12.
17. J. Abraham, C. Davis, Drug Evaluation and the Permissive Principle: Continuities and Contradictions between Standards and Practices in Antidepressant Regulation, Social Studies of Science, Vol. 39, No. 4, (2009), 569-598 at 590.
18. J. Downer, Trust and Technology: The Social Foundations of Aviation Regulation, The British Journal of Sociology, Vol. 61, Issue 1, (2010), 88.
19. J. Downer, On Audits and Airplanes: Redundancy and Reliability-assessment in High Technologies, Accounting, Organizations and Society, Vol. 36, (2011), 279.

20. J. Downer, Trust and Technology: The Social Foundations of Aviation Regulation, The British Journal of Sociology, Vol. 61, Issue 1, (2010), 84.
21. Scottish Buildings Standards Agency, A New Building Standards System for Scotland. https://www.ser-ltd.com/scotland/ClientGuide/ClientGuide.pdf
22. M. Bullock, A. Monaghan, The Development of Competency in Fire Engineering, International Fire Professional, (January 2012), Issue No. 7, 14-17, at 15.
23. http://www.istructe.org/resources-centre/technical-topic-areas/eefit My thanks to Luke Bisby for pointing out this distinction.
24. http://www.bbseven.com/ideas/files/professional-and-ethica-standards-in-fire-safety.html
25. S. J. A. Tolson, Design Liability, Defective Buildings and Remedies at Law 2007, 10-12 September 2007. http://www.fenwickelliott.com/files/Contract%2016%20-%20Design%20Liability,%20Defective%20Buildings%20and%20Remedies%20at%20Law.pdf