An investigation into resilient fire engineering building design

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An investigation into resilient fire engineering building design

Peter Wilkinson
AN INVESTIGATION INTO RESILIENT FIRE ENGINEERING BUILDING DESIGN

By

Peter J Wilkinson

A dissertation thesis submitted in partial fulfilment of the requirements for the award of the degree Doctor of Engineering (EngD), at Loughborough University

October 2012

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Finally, I would like to thank my wife and family for their support and invaluable proof-reading skills. I could not have done this without you.
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ABSTRACT

As an engineering discipline within the United Kingdom, fire engineering is relatively young. It has been accepted as an alternative to traditional prescriptive means of meeting the functional requirements of the Building Regulations since the publication of the 1985 edition of Approved Document B, which was one of a series issued to provide practical guidance on the requirements of the Building Regulations for England and Wales. It deals specifically with fire safety requirements for building work.

Performance-based fire engineering design methods have facilitated architectural design freedoms and supported creative construction. This research has established that for a successful and holistic fire engineering strategy to be developed;

- The end-user client should describe from the outset what they want their building or facility to achieve, and there should be an agreed process for this to happen;
- Commercial property insurers should be consulted and exploited as a useful and intelligent resource to the design team; and
- Fire engineering practitioners should fulfil their role as advisers to the architect, or building design team, in order to achieve the agreed objectives.

However, it has become evident that since fire engineering has become more established, it is clear that we are far from this ideal situation. Significant concerns have been raised regarding various elements of the design process including the ability to consider aspects other than life safety.

Within this discourse, the author has outlined their research investigating how performance-based fire engineering techniques are used within building design. The literature review
explores key concepts of fire engineering including definitions and benefits etc., and also describes concerns regarding the motivations for applying fire engineering techniques to building design. Survey-based research suggests that greater input is required from commercial property insurers at the building design stage in order to champion property protection and business resilience objectives. A case-study investigation, however, concluded that for a number of reasons, it is impractical to expect the insurer to influence the design team to the extent desired.

Therefore, in response to these various research activities, the concept of business impact analysis has been introduced and developed by the author to ensure that property protection and business continuity objectives are at the forefront of new building design, whether the insurer is involved in the process or not.

In order to help consulting fire engineers and architectural design teams incorporate business protection objectives in their fire safety designs, there is a requirement for the established British Standard, which defines a fire engineering procedure, to be enhanced. The author was instrumental in acquiring support from the Technical Committee within BSI responsible for maintaining the Standard, and PD 7974-8 Application of fire safety engineering principles to the design of buildings- Part 8: Property protection, mission continuity and resilience (British Standards institution, 2012) has been developed and published, led by the author.

This significant new Standard embeds the use of a business impact analysis as an integral part of the qualitative design review process. Without following the BIA process as described in the draft document PD7974-8, business resilience objectives may be missed within the building design phase, allowing an inferior package of fire protection measures to be incorporated into building developments. For the first time, this new document will enable the building designer to be fully cognisant of their client's critical processes and the resources
required to support these processes. It will therefore enable the appropriate fire safety measures to be incorporated into the building design to enhance business resilience.

Initial evaluations of this guide through various stakeholder dissemination activities and a public consultation process has been positive. The potential concerns that the evaluations have raised regarding the role of the fire engineer throughout the building design phase, and regarding the prevalence of BIA within organisations will be addressed in the guide and the way it is publicised upon its launch.

KEY WORDS

Fire engineering; Resilient building design; Business and property protection
PREFACE

The research presented within this thesis was conducted in partial fulfilment of the requirements for the award of an Engineering Doctorate (EngD) degree at the Centre for Innovative and Collaborative Construction Engineering (CICE), Loughborough University. The research commenced in 2008 and was completed in 2012.

The EngD is, in essence, an industry-based PhD, designed to produce doctoral graduates who can drive innovation in engineering with technical, managerial and business competence. This EngD research project was sponsored by the Fire Protection Association and the Engineering and Physical Sciences Research Council (EPSRC), and was supported by the RISCAuthority.

The EngD is examined on the basis of a thesis containing at least three research publications. This thesis contains a discourse which is supported by four publications, two journal papers and two conference papers, located in Appendices A to D. The reader is encouraged to read the appended papers in addition to the thesis.
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LIST OF PAPERS

The following papers, included in the appendices, have been produced in partial fulfilment of the award requirements of the Engineering Doctorate during the course of the research.

PAPER 1 (SEE APPENDIX A)


PAPER 2 (SEE APPENDIX B)


PAPER 3 (SEE APPENDIX C)

PAPER 4 (SEE APPENDIX D)

1 INTRODUCTION

This chapter sets the scene for the research and puts all subsequent chapters of this thesis into context. It highlights the need for the research and defines the aims and objectives, and then it describes the organisational context of the research in terms of the tasks undertaken, the publications and this thesis structure.

1.1 THE GENERAL SUBJECT DOMAIN

Fire engineering is the use of engineering principles for the achievement of fire safety (British Standards Institution, 2003). As an engineering discipline, fire engineering is relatively young, and it has been accepted as an alternative means of meeting the functional requirements of the Building Regulations since the publication of the 1985 edition of Approved Document B (Great Britain, 1985b). In the decades since its introduction, the use of fire engineering as a performance-based fire safety design methodology has steadily increased to a point where many new-build developments incorporate elements of non-compliance with prescriptive codes. It is now essential to review these developments in fire safety design approach, understand how fire engineering principles are applied in the UK, determine whether current practices are sufficient to ensure robust buildings, and address any identified inadequacies.

1.2 THE INDUSTRIAL SPONSOR

The Fire Protection Association (FPA) is the UK’s national fire safety organisation (Fire Protection Association, 2012), playing a pivotal role in promoting fire safety within industry, commerce and the wider public. One of 28 similar national bodies worldwide it was established in 1946 and receives strong support from the insurance industry, primarily
through the Association of British Insurers and Lloyd's. The FPA has close links to the fire and rescue services, insurance industry, Government, world-wide fire institutions and industry stakeholders. Operating on a not-for-profit basis the FPA invests in research developing and promulgating best practice in fire prevention and protection. Underpinned by an internationally recognised technical capability it also provides training to fire and rescue services and industry alike, and has a significant publications team and membership scheme.

The five stakeholders who currently sit on the FPA board are:

1. The Association of British Insurers (ABI);
2. Lloyd's of London;
3. The Chief Fire Officers Association (CFOA);
4. The Institution of Fire Engineers (IFE); and
5. The Fire Industry Association (FIA).

In addition to the Board of Directors, FPA has an Advisory Council, which has an independent chair and is made up of a broad range of stakeholders from the UK fire industry and includes representatives from both central and local government and from industry and commerce.

The agreed aims and objectives of the FPA are:

- To protect people and property and the environment by advancing fire prevention and protection techniques
- To collaborate with central Government, the Fire Service and other agencies in this work
- To focus national and European attention on these issues
- To influence consumers and business related decision making
Introduction

- To collect, analyse and publish statistics, identify trends and provide research
- To disseminate advice and information

Once wholly owned by UK insurers, but now independent, the Technical Division of the FPA remains the focal point for insurer technical support through a scheme called Risk Insight Strategy and Control Authority, known as RISCAuthority. RISCAuthority replaced the Medium Term Research Strategy funding scheme previously administered by the Association of British Insurers (ABI) in 2003. With a mission statement of ‘Reducing insurable risk through research, advice and best practice’ RISCAuthority was itself rebranded and launched to the market in November 2008.

In an analysis of emerging issues by RISCAuthority, fire engineering was identified as having the potential to influence some unforeseen adverse impacts on risks within the built environment.

1.3 THE CONTEXT OF THE RESEARCH

Within the European Union (EU), most national regulations define fire safety in prescriptive terms, i.e. the perceived required safety levels are achieved by specifying what has to be done, rather than what has to be achieved. As one of the principal aims of the EU is the removal of technical barriers to trade (BENEFUEU, 2002), there was a desire to move away from the prescriptive fire safety regime which can stifle innovation, lead to over design and higher construction costs and restrict the trading and use of products. In 1999, the consortium of six European fire safety institutions known as BENEFUEU held a workshop. It provided a first informal discussion between fire safety regulators on the need for change in the nature of national fire safety regulation. This workshop launched a European Commission study on ‘The benefits of fire safety engineering in the EU’. Reporting in July 2002, Task B of the
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study investigated the state of the art on fire engineering methodologies. It concluded that the evaluation of the fire safety design of a building is broken down, to simplify the process, into eight separate components of the system, known as sub-systems, belonging to either the tools for fire engineering evaluation, or the fire safety objectives. (BENEFEU, 2002) These sub-systems were described as follows;

1. Initiation and development of fire and fire effluents
2. Movement of fire effluents
3. Structural response and fire spread beyond the enclosure of origin
4. Detection, activation and suppression
5. Fire service intervention
6. Life, health and safety of people
7. Property protection
8. Environmental protection.

In the decade following this study, many of these sub-systems have been developed into codified documents and become established, in the UK, as best practice fire engineering processes. This is described in detail in Chapter 2, however fire safety objective described above as sub-system 7, Property protection, had not been developed.

Clearly, it is now essential to review these developments in fire safety design approach, understand how fire engineering principles are applied in the UK, investigate the consequences of the lack of fire engineering codes to address property protection specific objectives and address any identified inadequacies.
1.4 AIM AND OBJECTIVES

1.4.1 AIM

The aim of this research programme is to investigate resilient fire engineering building design, with a view to identifying best practices, current gaps and developing improvements.

1.4.2 OBJECTIVES

The key objective of this research programme is to influence change in the way fire engineering is often used with an emphasis on improving property and business resilience fire safety objective setting.

In order to achieve the key objective, work streams were identified, each with its own set of objectives. The work packages, as outlined below, have allowed the author to investigate well defined topics within the field of resilient fire engineering building design, gather evidence, form opinion, develop an understanding of the changes required, build a case to support the proposed changes, and then influence the change process;

1. A historic perspective of fire engineering.

• To establish the origins of, and review the state of the art of the fire engineering profession;

• To establish whether the skills and data required in order to practice fire engineering were available at inception, and whether the situation is different today;

• To understand the roles of, and the dynamics between, the varied stakeholders in fire engineering design processes; and

• To establish whether fire engineering has lived up to the expectation at conception.
2. Fire engineering and the role of the insurer.

- To understand the motivations of the stakeholders who champion business and property protection objectives;
- To establish whether the intended role of insurers within the QDR objectives setting process takes place in reality; and
- To demonstrate the benefits of early insurer involvement.

3. Fire engineering as a tool for business and property protection.

- To review current practices for ensuring business and property protection objectives are met in the building design process; and
- To develop methodologies for ensuring business and property protection objectives are met in the fire engineering design process.

4. Fire engineering- proposals for change.

- To draw together all strands of the previous sub-projects;
- To create a discourse to promote the concepts developed and propose further work to build on this research.

1.5 Novelty of Research

In light of very limited literature and research in this highly specialised domain of resilient fire engineering building design, this research has drawn many significant insights. The main novel insights from this research include;
• Contributing to the limited body of knowledge by documenting a detailed understanding of the historic development and state-of-the-art of fire engineering practices in the UK;

• Drawing new insights into the experiences and relationships between the various stakeholders in the fire engineering design process;

• Given deeper understanding of the role that the commercial property insurers play in the building design process, especially in the UK;

• Identified, articulated and documented a process involving Business Impact Analyses (BIA) to inform fire safety objective setting; and

• Created a significant new part to the British Standard which provides an important addition to the established framework used by fire engineering practitioners and the wider building design communities.

1.6 STRUCTURE OF THESIS

This thesis documents the work undertaken in this research project. This thesis is organised into five chapters as follows:

Chapter 1 introduces the EngD project, sets the context of the research, outlines the aim and objectives of the research and discusses the novelty of the research undertaken.

Chapter 2 presents a detailed review of existing literature on fire engineering and fire insurance.

Chapter 3 reviews a range of research methods and explains the methodology adopted in carrying out this EngD research.

Chapter 4 provides detailed descriptions of the Work Packages undertaken to meet the objectives of the research, the specific methods employed and the analysis conducted.
Chapter 5 outlines the key findings of the research and the impact of the research finding, a critical evaluation and areas for further research.

Central to this discourse are four papers, two published in journals and two presented at conferences. These papers also describe the steps taken in this doctoral research and should be read alongside the discourse.

Appendix A Journal paper, *A historic perspective of fire engineering in the UK*, defines fire engineering and documents the history of the development of the profession in the UK. It describes how fire engineering has matured and raises some concerns about how the methodology is sometimes applied.

Appendix B Conference paper, *Has fire engineering lived up to expectations?* builds upon a detailed literature review and includes knowledge elicited by interviewing key stakeholders. It concludes that fire engineering has facilitated architectural design freedoms, but concerns were raised about how fire engineering techniques are sometimes applied. The involvement of the commercial property insurer and the ability to champion fire safety objectives other than life safety were key themes.

Appendix C Conference paper *Insurer involvement in the fire safety engineering design process* explored the role of the commercial property insurer in greater detail via a case-study investigation. It concluded that, despite a small number of minor examples of good practice, the insurer does not play a suitably active role in the building design process.

Appendix D Journal paper *Using Business Impact Analyses to enhance resilient fire engineering building design* responds to these concerns and introduces a novel application of concepts to assist the building design team consider their client’s resilience requirements. It describes the development of a new British Standard guidance document to embed the use of a business impact analysis as an integral part of the qualitative design review process.
2 REVIEW OF RELATED LITERATURE

This chapter sets the research undertaken in context by thoroughly reviewing available literature and presenting the background and development of fire engineering. Whilst the main focus of this chapter is describing developments in the UK, the author’s participation in international conferences and Standards committees has given opportunities for the wider international perspective to be explored and exploited. Lessons learned from these events have contributed to the development of the tools as described in Chapter 4.

This Chapter sets out the chronology of the development of fire engineering in the UK and begins to discover some emerging issues.

2.1 FIRE ENGINEERING ORIGINS

2.1.1 DEVELOPMENT OF PRESCRIPTIVE GUIDANCE

Fire safety within the built environment has been a subject of concern for thousands of years. More than 2000 years ago, fires in Rome led to the development of rules governing the minimum width of roads in order to facilitate fire brigade access and reduce the likelihood of fire spread (University of Salford, Association of Building Engineers, 1994).

Statutory fire safety provision within the UK has evolved slowly over many centuries, largely driven in reaction to major disasters. In London, argues Law (1991), the most significant fire disaster was the Great Fire of 1666, when the major part of the city was destroyed. There was little loss of life, and the rules for rebuilding the city concentrated on reducing the spread of fire between buildings. Controls were placed on materials of construction, on the thickness of walls and on the width of streets, describes Law (1991) and Read (1993). These rules were rigidly prescribed.
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In the 19th century, after disastrous industrial fires killed fire fighters and gave major financial losses, further regulations were developed. In the 20th century, experiences of fires during the Second World War were incorporated into the Post-war Building Studies on Fire Grading of Buildings. Malhotra, et al. (1987) suggests that these were seen as landmark documents of their day influencing the technical content of the subsequent Building Regulations. By the time further amendments were made by 1976, the regulations comprised 307 pages, were highly prescriptive, and, in Law’s opinion, understood only by lawyers.

Whilst a detailed review of the development of fire safety legislation is outside the scope of this study, the following events and corresponding legislation during the 20th century are worthy of note (Loss Prevention Council, 1998);

Table 2.1: Significant fire events (Loss Prevention Council, 1998)

<table>
<thead>
<tr>
<th>Fire site</th>
<th>Death toll</th>
<th>Act of Parliament</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastwood Mills, Keighley, 1956</td>
<td>8</td>
<td>Factories Act, 1961</td>
</tr>
<tr>
<td>Henderson’s department Store, Liverpool, 1960</td>
<td>11</td>
<td>Offices, Shops and Railway Premises Act, 1963</td>
</tr>
<tr>
<td>Rose and Crown Hotel, Saffron Walden, 1969</td>
<td>11</td>
<td>Fire Precautions Act, 1971</td>
</tr>
<tr>
<td>Bradford City FC, 1985</td>
<td>58</td>
<td>Fire Safety and Safety of Places of Sport Act, 1987</td>
</tr>
<tr>
<td>King’s Cross Underground Station, 1987</td>
<td>27</td>
<td>Fire Precautions (Sub-surface Railway Stations) Regulations, 1989</td>
</tr>
</tbody>
</table>
Ferguson and Charters (1997) describe how even traditional prescriptive building regulation systems had procedures to oversee significant departures from the standard solution, albeit cumbersome in nature. In England and Wales such relaxations were at one time granted only by central Government, although this process was devolved to local Government.

Despite criticism, prescriptive building regulations have been an important component in the evolution of fire safety in buildings. It is acknowledged that (Hasofer, et al. 2007) prescriptive design has resulted in the achievement of safety levels which the community appears to accept.

2.1.2 Drivers for a New Approach

As a result of the large and rapid increase in innovative and diversified building design, including the expansion of air travel in the early 1970s, prescriptive regulations became demonstrably restrictive and inflexible. By way of example, air travel required airports to start handling large numbers of people, who were unfamiliar with the building, in a pleasant and efficient way. Designs based on the prescriptive standards of the time simply couldn’t cope with this new design requirement. Some engineers and scientists saw the possibility of applying scientific research directly to the design of individual buildings (Charters, 2006). These issues were discussed at the time of the design of Stansted Airport by Law (1985). One important issue relating to this airport design was the need for large compartment volumes, not permitted under Building Regulations without obtaining a relaxation. Law collected a range of data from experiments, surveys and fire statistics to illustrate how various measures could compensate for lack of fire resisting construction, known as compartmentation.
Others, including Ramachandran (2000), argued that prescriptive rules are highly empirical and could lead to costly over-designs, particularly for large buildings, thereby strengthening the case for an alternative approach.

The commitment of UK Government to deregulation and to reduce the burden on industry led, in 1985, to the introduction of new functional building regulations, i.e. the Building Regulations 1985 (American Society of Civil Engineers, et al. 1995).

The requirements for fire safety of buildings given in the 1985 regulations were set out in four functional requirements. Cooke and Deakin (ASCE, 1995) described the regime as thus. Designers were free to provide any solution that could be shown, to the satisfaction of the regulatory enforcement authority, to fulfil the functional requirements. Technical support to the regulations set out traditional approaches that were ‘approved’ by the Secretary of State as one way of satisfying the requirements. However, the functional nature of the regulations provided greater opportunities for the adoption of fire engineered approaches to fire safety design.

Interestingly, Billington, et al. (2002) reported that, with the introduction of the 1985 regulations, the property protection issue was deliberately set aside because the legislators’ role has been seen as being in life safety matters only.

Butcher (1992) added another note of caution regarding the use of fire engineering approaches immediately following the introduction of the 1985 regulations. Whilst he was very much in favour of the concept, he doubted whether the level of knowledge at the time could produce a genuine fire engineered solution. He identified that a vast amount of information was available in archives, research reports and studies of fire incidents which needed to be extracted and collated. He recommended a comprehensive research programme so that fire
engineered calculations could be based on experience rather than vague theory (Butcher, 1992). Bullock (1997) agrees with this assertion, stating that the fire engineer requires data in order to provide a quantifiable judgement and that sufficient empirically derived data and relevant analytical methods do not exist.

It was suggested by Cooke (ASTM, 1995) that the traditional prescriptive technical guidance accompanying the functional regulations would continue to be used for the majority of simple buildings, and that fire engineering would be used for large, complex buildings where the benefits were sufficient to justify the cost of the study.

Despite these contemporaneous insights from the time of the introduction of the 1985 regulations, no Regulatory Impact Assessment (RIA) has been found as part of the literature review. A RIA is a policy tool which assesses the impact, in terms of costs, benefits and risks of any proposed regulation which could affect businesses. The RIA process helps policy makers to think through the consequences of proposals, improving the quality of advice to Ministers and encouraging informed public debate (Home Office, 2012). If a RIA was not completed prior to the introduction of the 1985 regulations, then some of the unidentified risks must be manifest now.

From an overview of the development of performance code conducted by the National Research Council of Canada (Hadjisophocleous, et al. 1998), the following summary of advantages and disadvantages of prescriptive and performance-based regulations is shown in Table 2.2.
Table 2.2: Advantages and disadvantages of prescriptive-based regulations
(Hadjisophocleous, et al. 1998)

<table>
<thead>
<tr>
<th>Code type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prescriptive codes</td>
<td>• Straightforward evaluation of compliance with established requirements</td>
<td>• Requirements specified without statement of objectives</td>
</tr>
<tr>
<td></td>
<td>• No requirements for high level of engineering expertise</td>
<td>• Complexity of the structure of codes</td>
</tr>
<tr>
<td></td>
<td>• Requirements specified without statement of objectives</td>
<td>• No promotion of cost-effective designs</td>
</tr>
<tr>
<td></td>
<td>• Complexity of the structure of codes</td>
<td>• Very little flexibility for innovation</td>
</tr>
<tr>
<td></td>
<td>• No promotion of cost-effective designs</td>
<td>• Presumption that there is only one way of providing the level of safety</td>
</tr>
<tr>
<td>Performance codes</td>
<td>• Establishment of clear safety goals and leaving the means of achieving those goals to the designer</td>
<td>• Difficult to define quantitative levels of safety (performance criteria)</td>
</tr>
<tr>
<td></td>
<td>• Permit innovative design solutions that meet the performance requirements</td>
<td>• Need for education because of lack of understanding especially during the first stages of application</td>
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<td>• Eliminate technical barriers to trade for a smooth flow of products</td>
<td>• Difficult to evaluate compliance with established requirements</td>
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<td></td>
<td>• Facilitate harmonization of international regulation systems</td>
<td>• Need of computer models for evaluating performance</td>
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<td>• Facilitate use of new knowledge when available</td>
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<td></td>
<td>• Allow cost-effectiveness and flexibility of design</td>
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<td>• Non complex documents</td>
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<td>• Permit the prompt introduction of new technologies to the marketplace</td>
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2.2 THE DEVELOPMENT OF FIRE ENGINEERING

2.2.1 DEVELOPMENT OF A FIRE ENGINEERING CODE

Approved Document B was one of a series issued to provide practical guidance on the requirements of the Building Regulations for England and Wales. It dealt specifically with fire safety requirements for building work. Whilst formal recognition and acceptance of the use of fire engineering had been given in England and Wales within Approved Document B, no guidance on fire engineering processes, practices nor calculations methods was given. The pressure for guidance and a structure for the application of fire engineering principles to the design of buildings came from designers and an initiative by the British Standards Institution (BSI) to provide a Code of Practice on the subject.

In 1989 a format and list of contents for a comprehensive Code of Practice on the application of fire engineering principles to fire safety of buildings was presented to BSI. As described by Cooke (International Council for Building Research, Studies and Documentation. Working Commission 14: Fire Safety Engineering, et al. 1993), it was intended that the proposed code would cover general principles, life safety considerations, property safety considerations, mitigation of socially unacceptable events and reduction of economic loss. According to Cooke (1993) by the end of 1990, a small panel of fire safety engineers was formed with the support of Warrington Fire Research Centre, to undertake a three year contract, administered by BSI, to develop a framework for the application of fire engineering principles. This project would culminate in a Code of Practice giving a framework for the fire engineering design of buildings. The panel first met in March 1991 in order to discuss and agree the following objectives for the code;
The code should be analytical, with the acceptance that design could not always proceed entirely by quantification because some intuitive judgement might be necessary;

The code should state acceptable levels of life loss;

The code would be aimed principally at fire engineers. Whilst this means that only suitably qualified and experienced individuals might be able to undertake the analytical work, it would not necessarily mean that other members of the design, construction and building approval team would not be able to use the code;

The code would identify, allow and encourage the use of appropriate zone and field models;

Data and the methodology should have a high degree of transparency, i.e. the ability to trace where all the information came from; and

The principles and methodology should ideally be applicable to ‘any bounded space in which people might be present or nearby and where a fire might occur’.

Deakin (1999) described the resulting draft Code of Practice as the most important document produced in the UK in support of the use of more fundamental approaches to fire safety design. It provided the designer and the regulatory enforcement authorities with an overview of what was considered to be necessary. Deakin attempts to simplify the very complex design process and describes the way the code is divided into sub-systems. Importantly, it indicates that there are gaps in the knowledge, and that much has still to be achieved by the use of engineering judgement. Deakin comments that the ability to trace where the information within the code has come from, as described in the objectives above, focussed an unjustified emphasis on requiring demonstration of the validity and scope of the application of the
relationships cited. Interestingly, he concludes that the document has been viewed in a prescriptive manner, with focus on the theory rather than the framework for design.

The draft Code of Practice was published as a Draft for Development DD240 by BSI in 1997 (Billington, et al. 2002). Since then, the format and content were reviewed leading to, in 2001, BS7974 *Code of Practice on the Application of Fire Engineering Principles to the design of Buildings* being published. This code is supported by eight Published Documents, replicating the sub-systems defined in the draft, which contain detailed technical guidance on different aspects of fire engineering from background information to quantitative risk assessment (Charters, 2006).

In 2008, BS9999 *Code of practice for fire safety in the design, management and use of buildings* came into effect after over a decade in development. The concept behind the development of BS 9999 and BS 7974 is that technical guidance on fire safety is provided at three different levels. This permits a design approach to be adopted that corresponds to the complexity of the building and to the degree of flexibility required.

The three levels, as described by British Standards Institution (2008a) are as follows;

- General approach. This level is applicable to a majority of building work undertaken within the UK. In this case the fire precautions designed into the building usually follow the guidance contained in the documents published by the relevant government departments to support legislative requirements;

- Advanced approach. This is the level for which BS 9999 is provided. Guidance provided in this document gives a more transparent and flexible approach to fire safety design through use of a structured approach to risk-based design where designers can take account of varying physical and human factors. Much of the guidance in BS 9999 is based
An investigation into resilient fire engineering building design

on fire safety engineering principles, although it is not intended as a guide to fire engineering; and

- Fire engineering. This is the level for which BS7974 is provided. This level provides an alternative approach to fire safety and can be the only practical way to achieve a satisfactory standard of fire safety in some large and complex buildings, and in buildings containing different uses.

2.2.2 USE OF FIRE ENGINEERING

By the mid 1990s, it was possible to gauge how the use of the fire engineering was developing. Ferguson and Charters (1997) described the results of their review, twelve years after the introduction of the functional approach. They reported a pressure on Government to refine and update guidance documentation to address the inevitable questions relating to the new regime. Professional associations of building control officials set up closer links between their geographic areas in order to promote consistency of enforcement and agree answers to some frequently asked questions. The Ferguson and Charters paper highlighted that most construction projects involve a certain degree of variation from standard prescriptive design and that few projects, if any, are completely based on a fundamental fire engineering approach. They reported that the acceptance of fire engineered solutions is easier in some places, and for some things, than others. They argued that the reason for this relates to the skills within, and the policy of, the local authority Building Control department and the sensitivity of the project. They reported increasing concern of the qualifications required to practice fire engineering and the fear in some quarters that people acting outside their sphere of competence could mislead uninformed officials into accepting a scheme on spurious arguments.
Lucht (Institution of Fire Engineers. Northern Branch. 1995) outlined other barriers to the use of fire engineering. Lucht (1995) identified eight key issues:

1. Lack of design goals; a leading barrier to the use of emerging fire safety design methods.
   It was felt that codes and standards do not specify the overall level of safety that each is trying to achieve in the public interest;

2. Resistance to change; an attitudinal barrier. It was suggested that prescriptive codes are simply easier to use than performance based methods;

3. Education; the level of specialised technical education needed to implement prescriptive ‘choices’ is not nearly as high as that required to perform detailed engineering calculations, analyses and evaluations to achieve performance goals;

4. Technology transfer; work is needed to translate research results into tools that practitioners can easily understand and enforcing authorities can trust;

5. Economics; fire engineering design requires significant input from specialist consultants early in the conceptual development stage of building design;

6. Legal barriers; the fear of liability and law suits make engineers reluctant to use invalidated design methods;

7. Institutional barriers; established methods of ‘doing business’ can stand in the way of accepting new techniques. Codes and standards organisations are often slow to accept new methods; and

8. Technological base- the creation of effective fire safety design tools is an extremely complex problem from a scientific perspective and there are gaps in knowledge.
2.2.3 Stakeholders

One of the barriers to the use of fire engineering identified by Lucht, above, was discussed in greater detail by Dalloway (1995). Building Control officials enforce national building regulations in the UK, and are often cited as being resistant to change. Dalloway argued that the principal concerns of the building control surveyor was the ability to verify sources of information and validate emerging fire engineering models and formulae. Whilst he concluded that generally building control surveyors could cope with fire engineering submissions, he stated that if it was identified that, on particular projects that they couldn’t, they should seek specialist advice. Sugden (1998) argued a similar point regarding building control officials, stating that in their training, those officials who are responsible for the approval of buildings do not have a detailed knowledge of the arguments and calculations to be used by the fire engineer. He extended this argument to include the site control the construction of fire engineered buildings. He asks is site control adequate? Do we need to make greater use of certified products and accredited installers?

Sugden (1998) also identifies one further stakeholder - the client. He suggests that there are two core motivations when considering the use of fire engineering. Firstly, fire engineering is chosen to design the fire safety when a proposed structure is of a novel design or use that does not easily fit in with existing prescriptive legislation, or, secondly, it is chosen to reduce the cost of fire protection below the anticipated cost of meeting the prescriptive rules. The potential for cutting corners and safety in this scenario is obvious, argues Sugden, and he concludes that understanding the client’s motivation will throw light on fire engineering proposals made. This point is echoed in the interview-based research discussed in Chapter 4.
Another important stakeholder group in the fire engineering process is the fire and rescue service. Butler (Institution of Fire Engineers. Northern Branch. 1995) explained the contribution that the fire and rescue services can make to the advancement of fire engineering. One of the bodies most directly concerned with fire safety in buildings is the fire and rescue service. They protect their citizens in different ways and at different levels depending on national and local arrangements, by fighting fires, enforcing fire safety legislation, conducting fire safety education and influencing national standards and law. Butler recognised that there is an increasing need for operational fire-fighters to have an understanding of fire engineering in order to make dynamic risk assessments and judgements about fire-fighter safety at incidents. In addition, fire and rescue services are in an ideal position to thoroughly and systematically investigate fire events with a view to enabling greater understanding of the whole fire scenario and feed back into the fire engineering design process. Concerns about competency of fire engineering practitioners were also raised by Butler (1995). He suggests that the professional institutions must resolve this so that enforcers can be confident that the individual they are dealing with is suitably qualified and can recognise the limits of their expertise. Townsend (2000) takes the view of the fire and rescue service further. He talks about how fire and rescue services responded to the development and use of fire engineering by educating their own officers. With fire and rescue service enforcement officers holding fire engineering qualifications, Townsend (2000) reported greater a consistency of approach and a feeling of a collaborative approach between the architects, consultants, engineers and enforcing authorities when working on fire engineered building projects.

Insurers are an often overlooked stakeholder in the fire engineering design process. The insurer of the construction development may not be the insurer of the building when in use, and different insurers (or groups of insurers or re-insurers), are likely to be responsible for
providing cover for the building itself, the contents and perhaps business interruption insurance. This was highlighted by Young (Institution of Fire Engineers. Northern Branch. 1995) who explained the insurers’ views of fire engineering. Young agreed that there was a need for a fire engineering Code of Practice and welcomed the progress made on the draft code (DD240) but recommended that some five additional factors needed to be addressed in order to make the code of use to insurers.

1. Definition of a minimum standard for a ‘fire safe’ building; in the UK, the minimum standard for fire safety is usually equivalent to the fire safety provided by the application of Approved Document B. Young argues that this is a lower than desirable standard in many respects from an insurer’s viewpoint;

2. Definition of a fire engineer and their competency; Young asks what qualifications and experience should they have? Should they be registered or regulated? Who judges them?

3. Composition of Qualitative Design Review (QDR) team; Young argues that, when conducting the QDR- the initial stage of a fire engineering study, the input from insurers is essential. It is important that someone is able to contribute with regard to potential damage costs of both fabric and business interruption. If these factors are not properly addressed in the early stages of design, either high costs will be carried for later alterations, or unnecessarily high insurance costs carried for the life of the building;

4. Objectives and scope of QDR; Young suggests some further design objectives and limits including- What fire frequency is acceptable? What is the financial limit of loss? What about disruption of local community (loss of key amenity, etc)?; and

5. Outputs from QDR; whilst the draft code listed eight points to be covered in the report, Young suggests that these might not be enough for the insurance community. One key
output should be the financial assessment of losses in each compartment in the event of fire relating to building reinstatement, contents loss and business interruption.

All these factors are re-iterated fifteen years later in the survey-based research and case-study investigation within this doctoral project.

### 2.2.4 Development of Modelling Tools

Fire, as described by Rasbash et al (2004), is one of the most complex physical phenomenon occurring in nature, encompassing all disciplines of scientific investigation including thermodynamics, reaction chemistry, combustion and fluid mechanics. Any modelling approach, physical or mathematical, presents a formidable and challenging task, argues Rasbash. Yet, a fire engineering approach to building fire safety design requires many aspects to be quantified and modelling tools have been developed to assist the engineer.

Fire modelling can be grouped into two categories: probabilistic (or stochastic fire models) and deterministic models (Hadjisophocleous, et al. 1998). Probabilistic models involve the evaluation of the probability of risk due to fire, based on the probabilities of all parameters influencing the fire, such as human behaviour and the distribution of fuel load, etc. The results of the models are in terms of fire likelihood, but little information is given regarding the production and distribution of combustion products. Deterministic fire models are, in contrast, based on the physical, chemical and thermodynamic relationships and empirical correlation to calculate the impact of fire. Deterministic models can be classified as zone models, field models and other models (such as occupant movement and evacuation). Field models offer accuracy and detail in their results but require a great deal of experience from the user.
As described by Babrauskas (1996), some of the first theoretical underpinnings of fire modelling were created by the late Professor Kawagoe in Japan during the 1960s. The first computer-based fire model released commercially was created by Professor Magnusson of Lund University, Sweden, in 1973. During the early 1980s, fire models were still very much under development, but by the late 1980s, the situation had changed. With the arrival of relatively cheap and fast computer processors, numerical simulation became more commonplace and more frequently used by the fire engineer (Cox, 2004). In the mid 1990s, it was thought by Babrauskas (1996) that the extensive range of computational tools required for performance based design were still unavailable, or incapable of doing the job by themselves. He suggests that the limitations were due to funding restrictions and urged collaboration between the world’s fire research institutions in some joint development work.

2.3 FIRE ENGINEERING IN THE 21ST CENTURY

2.3.1 GENERAL

It is generally agreed that in a modern society, traditional prescriptive design techniques can hinder innovation and creativity, and are difficult, if not impossible to apply sensibly to buildings with special functions, such as sports stadia, high-rise developments and transportation termini. Fire engineering, as a means of satisfying the requirements of building regulation, is an approach which has freed up building design, whilst at the same time providing suitable levels of safety. Many of the exciting buildings currently being enjoyed in the UK have engineered fire safety and could not have been built under the previous prescriptive regime (Hopkinson, 2001).

Fire engineering, as an ever evolving discipline, is now responding to new challenges which require a greater depth and breadth of experience. One new area where fire engineering is
starting to make an impact concerns business resilience. Scott (2006) explains that, in a ‘post 9/11 and 7/7’ world, resilient design objectives are being explored more frequently, including the safety of public, commercial flexibility, market share and brand protection, security of information and robustness in response to attack. He argues that fire engineers have long recognised that adherence to prescriptive codes often does not produce a successful commercial building and the main thrust of fire engineering has been to enable buildings to open up, increase their flexibility and commercial value and, at the same time, improve the safety of the building occupants. Hence, resilient design further improves the function and adds long term value to a project.

It is also apparent that, whilst fire engineering was originally the pioneering method of enabling the successful design of buildings such as airports and enclosed shopping centres, such buildings are now commonplace. The new frontier for fire engineering design includes the design of very tall buildings. Projects such as those described by Hannah, Daniels et al. (2003), Lam (2007) and Kennett (2007) demonstrate innovative designs incorporating the use of elevators for rapid evacuation of occupants during a fire, the use of a ventilation system to protect common escape routes and the incorporation of a sprinklered single stairway, respectively, all in tall residential and office buildings.

Another area where fire engineering is making an impact concerns the sustainable construction agenda. Charters (Interscience Communications Ltd. 2007) suggests that fire safety in buildings contributes to all aspects of sustainability and can help address the balance between protection of the environment and prudent use of natural resources. However, he states that more research and guidance is required.
2.3.2 CONCERNS ABOUT APPLICATION AND MOTIVATION

Concerns exist as to whether the fire engineering design community has the knowledge, data and tool sets required to undertake advanced fire safety analysis. By way of example, Galea (Interscience Communications Ltd., 2004) argues that, although there are numerous computation tools available, without exception all models have limitations. In the case of evacuation models, he explains that current levels of model sophistication and application reflect our current understanding of human behaviour and evacuation conditions. However, as architects design more innovative structures and regulators strive to maintain, or improve safety standards, the fire engineer is expected to demonstrate performance in ever more complex and demanding evacuation scenarios. This increases the demands on model capabilities which in turn challenge our understanding of human behaviour in evacuation scenarios.

Galea (2004) argues that, if computational fire engineering (i.e. the use of computational models in performance based design) is to play a useful role in the design of safer structures, further targeted research is needed to generate the data required by complex modelling applications. Without this constant research, he suggests, fire engineering could eventually become as inappropriate as prescriptive codes.

Furthermore, the motivations for using fire engineering are increasingly being questioned. Ham (2007) warns architects against trying to buy their way out of problems they have created through poor design with complex technology and inappropriate fire engineering arguments. Dix (2003) also cites examples where fire engineering is used to justify designs which are, in certain circumstances, unsafe. He states that there is increased evidence of the emergence of performance justified engineering. This is where a decision is made with
respect to an aspect of design and then the techniques of performance engineering are used to explain why this otherwise inappropriate outcome is appropriate. The use of fire engineering in this way constitutes a significant threat to the credibility of its use as a design tool.

It is recognised that it is common practice for the fire engineer to be instructed to concentrate solely on life safety and evacuation because these are the elements mandated by the building regulations process. Although life safety is most importance, a solution which focuses exclusively on life safety may have a detrimental effect on property and business protection in comparison to a prescriptive code compliant solution (Fire Protection Association, 2008). Glockling and Barnett (2004) identify that a fire engineered approach might be chosen as a means of reducing the cost of fire protection at the time of construction by a design-and-build contractor and the building owner might not be aware of the potential differences in business protection that these changes might give, or the financial investment that may be required throughout the lifetime of the building in order to support the fire engineering features.

They also give a warning about the validity of fire engineering strategies throughout the life of a building. When a building is new, the fire engineered design and management should be in harmony with the activities conducted within it. Over time the prosperity and nature of the activities or processes employed may change and there is a potential for the original design concept to be lost. Therefore, there is a fear, warns Glockling (2004), that these changes will lead to a degradation in fire protection in excess of that which may be expected from prescriptively designed solutions. This concern is echoed by Dix (2003) when he states that regulators must acknowledge that using performance based engineering as a basis for design approval also requires ongoing inspection to ensure that assumptions used in the development are still applicable.
These issues can be overcome by ensuring that the insurer is involved at an early stage in the design process, all design assumptions and fire strategy information are kept and maintained in the building’s fire safety manual and updated as part of a regular fire risk assessment process.

### 2.3.3 Further Development

Fire engineering is an ever developing subject. In addition to the need for continuous research to feed computational modelling tools as described by Galea (Interscience Communications Ltd. 2004), Ogawa (Tokyo University of Science, 2005) suggests several other aspects which require development, including:

- Streamlined test methods for building materials to enable a harmonised world-wide approach.
- Performance evaluation methods of building design and facilities to support fire and rescue service intervention.
- Performance evaluation methods for risk of ‘urban fire’, i.e. fire spread to groups of buildings in densely populated areas.

In order to further develop the design of effective fire-fighting facilities within buildings, such as pressurised staging areas, fire-fighting bridgeheads, as well as retreating routes, Sekizawa and Notake (2006) assert that further research is required. Such research is necessary to determine how these factors should be incorporated in the performance requirement for supporting fire and rescue service operations.

Dannaway and Hurley (Tokyo University of Science, 2005) suggested other areas warranting urgent research, including;
• Risk analysis framework research to understand what constitutes an acceptable level of risk and quantify what is society willing to accept. A risk analysis framework would maximise cost effectiveness of fire protection designs by designing to meet the risk that is acceptable to society.

• Fire phenomena research; Current prediction of fire phenomena are too often based on rules of thumb, extrapolation from small scale testing or expensive large scale testing. Areas in which research is needed include better understanding fire development, predicting the response of detectors and suppression system efficacy.

• Human behaviour research; whilst there is a significant body of research on movement speed during evacuation, there is little understanding of how to predict pre-movement times. Human behaviour is complicated by variations in different people, for example people in family settings or those with mobility or sensory limitations. Such factors and their implications need to be better understood.

2.4 INSURER INVOLVEMENT IN BUILDING DESIGN

Much of the discussion and anecdotal evidence leading to this research project concerned the interaction between commercial property insurers and the fire engineering design process. Therefore, it is important to consider the commercial property insurance process in this literature review in order to understand the development of the industry, the complexities and the motivations of insurers in the context of new-build design.

2.4.1 INSURANCE AND REINSURANCE

Insurance is one method that businesses can reduce the financial impact of a risk occurring. Whilst holding an insurance policy does not remove a risk, it provides some security should
An investigation into resilient fire engineering building design

the worst happen (Dickson, et al. 1997). In simple terms, the concept of insurance works as follows. The insurer, a business that provides insurance, agrees to take on a risk on behalf of the insured. It does this by providing the insured with a policy, an insurance contract. Within the policy, the insurer states what risks it has agreed to insure against and what it will pay the insured if the risk happens. The insurer receives a fee from the insured, known as an insurance premium. To be included in an insurance policy, a risk must be capable of being measured in monetary terms. It must also be something that is not certain to happen, and the insured must have a direct interest in any loss (Lloyd's of London, 2008a).

Actuarial risk theory is concerned with the application of probabilistic techniques and models to the risk process involved in the operation of an insurance business. The risk arises due to the fact that an insurance company agrees to meet the claims of its policy holders to compensate their losses due to the occurrence of events they insure. The insurer would face ruin during a period if the total claim amount to be paid by the insurer during that period exceeded its assets, consisting of free reserves (capital) and total premiums received (Ramachandran 1998).

Insurers manage the risks they take on through the process of reinsurance. Reinsurance is an extension of the concept of insurance, in that it passes on part of the risk for which the original insurer is liable. Reinsurance contracts are similar to insurance policies, with the insured being the direct insurer, or the reinsured. A contract of reinsurance is between the insurer and the reinsurer only. There is no direct link between the original insured and any reinsurer (Lloyd's of London, 2008b). Reinsurance allows insurers to protect against large claims, such as catastrophic events like earthquakes, as well as increasing the capacity of the direct insurer.
2.4.2 **Fire Insurance**

Fire insurance provides financial compensation for damage due to and consequent on a fire to the owners or occupiers of the premises where this occurred. The compensation is normally for direct material damage (MD) by the fire itself, by heat or smoke from the fire and by water and other agents used to control and extinguish the fire. In addition, business interruption (BI) insurance provides financial compensation for such consequences as loss of orders due to late delivery, loss of key facilities and cost of reorganisation. The extent of these consequential losses may exceed the direct losses (Institution of Fire Engineers. 1989).

Fire insurance in Europe has two roots. In northern Europe, the rise of co-operatives and guilds during the Middle Ages generated the need for mutual protection, and the duties of co-operatives included providing mutual assistance in the event of fire. The idea of sharing the economic consequences of fires across a risk community of property owners was first developed in Denmark (Galey, Kuhn 2009). The Mediterranean provides the commercial roots for marine insurance which also branched out into property insurance on land, and thus into fire insurance. As early as the 14th century, marine insurance contracts were arranged in exchange for payment in Italian seaports. This is confirmed by the oldest known insurance document- the Genoa policy drawn up in 1347 (Gruss, 1982).

In the UK, the first insurance companies offering cover for property damage and financial losses were set up as a result of the Great Fire of London in 1666 (Read, 1993). By the end of the 17th century, three companies were engaged in providing fire insurance. These London based companies conducted business through a network of local agents, insuring virtually all types of buildings from residential properties to industrial sites. These early insurers set up their own fire brigades to protect the properties they insured (Galey, Kuhn 2009).
Today, fire insurance is provided by insurance companies and by Lloyd’s underwriters. Insurance may be placed directly with a company, or through an intermediary, usually an insurance broker. When a new insurance policy is proposed to an insurer, a fire surveyor will normally visit the premises to be insured to evaluate potential risk from fire and to advise the insured on fire prevention and protection. The fire surveyor prepares a report for consideration by the insurer’s underwriter. The underwriter decides on the acceptability of the insurance and the premium to be charged according to the conditions described by the fire surveyor (Institution of Fire Engineers. 1989). This process is described in greater detail below.

2.4.3 UNDERWRITING

Essentially, underwriting is the process of issuing insurance policies. Commercial property underwriters are keenly interested in how a building they insure is designed and therefore underwriting process and priorities are explored below.

Insurance underwriters evaluate the risk and exposures of potential clients, decide how much coverage the client should receive and how much they should pay for it. Underwriting involves measuring risk exposure and determining the premium that needs to be charged to insure that risk. The acceptance or rejection of risk is based on a prescribed capacity concept and is normally performed in accordance with organisational guidelines (Galey, Kuhn 2009). Fire underwriters perform a task which Galey (2009) describes as difficult, extensive and important, especially in industrial and large-risk business. He identifies the following individual responsibilities;

1. Gathering background information at the enquiry stage, with site survey from a specialist risk engineer, if appropriate;
2. Scrutinising insurance application;

3. Checking *objective* risk features such as type of operation, type of construction, separation, fire protection measures, exposure to natural perils, etc;

4. Understanding the *subjective* risk aspects, such as claims history, reputation, etc;

5. Checking the technical insurance conditions, sums insured, limits, deductibles, warranties, exclusions, etc;

6. Basic accept or reject decision; and

7. Determining the costing for the insurance policy, in order to maintain a *self-supporting* risk portfolio, i.e. aggregate premiums exceed claims expenditure and costs in that year.

Two financial *multipliers*, or *loadings* are generally imposed on the risk premium when calculating the total premium payable by the insured. The first is known as a *safety loading* and the second is an *administrative loading* to cover the insurer’s operating costs which include profits, taxes and administrative expenses. The premium rate should also be adjusted for any self-insurance (deductible) agreed between the insurer and the insured. When a deductible is introduced in an insurance contract, the insured is expected to take greater interest in adopting loss prevention and reduction measures. With adequate fire protection, particularly sprinklers, the insured can take the risk of accepting a large deductible which will minimise the total cost of insurance and protection. In order to promote this concept, it is necessary for the insurance company to establish statistically sound rebates on insurance premiums for different levels of deductibles, taking sufficient account of the reduction in loss due to a fire protection measure (Ramachandran, 1998).
It is customary to use estimates of expected loss under different conditions in data for estimating premiums. Some definitions of loss expectancy are listed in Table 2.3 (Rasbash, et al. 2004). The association of the loss with the failure of items of fire safety defence allows quantification of the probabilities of the loss occurring.

Table 2.3: Loss expectancy definitions. (Adapted from Rasbash, et al 2004)

<table>
<thead>
<tr>
<th>Definition</th>
<th>Description</th>
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<tr>
<td>Maximum possible loss</td>
<td>Financial loss that would occur under catastrophic or extremely unfavourable conditions (failure of two or more protection systems, active and passive)</td>
</tr>
<tr>
<td>Maximum probable loss</td>
<td>Maximum financial loss under normal conditions, for example one protective system failing.</td>
</tr>
<tr>
<td>Estimated maximum loss</td>
<td>Usually expressed as percentage of value of building under consideration; see full definition below.</td>
</tr>
<tr>
<td>Normal loss expectancy</td>
<td>Financial loss under average operating conditions- all protective systems operational.</td>
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Estimated Maximum Loss (EML) is the loss expectancy definition commonly used in the UK. The London Insurance and Reinsurance Market Association define EML as

\[ \text{Estimated Maximum Loss (EML)} = \text{an estimate of the monetary loss which could be sustained by insurers on a single risk as a result of a single fire or explosion considered by the underwriter to be within the realms of probability} \] (Rigby-Smith, 1995).

It is important for the fire engineer to be cognisant of the way an insurance underwriter assesses the attractiveness of a risk in order to influence the building design accordingly. Therefore, an understanding of EML is important. A simplified list of factors to be taken into consideration when assessing EML, as defined by the Insurance Institute of London (Rigby-Smith, 1995), now part of the Chartered Insurance Institute is as follows;

- Size, height and shape of area potentially exposed to a single fire or explosion.
- Construction of roof, walls and floors.
- Presence of combustible linings to walls, roofs, ceilings and partitions.
- Nature, distribution and combustibility of contents (fire load).
- Use of hazardous processes and substances and their degree of separation.
- Susceptibility of contents to damage by smoke, heat and water.
- Risk of explosion from any source.
- Hazards arising from gases or corrosive materials.
- Concentrations of values within a small area.
- Standards of management and housekeeping.
Similarly, the Insurance Institute of London (Rigby-Smith, 1995) defines factors which should NOT be taken into account when assessing an EML:

- Any horizontal separations.
- Fire resisting doors.
- The absence of any normal source of ignition.
- The existence or installation of fire detection, prevention or extinguishment arrangements including sprinklers and the adequacy or otherwise of Fire Brigade facilities.

Insurance EML is also of importance to reinsurers. Whilst reinsurers do not impose any underwriting or risk acceptance standards on their insurer clients, they do like to understand the insurer's approach in general terms, such as EML philosophy, and they periodically visit the insurer to gain a better understanding of the risk management undertaken with the insureds.

### 2.4.4 **Contract Works Insurance**

Insuring a construction project differs from insuring the occupied building. Often, the two insurance policies are provided by different insurers. Generally, contract works policies protect against the cost of unforeseen loss or damage to building works, machinery movement, advanced business interruption and public liability, installation and constructional plant.

Many insurers offer contractors *All Risks* policies, which are designed to provide protection for building and civil works during the contract period. The policy is written to enable the contractor or employer to comply with the insurance requirements of the contract and to cover the liability of the contractor for loss or damage during the maintenance period.
Policies are underwritten in a similar way to conventional fire insurance policies, with EML being an important factor. With most contracts there is a build up of value quite often associated with increasing fire risk as works progress. Accordingly, the actual EML will usually vary from very low during the initial shell and core stage, where fire load is likely to be moderate, to quite high in the latter stage of fitting out when values at risk are close to full contract value, a variety of trades and processes are being carried out, and fire protection features of the completed building have not been completed and commissioned.

### 2.4.5 Risk Management

Within the framework of loss prevention, insurers and reinsurers have long been analysing the quality of the risks they insure, and options for improving the quality of the portfolio. Loss prevention has a direct impact on the prices, terms and conditions in the sense of risk-adequate rating and is the basis for profitable business (Schadenspiegel, 2007). In order to assess and control the likelihood and magnitude of these risks, insurers have their own technical standards giving requirements for constructional measures, fire protection equipment and methods of work (Bickerdike Allen Partners, 1996). These standards are often used as benchmarks against which a building and its contents can be assessed. However, insurance is a business and is affected by economic considerations. In a soft market there is much competition between insurance companies for premium income in order to invest the capital profitably. This desire for premiums can override the need for stringent risk control, an attitude which in time must result in bad loss experience. This in turn leads to an increased emphasis on loss prevention and risk improvement and then the market hardens, i.e. insurance is more difficult to obtain unless insurers requirements are met (Bickerdike Allen Partners, 1996).
3 ADOPTED METHODOLOGY

This chapter outlines the methodologies applied to this research, together with a discussion to justify the choice.

3.1 METHODOLOGICAL CONSIDERATIONS

Research methodology refers to the principles and procedures of logical thought processes which are applied to scientific investigation (Fellows and Liu, 2008). The investigation of the development, current use and future use of a fire safety design process requires a diverse research methodology, largely qualitative in nature. In order to select the most appropriate methodology, it is essential review different methods and understand their respective strengths and weaknesses.

Research methods can be classified in various ways, however one of the most common distinctions is between qualitative and quantitative research methods. Quantitative research methods were originally developed in the natural sciences to study natural phenomena. Examples of quantitative methods now well accepted in the social sciences include survey methods, laboratory experiments, formal methods (e.g. econometrics) and numerical methods such as mathematical modelling (Myers, 1997). Qualitative research methods were developed in the social sciences to enable researchers to study social and cultural phenomena. Examples of qualitative methods are action research, case study research and ethnography. Qualitative data sources include observation and participant observation (fieldwork), interviews and questionnaires, documents and texts, and the researcher's impressions and reactions, according to Myers (1997). The motivation for doing qualitative research, as opposed to quantitative research, comes from the observation that, if there is one thing which distinguishes humans from the natural world, it is our ability to talk. Qualitative research
methods are designed to help researchers understand people and the social and cultural contexts within which they live. Kaplan and Maxwell (1994) argue that the goal of understanding a phenomenon from the point of view of the participants and its particular social and institutional context is largely lost when textual data are quantified.

As well as the qualitative/quantitative distinction, there are other distinctions which are commonly made. Research methods have been described as objective versus subjective (Burrell and Morgan, 1979), as being concerned with the discovery of general laws (nomothetic) versus being concerned with the uniqueness of each particular situation (idiographic).

### 3.2 PHILOSOPHICAL PERSPECTIVES

All research (whether quantitative or qualitative) is based on some underlying assumptions about what constitutes valid research and which research methods are appropriate. In order to conduct and/or evaluate qualitative research, it is therefore important to know what these, sometimes hidden, assumptions are.

The most pertinent philosophical assumptions are those which relate to the underlying epistemology which guides the research. Epistemology refers to the assumptions about knowledge and how it can be obtained (Hirschheim, 1992).

Qualitative research can be positivist, interpretive, or critical, as shown in see Figure 3.1. These three philosophical perspectives as defined by Myers (1997), are discussed below.
3.2.1 **Positivist Research**

Positivist research generally assumes that reality is objectively given and can be described by measurable properties which are independent of the observer (researcher) and his or her instruments. Positivists generally attempt to test theory, in an attempt to increase the predictive understanding of phenomena.

3.2.2 **Interpretive Research**

Interpretive research starts out with the assumption that access to reality, given or socially constructed, is only through social constructions such as language, consciousness and shared meanings. The philosophical base of interpretive research is hermeneutics and phenomenology (Boland, 1985). Interpretive studies generally attempt to understand phenomena through the meanings that people assign to them.

3.2.3 **Critical Research**

Critical research assumes that social reality is historically constituted and that it is produced and reproduced by people. Although people can consciously act to change their social and economic circumstances, critical researchers recognize that their ability to do so is constrained by various forms of social, cultural and political domination. The main task of critical
research is seen as being one of social critique, whereby the restrictive and alienating conditions of the status quo are brought to light. Critical research focuses on the oppositions, conflicts and contradictions in contemporary society, and seeks to be emancipatory i.e. it should help to eliminate the causes of alienation and domination.

3.3 QUALITATIVE RESEARCH METHODS

Just as there are various philosophical perspectives which can inform qualitative research, so there are various qualitative research methods (Myers, 1997). A research method is a strategy of inquiry which moves from the underlying philosophical assumptions to research design and data collection. The choice of research method influences the way in which the researcher collects data. The four research methods that will be discussed here are action research, case study research, ethnography and grounded theory.

3.3.1 ACTION RESEARCH

There are numerous definitions of action research, however one of the most widely cited is that of Rapoport’s (1970), who defines action research in the following way:

*Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework.*

This definition draws attention to the collaborative aspect of action research. Action research has been accepted as a valid research method in applied fields such as organisation development and education (Kemmis and McTaggart, 1990). Action research is discussed further in Section 3.4.4 of this Chapter.
3.3.2 **Case Study Research**

Case study research is one of the most common qualitative methods used. Although there are numerous definitions, Yin (2009) defines the scope of a case study as follows:

*A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.*

Case study research can be positivist, interpretive, or critical, depending upon the underlying philosophical assumptions of the researcher.

3.3.3 **Ethnography**

Ethnographic research comes from the discipline of social and cultural anthropology where an ethnographer is required to spend a significant amount of time in the field. Ethnographers immerse themselves in the lives of the people they study (Lewis, 1985) and seek to place the phenomena studied in their social and cultural context.

3.3.4 **Grounded Theory**

Grounded theory is a research method that seeks to develop theory that is grounded in data systematically gathered and analyzed. According to Martin and Turner (1986), grounded theory is;

*An inductive, theory discovery methodology that allows the researcher to develop a theoretical account of the general features of a topic while simultaneously grounding the account in empirical observations or data.*
The major difference between grounded theory and other methods is its specific approach to theory development - grounded theory suggests that there should be a continuous interplay between data collection and analysis.

3.4 METHODOLOGY DEVELOPMENT/REFINEMENT

3.4.1 DOCTORAL RESEARCH

This doctoral research programme progressed in accordance with an action research style as described by Fellows and Liu (2008).

Action research is known by many other names, including participatory research, collaborative inquiry, emancipatory research, action learning, and contextual action research, but all are variations on a theme. Put simply, action research is “learning by doing” - a group of people identify a problem, do something to resolve it, see how successful their efforts were, and if not satisfied, try again (O'Brien, 2001). The protocol is iterative or cyclical in nature and is intended to foster deeper understanding of a given situation, starting with conceptualising and particularising the problem and moving through several interventions and evaluations (MacIsaac, 1995). A simple model of the cyclical nature of the typical action research process was developed by Kemmis and McTaggart (1990), shown in Figure 3.3. Each cycle has four steps: plan, act, observe, reflect. The cycles reflect the research phases, as described in Chapter 4;

- Cycle 1- Exploration Phase
  - Scoping Study
  - Literature Review
Figure 3.2: Action Research Protocol after (Kemmis and McTaggart, 1990 cited in MacIsaac, 1995)

- Cycle 2- Conception Phase
  - Work Package 1- A historic perspective of fire engineering
  - Work Package 2- Fire engineering and the role of the insurer

- Cycle 3- Implementation
  - Work Package 3- Fire engineering as a tool for business and property protection
  - Proposals for change
Each cycle involved planning, action, observation and reflection which helped to define the subsequent cycle of investigation. Work package 3 itself followed an action research methodology, as described in 3.4.5.

### 3.4.2 Literature Review

An essential stage of all research is to search for and examine potentially relevant theory and literature. As described by Fellows and Liu (2008), the review of theory and literature must provide the reader with a summary of the state of the art- the extent of knowledge and the main issues regarding the topic which inform and provide rationale for the research which is being undertaken. As a random search is unlikely to reveal much of significance, a structured, triangulated search for relevant texts was undertaken. The key theories within the realm of fire engineering practices, leading authors and well defined topic keywords were established before embarking on the literature review. In addition, the available information repositories were investigated. These included traditional places such as university library collections and on-line databases, but also more specialist sources were used, such as the library of the Fire Service College, Moreton in Marsh, UK.

The scope of the literature review is outlined in Section 4.1.2, and the literature review, with discussion, is contained in Chapter 2. It is also discussed in the paper *A historic perspective of fire engineering in the UK*, in Appendix A.

### 3.4.3 Work Package 1 - A Historic Perspective of Fire Engineering

For the first work package, in order to investigate the issues relating to the application of fire engineering, a research methodology, employing multiple research methods, was adopted. As described by Sutrisna (2009), there are three major dimensions that need to be considered
when choosing a research methodology, namely the research philosophy, reasoning of the research, and data.

In order to elicit knowledge from a range of disparate, yet complementary stakeholders, an interpretive epistemology was needed. That is, as one person’s reality, derived by observations and perceptions, is likely to be different from another’s, the truth is a social construct, rather than existing independently (Fellows, Liu 2008). Therefore, the researcher needs to determine the reality from the participants’ collective perspectives - to see things through their eyes. Following the philosophy, the reasoning of the research was considered. This study employed inductive research methods, as discussed below, which tend to learn about the issues under investigation by applying a less structured methodology to gain richer and deeper information. Finally, on the data level, as this discourse focuses on the qualities of the information, rather than on numeric measurement, the data is qualitative.

In addition to an extensive literature review, other qualitative research methods were utilised to elicit knowledge, plus substantial data analysis. In order to fully understand current practice relating to the use of fire engineering, stakeholder groups have been identified and questioned in a series of two-stage knowledge elicitation sessions. This included communicating with the selected stakeholders from each group to give background information to the nature of the research and then, once consent had been received, the comprehensive questioning was undertaken via a mixture of face-to-face meetings and a self-administered, internet based, semi-structured questionnaire.

After considering the verbal data dimension (Gillham 2000) as shown in Figure 3.1 ranging from unstructured to structured questioning, an ‘open-ended’, semi-structured approach was chosen, using just a few key open questions.
Open questioning has the advantage of allowing freedom and spontaneity of answers, and gives the interviewer the opportunity to probe. However, as described by Oppenheim (2000), open questions are time consuming to analyse, costly in interviewer time and demand more effort from the respondents. The questions used are listed in Appendix A.

<table>
<thead>
<tr>
<th>Unstructured</th>
<th>Structured</th>
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<tr>
<td>Listening to other people’s conversations; a kind of verbal observation</td>
<td>Using ‘natural’ conversation to ask research questions</td>
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The UK fire engineering community is a relatively small group of identifiable individuals - a small population size. However, it was necessary to constrain the sample to an appropriately manageable number. Stratified sampling was used to select the stakeholders to question. Stratified sampling (Fellows, Liu, 2008) is considered appropriate where the population occurs in distinct groups, or strata. Ideally, the differences within each group or stratum should be small relative to the differences between strata. Each stakeholder chosen was selected for their expert status in their particular specialism, i.e. recognised by industry peers as having a great deal of knowledge about, or skill, training, or experience in their field of fire engineering application, thereby giving confidence in the reliability of the data. The stakeholders interviewed are described in Chapter 4.

There are three interview techniques to consider when designing a research method; face to face, telephone and self-administered. Bradburn and Sudman’s study (1979) concluded that
An investigation into resilient fire engineering building design

no data collection method is superior to all other methods for all types of probing questions. Therefore, face-to-face interview method was employed for the main data collection with nineteen stakeholders interviewed in this way. Supplementary data was gathered by a self-administered internet based questionnaire to which ten stakeholders responded. Both the face-to-face and the self-administered methods used the same set of questions, making a total survey sample size of twenty nine.

In order to enhance and expeditiously assist the analysis of data gathered during the interview process, computer-aided techniques were employed. Computer-aided qualitative data analysis (CAQDAS) offer techniques for the management and analysis of textual data in qualitative research, as textual database management systems for the automation of manual coding, indexing and sorting operations (Kelle, 1995).

It is important to choose a CAQDAS software package that fits with the method and methodology being employed. A qualitative data analysis tool known as Weft QDA was chosen as it provides the basic ‘code and retrieve’ features in a simple, easy to comprehend interface, without being encumbered by complex options and tools. Weft QDA was designed on the principle that this activity is a generic interpretive strategy and makes this activity straightforward (Fenton, 2006). How Weft QDA was used is detailed in Chapter 4.

3.4.4 WORK PACKAGE 2- FIRE ENGINEERING AND THE ROLE OF THE INSURER

The second work package, involved two research stages which built upon the findings of the first work package. Firstly, an extensive literature review was conducted to understand the background to the topic of commercial property insurance as well as the present day issues. Secondly, in order to fully understand current practice relating to the involvement of the insurance industry within the fire engineering design process, a case-study investigation was
undertaken. It was this element of the stakeholder interviews in work package 1 which was chosen as the most important to analyse in greater detail.

According to Yin (2009) a case-study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. This means that, a case-study investigation is used when one deliberately wants to cover contextual conditions, believing that they might be highly pertinent to the study. The case-study investigation relies on multiple sources of evidence, with data needing to converge in a triangulation fashion and benefits from the prior development of theoretical propositions to guide data collection and analysis (Yin, 2009).

The case-study investigation began by interviewing an individual who was influential as a Senior Property Risk Manager with responsibilities for a variety of building types, including those designed using fire engineering techniques. He was considered as an individual whose experiences were representative of those in his broader community of large commercial property insurance organisations. He was also identified as being a willing participant in the research with the necessary influence to encourage further input and participation from others as the case-study developed. From this first interview, further individuals were identified as being important to understand the issues due to their common involvement in a fire engineering building development from different stakeholder perspectives. The investigation then proceeded in a multi-method approach (Gillham, 2000) starting with site visits where the individuals were observed undertaking their professional role in an ‘exploratory’ manner, and then supplemented by and interviews and of face-to-face meetings.

The case-study investigation, involving a small group of people where the objective was to understand phenomena through the meanings that people assign to them, represents an interpretive epistemology. As the investigation was theory-generating, rather than theory-
testing, it was employing inductive research methods as discussed by Fellows (2008). It followed a less structured methodology in order to gain richer and deeper information, with the interviewees commenting on their personal experiences. Such commentaries are acceptable as scientific data, as asserted by Brown and Sime (Brenner, 1981).

### 3.4.5 Work Package 3- Fire Engineering as a Tool for Business and Property Protection

The third work package involved the development of methodologies for ensuring business and property protection objectives are met in the fire engineering design process. In order for the author to identify, promote and evaluate problems and potential solutions, an ‘action’ research style (Fellows and Liu 2008) was adopted. Early in the progress of the work package, a hypothesis was formulated as a result of initial investigations. The research for this work package involved the following steps, which are explained in greater detail within Chapter 4. Each group of tasks follow the Plan, Action, Observe and Reflect process of action research, and the grouping of tasks represent cycles as depicted in Figure 3.3, above;

- **Cycle 1- Preliminary ideas**
  - The choice and formulation of a Panel of experts (Plan – Action);
  - Participating in expert discussions (Action);
  - Developing ideas, and reviewing them (Action – Observe – Reflect).

- **Cycle 2- Developing processes**
  - Distributing tasks amongst the Panel (Plan);
  - Undertaking development tasks (Action);
o Reviewing the output (Observe);

o Discuss and refine in Panel meeting (Reflect).

- Cycle 3 - Developing a document

  o Assign Content Developer and create draft (Plan – Action);

  o Evaluating the resulting deliverable in Committee and refining (Observe – Reflect).

- Cycle 4 - Publishing a document

  o Organise Draft for Public Consultation (DPC) (Plan – Action);

  o Meet to discuss and respond to consultation returns (Observe);

  o Refine document for publication (Reflect).

This particular approach is best described as using the action research principle of Collaborative Resource. As described by Winter and Burroughs (1989), participants in an action research project are co-researchers. The principle of collaborative resource presupposes that each person’s ideas are equally significant as potential resources for creating interpretive categories of analysis, negotiated among the participants. It strives to avoid the skewing of credibility stemming from the prior status of an idea-holder. It especially makes possible the insights gleaned from noting the contradictions both between many viewpoints and within a single viewpoint. As described in Chapter 4, the system adopted by British Standards Institution for document development, involving collaborative Panels of experts and practitioners is well suited to collaborative resource action research approaches.
3.5 SUMMARY OF METHODS/TOOLS USED

This chapter provides a summary of the methodologies employed by the author in conducting the research. With the entire research project progressing in an action research way, each incremental piece of research helped to define and drive the next, resulting in a very focussed ultimate deliverable.

It began with a structured, triangulated search, investigating key theories and leading authors in order to develop a thorough literature review, which was used to inform the first Work Package

Work Package 1, investigating the application of fire engineering in the UK, involved a two-stage knowledge elicitation process employing an interpretive epistemological philosophy, with inductive reasoning to elicit qualitative data. The two stages comprised initial priming conversations with research participants followed by open-ended, semi-structured questioning.

Work Package 2, investigating the role of the insurer in fire engineering process began with a more focussed supplementary literature review, and then followed with a case study investigation. The multi-method case study investigation began in an exploratory fashion with observation of research participants, and then became much more focussed comprising interviews and face-to-face meetings.

Work Package 3, developing methods for ensuring business and property protection objectives are met in the fire engineering design process, required an action research approach. Using a cyclic process of plan, act, observe and reflect, the research was undertaken utilising collaborative resource to effect knowledge elicitation and produce a significant deliverable.
4 THE RESEARCH UNDERTAKEN

This chapter outlines the specific original work undertaken by the author to meet the research objectives. This is supplemented by conference and journal papers which can be found in Appendices B to E. The research methodology has been discussed previously in Chapter 3.

The research was completed in three phases by progressing through a series of well-defined work packages, as discussed earlier and outlined in Figure 4.1, below. This project phasing followed a logical journey through tasks initially of an exploration nature, then focussing research and consolidating some of the issues identified in a conception phase, and finally on solutions and tasks concentrating on targeted implementation.

Figure 4.1: Research phases and projects
4.1 EXPLORATION

4.1.1 SCOPING STUDIES

Prior to embarking on the research outlined within this discourse, the author’s career as a Chartered fire engineering practitioner allowed the development of a broad appreciation of the general subject domain and gain an understanding from the practitioner perspective. Latterly, employment with the Industrial Sponsor enabled the author to experience how fire engineering is often inappropriately applied, understand the process of fire engineering from the enforcer and insurer perspectives, and thereby begin to foster ideas leading to this research. Other experiences have helped to shape the author’s understanding of fire safety in buildings, and fire engineering processes, such as those gained via the taught element of the Engineering Doctorate. The Management and Professional Development module lead to activities such as;

- Authoring the Compartmentation chapter of the third edition of CIBSE Guide E; Fire Safety Engineering (Chartered Institution of Building Services Engineers, 2010) which helped to developing a close working relationship with leading fire engineering practitioners, researchers and enforcers;

- Being an active member of the Institution of Fire Engineers Registrants Group Steering Panel, a group with a remit to specifically represent Engineering Council registered engineer members, which was of vital importance when trying to identify failings in the profession and facilitate change.

- Being an active member of the British Standards Institution Technical Committee (FSH/24) responsible for developing best practice within the UK, which was of vital
importance when trying to identify failings in how fire engineering is sometimes applied and facilitate change through development of the relevant Codes.

Further project scoping consisted of brainstorm activities with the Industrial Sponsor, resulting in a fully defined research proposal document. The document contained background, initial outline aim, objectives and the anticipated methodology. Figure 4.2 shows the output from the initial brainstorm. The ten potential areas for research during this project were themed into four categories, namely, People, Policy, Product or Objectives related. As ideas developed following this initial exercise, it became apparent that some of these research areas will be pursued to a greater depth than others. This selection has been driven by the subsequent refinement and definition of sub-projects in order to achieve the ultimate desired exploitation path- to influence significant change in the UK fire engineering design practices.

![Diagram showing themes and categories]

**Figure 4.2: Research brainstorm diagram**
An investigation into resilient fire engineering building design

An important element of the initial research stages was to increase the breadth and depth of knowledge of the research topic. This was achieved by actively engaging in discussions and debates revolving around the key issues at fire engineering conferences and seminars, by discussing research ideas with the Industrial Sponsor and other industry experts, and by conducting a thorough literature review. The literature review was discussed in greater detail in Chapter 2.

During the scoping study stage, two experts in the field of fire engineering were interviewed. Both Professors, they have made significant contributions to research and developments in this area. For example, one is a Director of Fire Engineering at an internationally renowned building research centre. He is the Chairman of the British Standards technical committee concerned with fire engineering, a past International President of the Institution of Fire Engineers and visiting Professor at a leading UK university. The other is the Director of the Fire Safety Engineering Group at another leading UK university. He has worked in the area of computational fire engineering since 1986. The scoping study was useful in developing an in-depth understanding of experts’ views on the key issues surrounding the topic. This included both the benefits and the barriers for insurer objectives to be included within the fire engineering process. Three barriers were described as;

1. Property protection research and methods are not easily accessible for practitioners to use as individual insurance companies tend to retain their own research as company confidential information.

2. Building construction is increasingly a contractor driven industry, with fewer projects following the traditional architect-led route.

3. Property protection measures tend to be prescriptive in nature, which is perceived to be over-engineered with little obvious evidence base.
This discussion highlights significant challenges to be addressed during the proposed research. One Professor described how technological advances are running ahead of rigorous research, and cited an example. It is technically possible for elevators to be used in an evacuation strategy in very tall buildings. However, there is little evidence of research having been undertaken to know whether building occupants will choose to use elevators in fire conditions due to human conditioning from experience in low rise buildings where it is usual to prohibit the use of elevators in the event of fire. He also offered first-hand examples of where fire engineering has been used to justify a reduction in project cost, based on poor engineering judgement without valid conclusions.

The interviews described earlier, and preliminary information gathered from other sources, informed a scoping study undertaken by the author which helped the development of Figure 4.3. The figure lists a selection of drivers for use of fire engineering methods, and also some of the potential consequences of using the design approach. It is clear that the drivers and consequences are inextricably linked, with many of the potential consequences raising question about the validity of the perceived benefits which drive the use of fire engineering. This confirms the justification for this Engineering Doctorate research project and the planned approach.
Figure 4.3: Fire engineering drivers and consequences
4.1.2 LITERATURE REVIEW

The literature review undertaken is contained in Chapter 2 and within journal paper *A historic perspective of fire engineering in the UK* in Appendix C. It examines a wide range of published literature relating to the origins, development and current use of fire engineering. It draws information from contemporary academic journals, books, institutional documents and popular trade press. Information repositories utilised included traditional places such as university library collections, on-line databases and specialist archives, such as the library of the Fire Service College in Moreton in Marsh, UK.

Whilst the review includes literature gathered from international sources, the focus of the review remained the application of fire engineering in the United Kingdom. A wider international review, highlighting the differences and similarities between the way the discipline has developed and been accepted in differing jurisdictions has been identified as a potential area for future study.

4.2 CONCEPTION

4.2.1 WORK PACKAGE 1 - A HISTORIC PERSPECTIVE OF FIRE ENGINEERING

In order to develop an in-depth understanding of the origins, motivations, successes and concerns pertaining to fire engineering as a discipline, Work Package 1 centred around devising, conducting and analysing semi-structured interviews of key individuals from the past, and present day stakeholder groups (Wilkinson, et al. 2010b). The methodology for this work was described in Chapter 3. The stakeholder groups interviewed included;
• **Academics:** Those involved with teaching the fire engineers of the future, and also those actively involved in fire engineering related research, pushing the boundaries of knowledge in the field;

• **Designers:** Those architects and others, involved with the design of buildings and facilities, often as ‘principal adviser’ to the client. Those who are responsible for translating the client’s requirements into a brief, creating the architectural vision, and leading/coordinating the other design professionals;

• **End users:** Those who either commission buildings, or are responsible for operating them;

• **Enforcers:** Those authorities having jurisdiction (AHJ) for approving building designs against the requirements of the Building Regulations, within Building Control functions and Fire Authorities;

• **Practitioners:** Those engineering consultants and designers who assist the building design process by advising on fire safety matters;

• **Insurers:** Those insurers and brokers who are responsible for insuring commercial property and business interruption, and advising their clients on risk management issues;

• **Policy Makers:** Those responsible for determining Ministerial priorities, monitoring and affecting changes to Regulations; and

• **Institutions:** Trade bodies and professional institutions that have a role in informing, developing and/or regulating a membership.
The UK fire engineering community is a relatively small group of identifiable individuals. However, it was necessary to constrain the sample to an appropriately manageable number. Stratified sampling was used to select the stakeholders to question. The stakeholders interviewed are described in Appendix B.

4.2.1.1 Pilot study

Nineteen experts were interviewed and ten additional responses were received via an Internet based questionnaire. The questionnaire was designed to understand the interviewees’ opinions on their competency, the motivations for using fire engineering and their perceptions of the role of other stakeholders. Prior to undertaking the interviews, the initial questionnaire was piloted using a focussed group of experts (academic and industry) who had knowledge/experience in the fire engineering domain. The feedback from the pilot study was used to refine the questionnaire and ensure its robustness.

The methodology used for selecting the interviewees and the questionnaire design is described fully in 3.4.2, and the full questions are listed in Appendix E. The Weft QDA software has been used to assist in analysing the interview transcripts. The following comments, issues and trends were identified.

4.2.1.2 Interviewee background

As fire engineering is a relatively new discipline, it is unlikely that the pioneers of fire engineering received formal education in the subject prior to practicing the discipline. As suspected, high proportion of interviewees arrived at their role in fire engineering from a background in another discipline. The two most popular routes to fire engineering out of the people questioned are by degree qualifications in Physics or Civil Engineering. This is
because many of the interviewees undertook their higher education and training at a time before dedicated fire engineering qualifications were available.

Many interviewees described their relationship with fire engineering as multi-faceted. For example, many of the practitioners also play an active role in developing the profession by participating in code or guidance authoring activities or progressing and championing fundamental research in the field. This confirms the premise that, as the profession is young, key individuals are relatively few in number and each of these individuals is involved in a wide variety of activities. This is a good insofar as it helps to move the profession forward quickly.

4.2.1.3 Drivers for Fire Engineering

When asked why they thought fire engineering exists as a profession or discipline, the overwhelming views of the interviewees related to its ability to facilitate architectural design freedoms, in terms of form and materials of construction. It is described as existing to support creative architecture that would otherwise be restricted by prescriptive design standards. This very positive opinion is shared universally by all stakeholder groups alike, suggesting that customer demand has been a driver for fire engineering developments. Comments were made describing buildings as getting ever more complicated and clients want more fire engineered buildings to allow business to work in surroundings that support their processes. Similarly, a view held by many interviewees is that fire engineering is the result of a natural progression away from prescriptive design, i.e. moving away from the restrictions of compliance with rigid Codes, keeping apace with other developments in architecture and construction. It has also been suggested that this evolution was initiated as a response to the UK Government’s drive for self-certification during the early 1980s and that fire engineering provides a way of simplifying a complicated regulatory process.
The second most frequent comment made in response to this question about why fire engineering exists centred on the issue of fire engineering enabling the reduction of construction project costs by allowing the removal of certain fire protection features. Some practitioners of fire engineering saw this as a positive contribution, citing cost effective, risk appropriate fire safety measures. However, many more interviewees raised concerns about fire engineering being used primarily for construction cost saving reasons, with no consideration of building life-cycle costs and the implications to the end-user client with potentially increased maintenance and support costs over the life of the building. In addition, many of the policy makers and enforcers felt that fire engineering is used as a method of legitimising deviations from what would otherwise be code-compliant building designs, and even that fire engineering enables the abuse of these rules, giving developers the opportunity to avoid compliance. Numerous examples were cited where developers or architects have stated that they want to fire engineer the building because they cannot design it to be in accordance with the prescriptive code.

4.2.1.4 Competence and Data

The next question asked the interviewee about their fire engineering skills and knowledge, access to relevant and appropriate tools and data, and access to competent colleagues. The vast majority of interviewees considered themselves to be completely equipped, sufficiently equipped or at least felt competent to undertake their work. Being adequately equipped means having the foundation of a relevant educational background, the acquisition of meaningful experience as well as access to appropriate tools and data. Several interviewees indentified gaps in some of these elements, including; data/models, currency of research and educational qualifications. It was felt that there is a shortage of good data from which one can draw correlations, and test theories, and even where good data exists; obtaining access to
latest research and wider opinion is sometimes difficult. It was emphasised that whilst fire engineering is a relatively young discipline, the analytical tools and models are even younger. The profession as a whole lacks experience in applying these tools and lacks a life-cycle perspective that building design adopts by analytical modelling tools and approaches. One of the reasons attributed to this is the unavailability of data to give a meaningful insight in fire dynamics. For example, there is little of no data currently available that characterises materials by their combustion properties so that realistic scenarios can be simulated to assess the scope and magnitude of the fire. Another example cited was that of a lack of knowledge with regards to human behaviour in the event of fire. This missing, yet vital data is crucial for simulating realistic scenarios so buildings can be better fire engineered. Whilst some interviewees recognised that they did not necessarily hold directly relevant qualifications, there was some scepticism relating to the quality of the engineers graduating from some of the UK Universities that teach fire engineering. Several interviewees felt that their extensive experience and good judgement filled any gaps there might have been with their education. Many respondents added that successful fire engineering requires teamwork where support from colleagues and others, sometimes externally sourced, is essential. This sentiment is not restricted to fire engineers, but was equally expressed by the enforcers.

4.2.1.5 Development of fire engineering

The interviewees were asked about their perception of how the discipline of fire engineering, or its impact, has changed during their career. Also, the interviewees were asked how it is envisaged the profession might change in the future. Some interrelated issues emerged. It was widely accepted that the profession has matured, evolving from a pursuit for academics, to a situation today where it is emerging as a recognised, separate professional discipline. Interviewees agreed that fire engineering is becoming more accepted in the UK and there has
been a wider global acceptance of fire engineering by clients and authorities worldwide. The interviewees have also seen a change in how fire engineering has been applied to construction projects, or rather, the types of buildings that fire engineering is now being applied to, recognising that it is more frequently applied to more mundane projects.

The assertion that nearly all new commercial buildings contain an element of fire engineering analysis to save on cost and to justify departure from the prescriptive codes, leads to another important point raised by a significant number of interviewees. As one enforcer put it, there is a proliferation of designs for buildings which do not comply, but have been labelled as ‘fire engineered’ as it enables them to put forward an argument as to why it doesn’t need to comply. There is agreement with this opinion from other practitioners who state that there are very few buildings that have a full performance-based fire safety design approach carried out on them. Perhaps one reason for this is that there has been a ‘deskilling’ of the architectural profession over the last decade. It is suggested that fire engineers now do a lot more of the duties the architects used to do and the architect is now merely a project manager of expert consultants. One of the significant consequences of this, as described by a practitioner, is that the demand for fire engineering has outstripped the capacity of fire engineers.

A comment made by some interviewees from all stakeholder groups is that fire engineering is being used more widely, because the analysis tools that are now available are far more sophisticated, and easier to use. A practitioner adds a note of caution with the widespread, commonplace use and misuse of models without the fundamental understanding of when a mistake is made. An academic adds that not only is the misuse of modelling tools a concern, but the very proliferation of tools could be seen as an even greater concern. He warns of the existence of many fire and evacuation simulation tools that have not been validated, tested,
nor described in peer reviewed literature, yet are being used blindly and accepted by enforcers.

An academic who gave an international perspective from regions where fire engineering or performance based engineering is more mature, notes that the first phase of failure has been recognised and comments that there is now an attempt for regulatory regimes to put resources into reviewing fire engineering design proposals, as opposed to just accepting them. With a similar theme, many interviewees predicted that fire engineering failures, or examples where fire engineering has been incorrectly used within a building project, could come to light in the near future. A practitioner predicted that there will be a serious fire in a fire engineered building that will show the failings of practitioners of fire engineering. An academic is equally concerned suggesting that a disastrous fire in a fire engineered building which is later shown to be the cause of dubious fire engineering could set back the whole discipline. This statement is interesting as ‘dubious’ fire engineering will only be identified following a fire. There are no mechanisms in place to review older fire engineered buildings to check validity when, say, a design solution is based on the use of a modelling tool that has since been withdrawn.

### 4.2.1.6 Future developments

Other opinions concerning how fire engineering may develop in the future included an overwhelming thought that fire engineering will become more accepted, more sophisticated and be used more widely. This was stated by interviewees from all stakeholder groups. In terms of how the profession might develop, practitioners and academics suggest that fire engineering will develop to reflect modern methods of construction and environmental and sustainability issues. Two practitioners of fire engineering posed a change which is
considered necessary to enable the discipline to be better applied. They described the need for fire engineering input throughout all stages of a building’s life-cycle, developing a fire safety ‘circle’, and making sure that operational fire safety is a key part of the early design process. The concept of the fire engineering ‘circle’ was repeated by other interviewees, and the need for fire engineering input at all stages of a building’s life cycle, from design to demolition, was compelling.

The need for further research to expand the pool of data available to support fire engineering concepts was discussed at length. Practitioners commented how research is needed to keep pace with new fire safety developments, such as research into human behaviour to inform the use of lifts for evacuation. Additionally, an academic raised the issue of keeping data current and appropriate, citing an example where a researcher has asked for his material to be removed from an international fire engineering guidance document because he was concerned that the data was no longer valid.

An interesting point or concern about how fire engineering, or fire engineering codes and standards might develop in the future was raised by two practitioners. The issue concerns reconciling the very definition of performance based engineering with the necessity to provide a standardised methodology. It was hoped that fire engineering doesn’t become ‘too prescriptive’.

4.2.1.7 Perceptions

The most controversial part of this knowledge elicitation exercise involved asking the interviewees about their perception of the roles of the other stakeholders involved in fire engineering. Analysis of the responses shows clearly that interviewees had more critical comments than positive when describing their fellow professionals in the industry. The four
stakeholder groups attracting the most criticism were architects/designers, enforcers, insurers and practitioners.

Whilst the input from academics is widely valued, it was felt that they are disconnected, or removed from the real world. This disconnection was felt, both in terms of teaching and research, as their industrial experience is perceived to be limited and they struggle to keep up to speed with change.

The work of building designers and architects was described as mostly well intended; however, they received much criticism from the interviewees for not understanding fire safety issues, and not understanding how to use fire engineers. The issue of architects losing skills was again raised, as well as many interviewees criticising what they consider to be inadequate fire safety related training within architectural training. Examples cited included one academic who recalled contributing to architectural degrees of five or seven year duration which contain merely four hours on fire safety. The way architects use fire engineering was again criticised, an academic described fire engineering as the ‘new liquid paper’, enabling their mistakes and omissions to be conveniently endorsed. Further comments of building designers and architects was a criticism of their lack of understanding of their clients’ needs, and the poor way in which they attempt to define the objectives of the design.

The criticism of end users within the fire engineering process can be summed up as a lack of engagement when the building is designed and then falling short of their responsibilities during operation. Again, a disconnection was described between the designers and practitioners, and the end user stakeholder group, which, one academic commented is being addressed by the Regulatory Reform (Fire Safety) Order (Great Britain, 2005). A practitioner stated that often end users don’t even know that they’re in fire engineered buildings, because of a lack of information transfer from the practitioner, through the construction company, to
the client. These issues were echoed by many of the interviewees, practitioners, enforcers, academics alike, with the importance of good dialogue and transfer of knowledge to the end users being emphasised. A differing view was posed by an academic, who suggests that, actually the end users shouldn’t know that there has been a fire engineer involved at all. If the fire engineering is done well they shouldn’t have to worry about anything.

Whilst some encouraging comments were made about the competency and actions of enforcers, both Building Control body and Fire Authority based, far more critical statements were made. A common feeling was that the quality of enforcement varies dramatically across the UK, with consistency of approach really lacking. A specific criticism of the skills base within the Building Control enforcement community was made by a practitioner, questioning their skills and experience, simply accepting fire engineering submissions without any third-party validation. An academic commented similarly, that the enforcers don’t know what to look for, and they don’t know how to challenge. Also it was stated that Building Control enforcers do not inspect on-site installations. There was agreement that the enforcers need to be trained as well as, if not better than, the engineers, and to work in a performance based environment.

Practitioners of fire engineering, i.e. those consultants who use fire engineering methods, received significant criticism from their colleagues. Comments ranged from criticising their perceived intentions, to their working practices and the commercial pressures that practitioners often work under.

Insurers receive a similar level of criticism. It is thought that insurers do not play an active role in the fire engineering process, and when they do, their poor levels of knowledge and understanding precludes any meaningful interaction. An academic commented that fire engineering is not used by insurers because only few can assess the risks, and a practitioner
added that insurers simply have no role at all in fire engineering, adding that in most cases they wait until the building is completed and then decide whether or not to insure it. Many practitioners’ perception of insurers is that they rely solely on sprinklers as a form of fire safety. This message was echoed by a different practitioner who said in relation to an industry event he had attended, that their only message seemed to be ‘Put in sprinklers’. Whilst this might appear as an over-simplified message for the insurer to give, it might be argued that because of the issues with fire engineering already discussed in this Section, such as dubious motivations, poor material choices, poor construction, etc., then the insurers’ message is perfectly reasonable.

Further comments concerned the commercial nature of insurance. It could be argued that commercial pressures make insurers over cautious with their advice, rendering them unable to influence the built environment. Some advice was given by some practitioners to those within the insurance community urging them to engage in the design process, having an input into the objective setting and then determining the premium according to those objectives. A counter-argument, given by an insurer is that the insurance industry would welcome being more greatly involved, but the opportunities presented to insurers are few and far between, in his view. He suggests that they are only asked to be involved after the design stage has been agreed. These two arguments suggest a lack of dialogue between the stakeholder groups, and a lack of understanding of the complexities of each others’ role.

Manufacturers of building products that support fire safety strategies, and enable fire engineering, are needed and welcomed in the UK. As one practitioner described, without them, we wouldn’t have many of the products that are available to us as part of the armoury of measures available to deploy in designs. However, it became clear that the interviewees have also experienced manufacturers who disregard fire safety when they are developing their
building products. An enforcer described how his organisation had experienced poor quality materials originating from the Far East being used in construction projects. Aligned to product manufacturers are product installers, and an important problem identified is the quality of workmanship on site. Criticism was levelled at the lack of supervision and checking of on-site construction so that the ability to deliver high quality in accordance with the specification is limited. This fact poses a problem for fire engineering as when designs become more and more sophisticated, the room for a margin of error in terms of the workmanship diminishes.

The criticism of policy makers focussed on the slow nature of policy change. They also discussed the way policy makers prioritise, and how they interpret the financial cost of action, or inaction. Comments about perceived attitudes were made such as current political focus on environmental and climate change issues.

Institutions and trade bodies are seen as vital within the fire engineering process as they are the groups who translate research into practical every day advice. However, the Institution of Fire Engineers (IFE) received much criticism from interviewees. Many practitioners feel that the role the IFE plays in fire engineering is inadequate. It was stated that the IFE has moved away to some extent from being a predominantly fire and rescue service organisation, but it was felt that it hasn’t moved far enough yet. Two interviewees gave examples of similar large membership professional organisations that the IFE could aspire to be like. The Institution of Occupational Safety and Health (IOSH), the Chartered body for health and safety professionals and the British Medical Association (BMA), the doctors’ professional organisation in the UK are both respected organisations who train and regulate their members well, acting as governing bodies for their respective professions. It was thought that the IFE is not taking that task on very responsibly. An academic adds the IFE needs to be pushing good
practice and coming up with guidelines, and cited the Society of Fire Protection Engineers (SFPE) as an organisation taking a much more pro-active stance in developing guidelines and informing its members about best-practice methods.

The critical comments about fellow stakeholder groups participating in the fire engineering process highlights a disappointingly polarised attitude which is far from collaborative in nature. Surely, these attitudes are contributing to some of the problems.

4.2.1.8 Summary of findings

This research has shown that the common expectation across all stakeholder groups was that fire engineering would facilitate architectural design freedoms and support creative construction allowing the UK, and more specifically London, to continue to develop its reputation as a city of world-class importance. London now has many prestigious and innovative buildings, worthy of a global financial centre. Along with equally impressive airports and public entertainment venues, a message of innovation, good design and prosperity is given to all visitors. However, it has also become evident that since fire engineering has become more accepted, significant concerns have been raised regarding various elements of the design process including,

- The appropriateness of application of fire engineering to some design issues and misuse of the term ‘fire engineering’ to describe simple code-deviation design;

- The motivations of the client and design team for using fire engineering techniques on some projects, which are often economic motivations, or to address a design error or omission;
- The ability of building control professionals to approve designs, and of fire and rescue service personnel to contribute to the process;

- The ability of the construction industry to select high quality materials and to ensure the high standards of installation workmanship which is crucial for successful fire engineering;

- The involvement of the insurer and the ability to champion objectives other than life safety;

- The ongoing validity of fire engineered solutions during the building’s life-cycle, and the continued input of fire engineers from design to demolition;

- The limitations of the knowledge, data and tools that support fire engineering design concepts; and

- The ability of professional institutions to guide and regulate practicing fire engineers.

All these issues need to be addressed if fire engineering is to enjoy continued growth as a profession, and continued acceptance as a legitimate contribution to the building design process, but the contribution the commercial property insurer makes is of paramount importance in the context of business and property protection design objectives.

4.2.2 WORK PACKAGE 2- FIRE ENGINEERING AND THE ROLE OF THE INSURER

Work Package 2 built upon the results of Work Package 1 and investigated in greater depth, the role the commercial property insurer plays in the fire engineering design process. Firstly, an extensive literature review was conducted to understand the background to the topic as well as the present day issues. Secondly, in order to fully understand current practice relating to the involvement of the insurance industry within the fire safety engineering design process, a case study investigation was undertaken. The investigation involved a combination of face-
to-face meetings and site visits where the individuals were observed undertaking their professional role (Wilkinson, et al. 2010a). The following people were involved in the case study investigation;

Table 4.1: Backgrounds of Case Study Participants

<table>
<thead>
<tr>
<th>Job Title</th>
<th>Employer</th>
<th>Stakeholder Group</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property Risk Manager</td>
<td>Major UK commercial insurance company</td>
<td>Insurer</td>
<td>Senior managerial role overseeing surveyors and influencing company commercial property underwriting strategy.</td>
</tr>
<tr>
<td>Risk and Insurance Manager</td>
<td>Property portfolio with 33 high-rise office buildings.</td>
<td>End-user client</td>
<td>Senior role responsible for insurance procurement, risk transfer and risk management.</td>
</tr>
<tr>
<td>Risk Surveyor and Sprinkler Risk Surveyor</td>
<td>Major UK commercial insurance company</td>
<td>Insurer</td>
<td>Field-based team assessing the acceptability of properties in relation to the insurer’s requirements.</td>
</tr>
<tr>
<td>Associate</td>
<td>Major fire safety engineering consultant</td>
<td>Practitioner</td>
<td>Experienced practicing fire engineer.</td>
</tr>
</tbody>
</table>

4.2.2.1 Underwriting

As defined within Chapter 2, underwriting is the process of issuing insurance policies and how underwriting practices are influenced by the building design process is important to understand fully. During the case study investigation interviews, those ideas which developed in the literature review were confirmed, i.e. that underwriters are interested in five key issues when writing insurance policies;

- Estimated maximum loss (EML)- the calculated worst case scenario;

- The materials the building is constructed from;
The Research Undertaken

- The attitude of the insured to risk improvement, and housekeeping;

- Hazards to which the building is subjected, including external exposures such as deliberate fire setting; and

- Protection measures included within the building.

It is also understood that the geographical proximity of other properties being insured by the company is considered so as to limit their exposure within a defined area. However, it is the EML calculation that is the most important factor for the underwriter. Within the firm investigated, surveyors will comment on EMLs as part of the survey and provide a percentage EML for buildings, contents, and business interruption where requested by underwriters. However, the final decision on the percentage EMLs to use to calculate exposures rests with the underwriter, although the underwriters must assess the EML on the information provided by the Risk Adviser. Where in the opinion of the underwriter, the EML is significantly different than that suggested by the Risk Adviser; the underwriter would discuss their rationale with the surveyor for agreement. It was suggested that the fundamental reasons for calculating the EML of a risk are:

- To ensure that the firm underwrite to their maximum capacity, which would not necessarily be the case if acceptance was based purely on the sum insured.

- To avoid over-exposure, i.e. writing above the firm’s acceptance level.

**4.2.2.2 Risk Management**

During his interview, the insurance Property Risk Manager revealed that his firm undertake between 35000 and 40000 surveys each year at properties they insure. By discussing the role of the Risk Adviser, it is apparent that insurers have a big commitment to active risk
management and loss prevention activities in order to maintain and improve their portfolio of risks.

### 4.2.2.3 Fire Engineering Design

A framework for a fire engineered approach to building design is described in BS7974-0 (British Standards Institution, 2001) and illustrated in Figure 4.4. Clause 4.1 of that Code divides the framework into three stages;

1. Qualitative design review (QDR) where the scope and the objectives of the fire safety design are defined, and where performance criteria are established and acceptance criteria set;
2. Quantitative analysis, where engineering methods are used to evaluate potential solutions; and
3. Assessment against criteria, where the results of the quantitative analysis are compared against the acceptance criteria.

It is suggested in BS7974-0 that the QDR team on a major project might include a representative of the approvals body and/or the insurer. However, the insurance industry sees this as an important stage in the building design phase and suggests that, wherever practicable, the insurer must be invited to join the QDR team (Fire Protection Association, 2008).
The objectives for the fire safety design are discussed and described in the QDR process. Objectives of fire safe building design are life safety, property protection and continuity of operations (Cote, 2004), although others include environmental protection and protection of heritage. Life safety objectives are those mandated in the UK Building Regulations (Great Britain, 2006a) and are often achieved by providing systems for early warning of fire, extinguishing of a fire and proper egress for prompt egress from the building. Property protection is not a mandated objective, but is of concern to insurers as they have a financial interest in minimising losses. It can be achieved by installing fire extinguishing systems, by providing compartmentation features to confine or limit fire spread within a building, and by constructing the building with materials that resist fire development. Continuity of operations objectives are not mandated, but of interest to insurers as commercial property insurance policies cover not only material damage (MD), but also business interruption (BI). It
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considers the specific and unique functions of the building and its contents and is best accomplished through the installation of automatic fire extinguishing systems and by ensuring duplication of the ‘unique’ function, either within the building under consideration, or elsewhere. Within the BS7974-0 framework, support is given to the consideration of property protection and continuity of operations objectives. For example, clauses 6.3.1 and 6.3.3 state that;

“The fire safety objectives that might typically be addressed in a fire safety engineering study [include] loss control...It might be desirable to take measures to reduce the potential for large financial losses...Consideration may be given to minimise damage to the structure and fabric of the building, the building contents, the ongoing business viability, the corporate image.” (British Standards Institution, 2001)

Therefore, to meet the requirements of the insurance industry, the fire safety objectives of the QDR must include property and business protection matters, to the extent determined by the agreed acceptance criteria.

4.2.2.4 The Insurer’s Role

The process described in the preceding section describes how a recognised and well used fire safety engineering design process should actively engage insurers; however, the reality is very different. Recent research by Wilkinson et al (2010b) suggests that insurers do not play an active role in the fire safety engineering process, and when they do, their poor levels of knowledge and understanding precludes any meaningful interaction. An interview with one insurance Property Risk Manager confirmed that his firm does not often get involved in the building design process, citing less than 10 percent of their property risk portfolio having had
insurer input at design stage. Although he believes there is a good understanding of fire safety engineering, and its potential implications to the insurance industry, he explained that there could be numerous reasons why insurers do not appear to get involved. As approximately 90 percent of his firm’s commercial property insurance comes to them via brokers. It could be that the broker hinders good communication between the insurer and the client’s design team.

This alone is, however, not the only reason why there is limited insurer engagement in the building design process. Another study (Barrett, 2010) suggests that often insurers are willing to engage with designers, but many times they are either not invited to do so, or are involved very late in the process, where they merely ‘rubber-stamp’ design decisions. There is a need to improve such adversarial practices as the benefits of early insurer involvement, as described previously, are many. There is, however, a glimmer of hope in that there are a few advocates who regularly consult with insurers on a majority of their projects, which is consistent with the findings of Barrett (2010).

The insurance company Property Risk Manager was able to list some examples where his firm had contributed in the building design process, and even influenced significant changes in terms of installed fire safety measures. However, these ‘successes’ are often limited to very prescriptive type messages, such as ‘put in sprinklers’, rather than full engagement with a performance-based methodology. This is a point echoed in research by Wilkinson, et al. (2010a).

The interview with the insured’s Risk and Insurance Manager described how the insurer was recently invited to participate in a QDR process as part of the design of a transport interchange within their site. The fire engineering consultants invited the client and the insurer to discuss the development of a fire strategy for the station design. The insurer was
able to convince the client and fire engineers that the addition of fire sprinklers within voids over false ceilings in the retail areas of the station would be a prudent investment, based on the insurers experience of fire related losses in situation where sprinklers were not installed. This anecdotal example illustrated good practice where a responsible fire safety engineer had involved an experienced insurer and the result was the inclusion of additional fire suppression features. Just as there are benefits, there are some basic limitations that need to be recognised and addressed. For instance, in this case, because of insurer involvement, the discussion mostly concentrated on a prescriptive solution, rather than a discussion of performance-based objectives. Also, where insurers are seen to impose their requirements too forcefully, the chances are that they alienate the end-user client, or their Broker, who may seek an alternative insurance provider.

The interview with the insurance company’s Risk Adviser and Sprinkler Risk Adviser revealed that when invited to survey fire engineered buildings, insurance risk surveyors are aware of the common physical differences of fire protection measures provided when compared to code compliant properties. They described how they give more consideration to potential fire inception hazards, the distribution of fire load and the potential for fire spread, especially when novel construction materials or design features are encountered. However, this approach is reactive, i.e. surveying the constructed building, rather than active, i.e. being an influential part of the design process, where fires can be controlled and therefore properties protected. These reactive approaches may work in the short-term, however for a truly effective strategy; the approach would need to be proactive, engaging designers and insurers alike at ‘defined’ points in the property development and management processes.
From the discussion above, it is clear that the insurer does not play a suitably active role in the building design process, nor do they command sufficient influence. This is due to a number of reasons, including:

- Commercial property insurers are often not identified at the conceptual design stage and are therefore not able to participate;

- If a contract works insurer is appointed, their priorities are quite different where their focus is concentrated on the construction process, rather than the occupied building;

- Insurance brokers acting as the intermediary between insurer and insured can mean that any opportunities to be involved with design are missed;

- In a soft market, insurers are less inclined to insist on costly fire protection measures when they are competing for income premium against other insurers, and are therefore less likely to want to participate in the design process, or fearful of losing the client; and

- Fire safety engineering designers are often reluctant to invite insurers into the QDR process for fear of the project incurring costly fire protection features in addition to the mandated life safety requirements.

Any effective fire safety strategy would therefore consider the above issues and devise measures to alleviate the problems. The bottom line remains that insurers have a big commitment to the risk management of the properties they have a financial interest in, but appear to lack the skills, and sometimes the willingness or authority, to commit the same effort when properties are being designed. Even with the best intentions and regardless of whether the insurer is involved in the design process or not, the current approach is not effective and the robustness of the fire engineering design becomes questionable. Fire
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Engineering is a technique, which supports innovative architectural design, vital for sustaining a modern economy. However, the probable inevitable outcome is that more buildings can suffer greater material damage and business interruption if insurers are not involved in the design process. It would be naive to assume that this will not have an impact on insuring such buildings.

4.3 IMPLEMENTATION

4.3.1 WORK PACKAGE 3- FIRE ENGINEERING AS A TOOL FOR BUSINESS AND PROPERTY PROTECTION

In response to the concerns raised in the previous Work Packages, it is clear that a new approach to fire engineering objective setting is required. The key step is to actively involve the end-user client, i.e. the organisation that has commissioned the new building and intends to occupy and use the facilities, in order to derive a complete set of design requirements. As the research undertaken in Work Package 2 has shown, commercial property insurers, whilst important stakeholders, are not necessarily best placed to inform the building design and fire engineering design processes as their early involvement in the design process is not always guaranteed. Therefore, Work Package 3 involved the development of methodologies for ensuring business and property protection objectives are met in the fire engineering design process. As described in Chapter 3, the research involved the following steps, following an Action research approach. Following the postulation of a hypothesis, each group of subsequent tasks follow the Plan, Action, Observe and Reflect process of Action research, and the grouping of tasks represent cycles.
4.3.1.1 Hypothesis

As described in Section 3.2.4 of Chapter 3, an Action research approach was adopted for Work Package 3. Early in the progress of the work, a hypothesis was postulated in response to the foregoing investigations. The hypothesis states that a process which is used to assess business risks, known as business impact analysis (BIA), can be utilised to inform the fire engineering objective-setting process. The following discussion provides evidence to support this hypothesis, before describing the research tasks, in their various cycles, undertaken to implement this theory.

BIA is defined as the procedure for collecting and analysing the urgency of organisational functions or activities, and the organisation’s tolerance of loss. It describes the resources necessary for the activities to be accomplished (Reuvid, 2006). Whilst BIA is a process which is commonplace within business continuity management (BCM) techniques, it is a method of analysis that has not yet been applied within the building design process. It is felt that where the client is able to conduct a BIA, the protection of company resources associated with the built environment that underpin the conduct of business critical activities, may be added to the fire engineering objectives to inform the qualitative design review (QDR) process, as described in PD 7974-0 (British Standards Institution, 2001).

4.3.1.2 Business Resilience, Interest and Responsibility

BIA is fundamental to ensuring a successful building design that fully meets the needs of the client. It is also essential for ensuring the continued viability and success of the client organisation. For example, a Managing Director or Chief Executive of an organisation includes the requirement to be accountable for the overall performance of the organisation and
for the day-to-day running and management of it, under delegated authority from the Executive. Their specific responsibilities include (Prospectus, 2004):

- Implementing the Executive’s policies and strategies;
- Managing the day-to-day operations of the organisation;
- Managing resources efficiently and effectively to achieve the organisation’s objectives;
- Ensuring that appropriate internal audit processes and procedures are in place;
- Developing and implementing a risk management plan; and
- Ensuring that there is a succession plan in place.

The analysis of business vulnerabilities and the appreciation of the benefits of good business continuity planning are at the heart of many of these responsibilities and as such business continuity initiatives need to start at the top of an organisation and promulgate downwards.

Indeed, it is stated in the Companies Act (Great Britain, 2006b) that a director of a company has a duty to act in the way he considers, in good faith, would be most likely to promote the success of the company for the benefit of its members as a whole, and in doing so have regard (amongst other matters) to:

- The likely consequences of any decision in the long term;
- The interests of the company's employees;
- The need to foster the company's business relationships with suppliers, customers and others;
- The impact of the company's operations on the community and the environment;
• The desirability of the company maintaining a reputation for high standards of business
  conduct; and

• The need to act fairly between members of the company.

Therefore, the responsibility to ensure a business’ long-term viability rests at the very top of
the organisation. A business that fails following a major event, such as fire, has demonstrated
a fragility that results from poor management.

4.3.1.3 Business Continuity Management

Business Continuity Management (BCM) is a business-driven process that establishes a
strategic framework to an organisation’s resilience against disruption, provides a reliable
method of restoring an organisation’s ability to supply its key products and services to an
agreed level within an agreed timescale after a disruption, and delivers a proven capability to
manage a business disruption, protecting the organisation’s reputation and brand (British
Standards Institution, 2006). BCM requires a process to be planned, implemented and
improved on a regular basis, and BS 25999-1 introduces the concept of a BCM lifecycle, as
depicted in Figure 4.5.
Figure 4.5: BCM Lifecycle (British Standards Institution, 2006)

The lifecycle follows a common ‘plan-do-check-act’ approach that begins with understanding the organisation fully.

Any business activity is sometimes subject to disruptions caused by technology failure, denial of access and fire. BCM provides the capability to adequately react to operational disruptions while protecting welfare and safety. Some of the benefits of an effective BCM (British Standards Institution, 2006), are that the organisation;

- Is able to proactively identify impacts of an operational disruption;
- Has in place an effective response to disruptions which minimises the impact on the organisation;
- Maintains the ability to manage uninsurable risks.
Central to BCM is the identification of critical activities and the resources upon which they depend. Resources are often grouped into categories such as people, plant, premises and infrastructure, and where the built environment is a part of the provision of these resources, there is clearly a need to take advantage of these analyses and consider the information during the building design phase.

4.3.1.4 Business Impact Analysis

Whilst the protection of resources that underpin critical activities with fire suppression systems goes some way towards reducing the likelihood of critical damage from fire, no system is infallible, and as such no contribution is made in ensuring critical activity availability when such systems fail (British Standards Institution, 2012). Business continuity solutions ensure that there is always adequate provision for the continuity of critical activities irrespective of the type and scale of the event behind the loss of resource.

According to British Standards Institution (2012), solutions relevant to the built environment where fire engineering tools may be used include:

- Duplication of assets;
- Splitting and separation of assets;
- Protection of assets;
- Early detection of threat.

The effects of fire are only some of the causes of disruptions that would be identified and managed within a holistic business continuity plan. However, by identifying these fire-related disruptions and potential consequences at the design stage of a building or plant, it is possible to incorporate design features designed to reduce property loss, assist in ensuring business
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continuity and provide resilience against the effects of fire. For the fire safety engineer, the
BIA (British Standards Institution, 2012) process will:

- Identify those activities critical to the end user client’s organisation;
- Identify the resources needed to support the activities; and
- Identify the fire safety objectives necessary to protect the resources.

The BIA describes;

- The importance of business activities to the company in delivering its strategic plan;
- The timescales upon which the activity must be recovered before the company sustains
critical damage;
- The resources upon which the activity depends;
- The percentage loss of resource deemed tolerable; and
- How the organisation will need to resume over time, from the minimum staffing of the
  emergency team to the full reinstatement of all services (Reuvid, 2006).

Using this information to augment the mandated life safety objectives the fire safety
objectives for consideration would contain activity specific requirements, which include the
following;

- Fire must be detected and extinguished before reaching x kW in size;
- Compartment / equipment must be recovered in 7 days; and
- Business Stream must be operational in 14 days.
Whilst fire safety engineering alone will be unable to, or may not be the most appropriate means to achieve these aims, some building elements could be instrumental in meeting these goals.

Qualitative design review (QDR), as described in Section 4.2.2.3 of Chapter 4, is one of the initial stages in the fire engineering design process. Whilst the QDR is essentially a qualitative process, it can often be useful to carry out simple calculations to resolve a difference of opinions between team members or to establish the most significant scenarios for detailed quantification. The fire engineer, architectural design team and insurer should endeavour to fully understand the end-user client’s organisation in terms of its objectives, stakeholder obligations, statutory duties and the environment in which the organisation operates. By including the information derived from a BIA, within the QDR process, the fire safety objectives can be informed from a business resilience point of view (how the building can protect the operations being undertaken, or provide for alternative facilities on a short term basis, for example), which will add to the traditional architecturally driven objectives of form and functions (how the building looks aesthetically, and works spatially, for example), and the statutory driven objective of life safety (how the means of escape are arranged, for example), providing a more complete set as shown in Figure 4.6.
4.3.1.5 BIA/QDR process

Section 4.3.1.4 describes the BIA process and suggests how it can inform a fire engineering QDR. This section continues to develop that idea.

The data gathered from the organisation’s continuity and recovery strategy, and BIA will identify mission critical activities and the timeframe within which they must be recovered (the maximum tolerable outage, or recovery time objective), and will be used as a means to establish dependencies and relationships between business processes and supporting infrastructures.

As described by Sharp (2008), Hiles (2007) and others, the BIA is an integral part of an organisation’s business continuity plan. Therefore, it is a document already in existence, undertaken by the end-user client organisation. Where a BIA is not available, or documented, the fire engineer or architectural design team could facilitate a BIA on behalf of the client.
However, there is little purpose in undertaking a BIA unless the management of the end-user client’s organisation understand the requirement and are willing to act on the findings. For a BIA to be undertaken successfully, its purpose must be appreciated and supported by senior management in advance of the process commencing. Before a BIA is undertaken, a clearly stated commitment to the wider goals and objectives of business continuity management should be sought from senior management within the client’s organisation. This commitment should include the organisation’s appetite to invest in the solutions that result from the use of a BIA to help define the design requirements.

Figure 4.7 shows the three steps in the BIA process (British Standards Institution, 2012).

![BIA process steps](image-url)
Step 1: Scope. This will largely be influenced by the scope of the building or plant being designed. However, a new facility being constructed within an existing site, will require a BIA which analyses the entire site, or facility in order to fully understand the influences and dependencies within the new building.

Step 2: Data Collection. This requires a collaborative approach to be taken, but it is essential that the end-user client is responsible for undertaking the analysis. The client’s insurer, or insurance broker will often have a good understanding of the organisation, the hazards, and business interruption consequences, however, it is the only the end-user client who can convey the full picture. The senior management team should be asked to consider the organisation as a whole and provide a ranking for key products or services and the point at which the maximum tolerable period of disruption (MTPD) occurs. This team will also need to set the timescale for resumption within the MTPD, which is called the recovery time objective (RTO). The outcome of this data collection is to determine the critical activities across the organisation that is needed to deliver these products and services (Sharp, 2008).

Step 3: Moderation. It is essential to subject the findings to a moderation process, rather than simply accepting the findings at face value. Moderation is best conducted by senior managers within the client’s organisation so they can give the global perspective, but other various methods to moderate the BIA data include (Hiles, 2007);

- Comparison of output with findings of earlier reviews, or across other divisions, or with internal expectations;

- Use of peer review with other BCM experts; and

- Use of a senior figure within the client organisation (or panel) to assess the initial findings.
Once the BIA has been completed, the process undertaken and the findings should be documented in such a way that it:

- Provides a meaningful input into the fire engineering objective setting within the QDR;
- Feeds back into the wider client organisation’s business continuity management plan; and
- Provides sufficient evidence of the process to satisfy later audit.

The incorporation of such a BIA, or the interpretation of the end-user client organisation’s BIA, into the QDR and objective setting process will then allow the fire engineer to establish scenarios for quantitative analysis utilising appropriate fire protection tactics, as depicted in Figure 4.8, resulting in resilient building designs.
4.3.1.6 Standardising the Method

Modern fire engineering design is an integral part of the entire building design process from the conceptual phase onwards (CIB W014, 2001). Typically, the architect makes a draft design based on his interpretation of the end-user client’s objectives. As the building design evolves, with the input of the structural engineer and the building services engineer, the fire engineer selects and designs appropriate components to satisfy the functional fire safety objectives. However, in order to inform the objective setting process as outlined earlier, there is a requirement for business resilience objectives to be explored at the earliest opportunity. Therefore, in order to promote the concept of utilising BIA discussed in the previous sections of this paper and ensure that an organisation’s resilience objectives are considered in the building design phase, the process needs to be embedded within the established fire engineering design framework.

As outlined in Section 4.2.2.3 of Chapter 4, an established framework for a fire engineered approach to building design is described in BS7974-0 (British Standards Institution, 2001). As a performance-based fire safety design process, BS7974 is widely used globally to varying degrees, but is often considered the framework against which fire engineering proposals are appraised in the UK’s national building regulation approvals process, such as in England and Wales (Department of Communities and Local Government, 2007).

FSH/024 is the Technical Committee within the British Standards Institution that, under the direction of the Standards Policy and Strategy Committee is responsible for the development and maintenance of standards for fire engineering in buildings. It represents the UK on European and International standards organisations and it drafted the standard BS7974 Code of Practice on the Application of Fire engineering Principles to the design of Buildings which
The Research Undertaken

is supported by eight Published Documents each containing detailed technical guidance on different aspects of fire engineering from background information to quantitative risk assessment (Charters, 2006).

Following the postulation of a hypothesis earlier in this Chapter, the research undertaken followed the Plan, Action, Observe and Reflect process of Action research, with the grouping of tasks representing cycles, as detailed in Section 3.2.4 of Chapter 3.

**Cycle 1: Preliminary ideas.** During 2010, the author brought the concerns relating to the use of fire engineering and possible degradation of resilient fire engineering building design to the attention of the FSH/24 Technical Committee. The Committee appreciated the requirement to promote business resilience objectives within the fire engineering QDR process and quickly gave their support. The author championed the concepts within the Committee, established, and then led a working party of experts, known as a Panel to develop some initial ideas (Plan). The author enlisted expertise from various fire engineering stakeholder groups and encouraged members to join the Panel. The panel comprised practitioners, insurers, academics and various approval bodies. In November 2010, under the leadership of the author, the Panel met for the first time to propose then review ideas and discuss potential output, including the idea of creating a new published document in the BS7974 series to describe and standardise the BIA process (Action – Observe – Reflect).

**Cycle 2: Developing processes.** A business case was developed by the author, which was presented to BSI. Once approved, the author drafted a guidance document which is now known as *PD7974-8 Application of fire safety engineering principles to the design of buildings – Part 8: Property protection, mission continuity and resilience* (British Standards Institution, 2012). Starting by agreeing a structure for the document, the author quickly developed a framework for the text and the author led in distributing tasks amongst the Panel
members with individuals concentrating on certain elements, such as describing the process, developing worked examples, etc. (Plan – Action). Under the leadership of the author, the Panel continued to meet at regular intervals so the group could review the output (Observe) and then discuss and refine (Reflect). In September 2011, an initial draft document containing PD7974-8 was presented by the author to the FSH/24 Technical Committee for discussion and approval.

**Cycle 3: Developing a document.** Following approval from FSH/24, a Content Developer was appointed by BSI to assist with formatting of the draft PD7974-8 (Plan – Action). As a Standard needs to be of a sufficiently high quality that it will be widely adopted and used by the community for which it is intended, the Content Developer is assigned to help reduce the burden, allowing the Panel to concentrate on agreeing the technical content. The Content Developer carried out many of the administrative, editorial and project management responsibilities, under the direction of the author, in the role of Panel leader. The Content Developer edited the draft in accordance with the guidance in BS0 *A Standard for Standards* (British Standards Institution, 2011) and arranged for the BSI Drawing Office to prepare the necessary figures. The author managed this process and, after several reviews via email correspondence between the Content Developer and the author, the resulting draft PD7974-8 was circulated to the Panel and the parent Committee (FSH/24) for approval (Observe – Reflect).

**Cycle 4: Publishing the document.** The Content Developer circulated the ‘approved draft’ to all interested Committees, nominating organisations and external contacts, such as the Association of Specialist Fire Protection and the Fire Industry Association. The document was made available via the BSI Consultation website (Plan – Action) and in May 2012, following a two-month full public consultation period, 13 comments were received. The
The Research Undertaken

Panel met, under the leadership of the author, to discuss and ultimately decide whether to accept, note or reject the comments made (Observe). The 13 comments came from a small number of well respected organisations such as the London Fire and Emergency Planning Authority and the British Automatic Fire Sprinkler Association. As they are organisations who already promote best practice in fire engineering and promote resilience in building design, their comments and proposed changes were well received by the Panel. Only minor amendments were made to the draft document (Reflect), which was then presented by the author to FSH/24 Technical Committee, approved and published. PD7974-8:2012 Application of fire safety engineering principles to the design of buildings – Part 8: Property protection, mission continuity and resilience was published in September 2012. The research undertaken as part of this Engineering Doctorate underpins the text of the guidance document. The small quantity and minor nature of amendments reflects the fact that the research work is sound and accepted by the industry. Full description of an evaluation exercise is in Section 5.6.3 in Chapter 5.

4.3.1.7 Document Structure

The draft PD7974-8 was developed in accordance with the established protocol for all British Standard codes, and follows the requirements of BS0, A Standard for Standards (British Standards Institution, 2011) which aims to ensure that standards are clear, consistent and usable. It begins by describing the relationship of PD8 with other publications in the BS7974 series. It introduces the concepts, terminologies and drivers for adopting the approaches outlined in the document; and then defines the scope. As PD8 is intended to supplement the existing design process as established within BS7974, PD8 sets out clearly when fire engineering design objectives are considered. It describes the established QDR process and how PD8 should be used to incorporate the clients’ resilience objectives.
An investigation into resilient fire engineering building design

The main body of the document describes the BIA process, how a BIA can be interpreted for fire engineering purposes and then details numerous examples of resilience objectives and fire safety tactics to meet these objectives. Case study examples of how the process in PD8 can influence fire engineering design are presented from a wide spectrum of building occupancies, a school, a food manufacturing site and a nuclear power station. Within the guidance document, appendices include background information in relation to business continuity management as described in BS25999 (British Standards Institution, 2006) and example BIA formatting with typical BIA data.

4.4 DISSEMINATION AND STAKEHOLDER ENGAGEMENT

 Throughout the research programme, dissemination activities were undertaken in order to describe the research, garner formal and informal feedback, engage with all stakeholder groups and promote the concepts being developed.

The dissemination activities are shown in Table 4.2, below, and included numerous poster presentations at related conferences, which proved useful in stimulating discussion with interested stakeholders. In addition, formal academic conference and journal papers have been produced (reproduced in Appendices A to D) as well as articles and presentations specifically targeted at the practitioner community. The other outputs that have been developed as part of this research are also shown in Table 4.2, below.

At various stages throughout the research programme, workshops with selected stakeholder groups were conducted. The aim of the stakeholder workshops was to inform the group of the need for, and the progress of the research, discuss the planned deliverables, gain the benefit of input and suggestions from the groups as well as gauge the success of the research via
The Research Undertaken

informal feedback. The stakeholder groups were Enforcers, Practitioners, Insurers and End-users and the workshops are detailed in Table 4.3, below.
An investigation into resilient fire engineering building design
## The Research Undertaken

### Table 4.3: Stakeholder Engagement Workshops

<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>Workshop Events</th>
<th>Date</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enforcers</strong></td>
<td>Core Cities Building Control Meeting</td>
<td>September 2011</td>
<td>Started by giving a presentation of research and outputs to this group of Local Authority Heads of Building Control from the major UK cities. Next, opened discussion about their experiences of fire engineering, and gained positive feedback about use of PD7974-8.</td>
</tr>
<tr>
<td></td>
<td>Hampshire Fire and Rescue Service visit</td>
<td>December 2010</td>
<td>Met with Chief and other senior Fire Officers at Hampshire Fire and Rescue Service to discuss research and a local fire incident where a devastating fire had a significant impact on valuable research work.</td>
</tr>
<tr>
<td><strong>Practitioners</strong></td>
<td>Institution of Fire Engineers; Technical Strategy Advisory Group meeting</td>
<td>March 2011</td>
<td>Started by giving a presentation of research and outputs to this group of fire engineering practitioners from well respected consultancy practices. Next, opened discussion about the research, their experiences of dealing with other stakeholders in the process of fire engineering, and gained positive feedback about use of PD7974-8.</td>
</tr>
<tr>
<td><strong>Insurers</strong></td>
<td>RISCAuthority Passive Working Group</td>
<td>Various dates through 2011 and 2012</td>
<td>At numerous Working Group meetings of these two groups of leading commercial property insurers, progress of research has been given. These meetings have provided regular opportunities to gauge the direction of the research and gain feedback.</td>
</tr>
</tbody>
</table>


## Stakeholder Group, Workshop Events, Date, Discussion

<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>Workshop Events</th>
<th>Date</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>End users</td>
<td>London Health and Safety Group- Fire Safety Symposium</td>
<td>Jan 2012</td>
<td>Gave presentation to this group of health and safety professionals, largely working in end-user organisations. The presentation provoked discussion about the challenges of engaging the Board, challenges directing architects, etc. Feedback regarding use of PD7974-8 was very positive.</td>
</tr>
</tbody>
</table>

### 4.5 SUMMARY

This chapter has described the research activities and development undertaken by the author. Research activities have progressed through three phases, namely exploration, conception and implementation.

The long-term aim of this research programme was to examine fire engineering practices in the UK, with a view to identifying best practices, current gaps and developing improvements.

By undertaking knowledge elicitation exercises involving interview-based investigations and case-study investigations; stakeholder workshops; the development of a significant deliverable and pilot evaluation of that deliverable, the author has investigated well defined topics, gathered evidence, formed opinion, developed an understanding of the changes required, built a case to support the proposed changes, and then influenced the change process. The original aims of the research programme have been met.
5  FINDINGS & IMPLICATIONS

5.1  THE KEY FINDINGS OF THE RESEARCH

Work Package 1 concluded that fire engineering facilitates architectural design freedoms and supports creative construction allowing the UK to continue to develop its reputation as a centre for world-class developments. London, for example, now has many prestigious and innovative buildings, worthy of a global financial centre. Along with equally impressive airports and public entertainment venues, a message of innovation, good design and prosperity is given to all visitors. However, it has also become evident that since fire engineering has become more accepted, significant concerns have been raised regarding various elements of the design process including, the appropriate use of fire engineering, the ability of building control professionals to approve designs, and of fire and rescue service personnel to contribute to the process, the involvement of the insurer and the ability to champion objectives other than life safety, the limitations of the knowledge, data and tools that support fire engineering design concepts, and the ability of professional institutions to guide and regulate practicing fire engineers. All these issues need to be addressed if fire engineering is to enjoy continued growth as a profession, and continued acceptance as a legitimate contributor to the building design process.

Work Package 2 concluded that, at least within the largest insurance companies, there is an understanding of the differences between prescriptive, ‘code-compliant’ buildings and performance-based, ‘fire engineered’ buildings. There is an acknowledgement that processes within insurance underwriting for fire engineered buildings should take account of these differences in risk, and examples have been cited. However, despite a small number of minor examples, it is clear that the insurer does not play a suitably active role in the building design
process. Insurers display a big commitment to risk management of the properties they have a financial interest in, but appear to lack the skills, and sometimes the will, to commit the same effort when properties are being designed. The probable inevitable outcome is that more buildings will suffer greater material damage and business interruption without early insurer involvement in the design process.

Therefore, Work Package 3 responded to these initial research activities. The concept of business impact analysis has been explored to ensure that property protection and business continuity objectives are at the forefront of new building design, whether the insurer is involved in the process or not.

The concepts developed and the findings of this research were pivotal in defining and developing the contents of PD7974-8 (British Standards Institution, 2012).

5.2 CONTRIBUTION TO EXISTING THEORY AND PRACTICE

In order to help consulting fire engineers, and architectural design teams, incorporate business protection objectives in their fire safety designs, there is a requirement for the established British Standard which defines a fire engineering procedure, to be enhanced. This idea gained support from the Technical Committee within BSI responsible for maintaining the Standard, and PD 7974-8 Application of fire safety engineering principles to the design of buildings-Part 8: Property protection, mission continuity and resilience (British Standards Institution, 2012) has been drafted.

The new Standard, developed as part of this research study, embeds the use of a business impact analysis as an integral part of the qualitative design review process. Without following the BIA process as described in the draft document PD7974-8, business resilience
objectives may be missed within the building design phase, allowing an inferior package of fire protection measures to be incorporated into building developments.

For the first time, this new document will enable the building designer to be fully cognisant of their client's critical processes and the resources required to support these processes. It will therefore enable the appropriate fire safety measures to be incorporated into the building design to enhance business resilience.

5.3 IMPACT ON THE SPONSOR

The Fire Protection Association and the RISCAuthority have an interest in ensuring that fire engineering methods are applied responsibly and appropriately, and that design decisions are made for the right reasons, not purely for short-term financial gains. This research has investigated and reported widely concerns that have been anecdotally acknowledged for some time. The new Standard, developed as part of this research study, has gained the support of the commercial property insurance companies who are RISCAuthority members and it is hoped that, with its widespread use and acceptance, a positive impact towards a reduction in commercial insurance losses will be measured.

5.4 IMPACT ON THE WIDER INDUSTRY

It is envisaged that this research has the potential to have an impact at International, National, Organisational and Societal levels.

This study and its resulting outputs have the potential to be adopted as European and International standards through the mirror standards committees attended by BSI FSH/24 members, including CEN and ISO technical committees.
The BIA concept for gathering building design objectives should become part of an architect’s tool kit and used frequently. In order to gain maximum benefit from the methods, this process ideally sits within Work Stage A *Appraisal* stage of the Royal Institute of British Architect's (RIBA) Plan of Work. Work Stage A comprises the identification of client's needs and objectives, business case and possible constraints on development. It is also the time for preparation of feasibility studies and assessment of options to enable the client to decide whether to proceed (RIBA, 2009). Similarly, this is described in Work Stage 1 *Preparation* in the proposed 2013 edition (RIBA, 2012). As use of the process increases, this will lead to a shift in culture towards a real appreciation of the end-user clients’ organisational priorities, and an understanding of how the built environment can assist the resilience of these priorities, benefiting the long-term interests of the client and society at large. It will also lead to shift in appointment of a fire engineering practitioner to a project, from the current practice of appointment at Work Stage C or D, *Concept* or *Design Development*, to much earlier in the process at Work Stage A (RIBA, 2009).

PD7974-8 (British Standards Institution, 2012) aligns well with quality management and health and safety management frameworks such as BS EN ISO 9001:2008, *Quality management systems; Requirements* (British Standards Institution, 2008b) and BS OHSAS 18001:2007, *Occupational health and safety management systems; Requirements* (British Standards Institution, 2007). This alignment is a positive feature as it means that its use should feel less daunting to the business community who already used to these other compliance processes. Familiarity to the approach will hopefully assist in acceptance of the process by industry, thereby helping the building design community to embrace their clients' requirements.
5.5 RECOMMENDATIONS FOR INDUSTRY AND FURTHER RESEARCH

The conducted research has highlighted two specific areas for further research, and development.

5.5.1 DEVELOPMENT OF EXEMPLARS

Until PD7974-8 (British Standards Institution, 2012) is widely used by the building design community, the concept is likely to be challenging to apply by those unfamiliar with business continuity planning concepts. Where the end-user client organisation has not conducted a business impact analysis themselves, facilitating one for the purposes of building design is likely to meet with resistance, without the potential benefits being explained.

A series of case study examples of how the process has been applied to a range of building occupancy types, with true BIA output and translation into fire safety design objectives, would greatly assist in communicating the potential benefits, refining the process and spreading best practice application.

5.5.2 PROPERTY PROTECTION GUIDANCE

Whilst the research documented in this thesis helps building designers to formulate a complete set of performance objectives by utilising a BIA to inform a QDR, the next step is to specify, design and approve the fire protection measures or systems in order to realise these objectives. The research conducted here supports the view that fire engineering practitioners and other fire safety professionals are misinterpreting the additional design requirements that require consideration when their clients require business, property or heritage protection objectives to be met.
In order to address this need, a guidance document is required, which describes the additional requirements placed on the fire engineer when tasked with a project that specifically requires the consideration of property, business or heritage protection.

It is likely that such a guidance document would:

- Describe the role that every managing director should play in the protection of their business as described in the Companies Act (Great Britain, 2006b) and the role of the fire engineering practitioner in supporting them in this;

- Introduce the subject with a simple overview of the differences between a life-safety focused designed building, and one designed for property protection and the different stakeholders required in the consultation (extension of remit from evacuation of personnel only, to include prevention and building protection objectives);

- Clarify where sprinklers are referenced in fire engineering codes and reinforce that they specifically relate to sprinkler systems and not other water-based suppression technologies giving appropriate reasons;

- Provide specific details of property protection tactics;

- Analyse the design objectives to identify where to place prevention/protection effort;

- Understand the need for considering a wide spectrum of risks (particularly arson and malicious fire raising from those associated with the building, and strangers);

- Understand the preference for fixed, automatic systems rather than man-managed protection;

- Understand the requirement for ‘total coverage’ of protection over choice selection of areas;
Findings & Implications

- Bring in the goals of the essential principles described in the LPC Design Guide for the Fire Protection of Buildings (Loss Prevention Council. 1996) but allow the fire engineer to determine how they are achieved;

- Enforce the need for evidence of performance of systems that support the overall fire engineering solution; and

- Cross reference other relevant sources of information, including PD7974-8 (British Standards Institution, 2012).

Such a guidance document would require disseminating to every fire engineering practitioner in the UK and would be ideally referenced in BS7974 (British Standards Institution, 2001).

5.5.3 Other Areas for Further Research

The potential benefits that Building Information Management (BIM) systems bring to fire engineering practitioners is worthy of further research in order to maximise these benefits of the collaborative nature of the BIM philosophy.

The research and earlier discussion concerning the various stakeholders in the fire engineering design process shows that there are many factors that need consideration when defining strategies for collaborative working. As observed by Emmitt and Ruikar (2013), these range from hard issues such as system platforms, software and hardware requirements, to soft issues concerning culture, working methods, governance, motivation, competence and absorption (or learning) capacity of end-users.

The multi-disciplinary and collaborative nature of the construction industry necessitates the development of 'collective' competence and multiparty commitment for seamless and successful project delivery, such as that facilitated by BIM. The success of the implementation of the methods described in PD7974-8 (British Standards Institution, 2012)
demands such collaboration and so such competence and commitment is vitally important. In collaborative environments interoperability between different systems is a major issue due to the existence of multiple teams with varying levels of technology competence. Issues such as these which are common to complex systems can potentially be resolved by adopting innovative, interdisciplinary approaches such as those facilitated by BIM tools. Such BIM-supported a collaborative approach challenges the traditional single-discipline, silo-based approach and is inherently complex, since the behaviour of and interaction among system components are not always well defined or easily understood. The key consideration therefore should be not simply the system itself, but also the human element. The introduction of IT systems (e.g. BIM systems), thus has a powerful behavioural and organisational impact. It transforms the way various individuals and groups perform and interact. From a fire engineering perspective, thus, this change would require active engagement of designers, insurers, enforcers and practitioners during the design stage so that their needs are fully understood and input into the design at conception. Only then can the full potential of a fire resilient building design be realised. Therein lays the challenge.

5.6 CRITICAL EVALUATION OF THE RESEARCH

5.6.1 EVALUATION OF THE RESEARCH PROCESS

At various stages throughout the research programme, workshops with selected stakeholder groups were conducted. The aim of the stakeholder workshops was to inform the group of the need for and the progress of the research, discuss the planned deliverables, gain the benefit of input and suggestions from the groups as well as gauge the success of the research via informal feedback. The stakeholder groups were Enforcers, Practitioners, Insurers and End-users. The Enforcer workshop events included a group of Local Authority Heads of Building
Control from the major UK cities, and delegation from a county Fire and Rescue Service including the Chief Fire Officer and other senior officers. Both Enforcer workshops were well received, gaining support and positive feedback for the research. The Practitioner workshop event involved leading fire engineers who participate in the Institution of Fire Engineers Technical Strategy Advisory Group. The wide ranging discussions were generally supportive and echoed many of the findings of the research. Insurer stakeholder events concentrated on those commercial property insurers who already demonstrate a commitment to research and development by being actively engaged in RISCAuthority working groups. Regular engagement with these groups has facilitated opportunities to gauge the direction of the research and gain feedback. The End-user workshop event provoked much discussion about the challenges of engaging the Board and also the challenges of expression the clients’ requirements to building design professionals.

All workshops provided the opportunity to reflect on the research topic, the adopted methodologies and the resultant findings. Whilst this reflection has largely confirmed the appropriateness of the research, this reflection has developed into critical evaluation, especially when considering how certain constraints have impacted on the nature of the outcome. Whilst it is understood that standardising the way documents are produced is necessary, it is felt that the BSI editorial procedures have had a limited stifling effect on the development of the text resulting in a possible dilution in the strength of the message.

5.6.2 EVALUATION OF THE RESEARCHER

Due to the exposure conducting this doctoral research had generated, the author was invited to deliver the 2011 Fire Technology Seminar, in Johannesburg, South Africa, organised by the Fire Protection Association of Southern Africa. As the invited expert, the author prepared, developed and presented seven lectures over two days to an international audience comprising
practitioners, enforcers, academics and the wider fire safety community in a jurisdiction where performance-based fire engineering design is beginning to become accepted and used more widely. The lectures covered all of the aspects of this doctoral research and provided an opportunity for the research findings to be presented to an informed audience and to benefit from active engagement in discussion about these themes. The lecture topics were presented as;

- Building needs of a modern society;
- Fire engineering; The UK experience;
- Fire safety challenges; The drive for sustainability;
- Business continuity planning; How it can influence resilient building design;
- Codes and methods; BS9999;
- Codes and methods; BS7974; and
- Fire engineering tools.

The subject matter presented to the audience directly drew on the knowledge elicited from the doctoral research. Discussion generated by the lectures gave a valuable confirmation that the experiences within the UK were similar to those internationally, and supported the view that the author remained objective, i.e. was not biased by looking at the issues surrounding resilient fire engineering building design from the practitioner perspective alone. The delegates were asked to complete evaluation forms. 91 delegates submitted feedback via the ‘tick sheets’ provided, with 67 of them writing specific comments. This feedback provided qualitative dissemination evaluation regarding the knowledge of the author, the research being presented and communication skills, with the feedback being generally very positive and complimentary. The Fire Technology Seminar was followed up by the author publishing an

The author won Student of the Year category at the CIR Business Continuity Awards 2011 and the doctoral research project was shortlisted for the Association of Building Engineers’ Fire Safety Award 2012.

### 5.6.3 Evaluation of the Main Project Deliverable

In May 2012, following a full public consultation period, where comments are invited from all interested parties, 13 comments were received. The Panel met to discuss and ultimately decide whether to accept, note or reject the comments made. It is noted that these 13 comments were made by people and organisations that have genuine interest in promoting best practice and resilient designs which demonstrates that the consultation reached the sector of the industry who share concerns in resilient fire engineering building design, and generated appropriate interest. Minor amendments were made to the draft document, which was approved by FSH/24 Technical Committee and published.

In addition, the document has been exposed to various fire engineering stakeholder groups during a range of dissemination activities, including the commercial property insurance community, fire engineering practitioners and building user client groups. On each occasion, the discussions have generated positive feedback and support for the approach.

However, in order to evaluate the practicality of the methods described within PD7974-8 in greater detail, a desk-top pilot study was undertaken. The pilot study involved a detailed discussion with a commercial property insurer, evaluating a recent fire engineering project they had been involved with. The pilot study involved an established small-scale snack food producer and their plans to expand production capabilities to meet a significant increase in
sales including substantial plans to develop an export market. It was described both in terms of a ‘conventional’ fire safety design where life safety objectives were considered, and in terms of an approach considering objectives gleaned from a BIA-type study. In more detail, the site being studied was described as compact, comprising an office building, a production building and a storage building. The storage building can house up to 7 days’ worth of product, so essentially the business operates a “just in time” manufacturing philosophy. The production building is a converted farm building which houses frying ranges, protected with automatic fire suppression local to the ranges. The ranges are provided with a single feed from the bulk oil storage tank.

The client and their team originally chose the most cost-effective option of expanding the original production building by building a simple extension, thereby providing the space to locate additional frying ranges, etc. This option met all Building Regulation requirements and met with approval from the Building Control body. However, after conducting a BIA, the following business resilience issues were taken into account in order to adjust the fire safety objectives.

- With fruition of successful business development, loss of production for more than two days is unacceptable;

- The original expanded building designs represents a large “single and communicating risk”, which would be considered by insurers as an estimated maximum loss (EML) of 100%. For many insurers, this EML would be too high to cover and would require reinsurance, increasing costs for the client;

- The client is the largest employer in the surrounding rural area and therefore the loss to the community resulting from a disruptive fire is large;
Findings & Implications

- The business is owned by a venture capitalist organisation, which is keen to look after its investment and acts as a vocal Board member; and

- Having identified these issues, to proceed as planned, would mean the MD would be falling short of an MD’s responsibilities.

Following the BIA process and after discussions with their insurer, the client chose to convert the existing warehouse into a new production facility, separated by more than 20 m from the original production building. A new warehouse is planned which will be sprinklered which means that the client will now have two separate production lines operating in parallel, both protected by high-pressure fog fire suppression, giving protection of production operations, with a new sprinkler protected warehouse giving additional business resilience. The new arrangements will attract the maximum discount from their insurers.

Without following the process as described in the draft document PD7974-8 (British Standards Institution, 2012) such business resilience objectives may have been missed within the building design phase, allowing an inferior package of fire protection measures to be incorporated into the development. PD7974-8 now provides a standardised method for building designers and fire engineers to fully appreciate their client’s requirements.

5.6.4 Key Contributions of This Research

This thesis presents the findings from a four year Engineering Doctorate (EngD) research project into resilient fire engineering building design.

As described in Section 1.4.2 of Chapter 1, the key objective of this research programme is to influence change in the way fire engineering is often used with an emphasis on improving property and business resilience fire safety objective setting.
An investigation into resilient fire engineering building design

The findings have demonstrated that this objective was achieved by undertaking a series of work packages, as outlined Chapter 1.

In light of very limited literature and research in this highly specialised domain of resilient fire engineering building design, this research has drawn many significant insights. The main novel insights from this research include;

- Contributing to the limited body of knowledge by documenting a detailed understanding of the historic development and state-of-the-art of fire engineering practices in the UK;
- Drawing new insights into the experiences and relationships between the various stakeholders in the fire engineering design process;
- Given deeper understanding of the role that the commercial property insurers play in the building design process, especially in the UK;
- Identified, articulated and documented a process involving Business Impact Analyses (BIA) to inform fire safety objective setting; and
- Created a significant new part to the British Standard which provides an important addition to the established framework used by fire engineering practitioners and the wider building design communities.
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**APPENDIX A  A HISTORIC PERSPECTIVE OF FIRE ENGINEERING IN THE UK**


**Abstract**

By thoroughly reviewing the wide range of literature available, this paper documents the history of fire engineering within the United Kingdom. It defines fire engineering, gives a brief overview of how fire safety legislation, codes and guidance have developed over the centuries, and describes the point at which fire engineering began to be used as a design methodology and how it was implemented in the UK.

Furthermore, this report describes how fire engineering has matured as an engineering discipline from the initial direct application of research data, through the development, to the use of a structured fire engineering Code of Practice, and the use of fire engineering principles in contemporary construction projects.

Whilst it has been accepted that fire engineering is a necessary process which brings many benefits to the creative architectural community, and is further developing to address new design challenges, many concerns still exist.

**Keywords:** Fire engineering / Buildings, structures & design / Risk & probability analysis

**Paper type:** Journal paper
1. INTRODUCTION

1.1 Background

Fire engineering is increasingly being used as an alternative to the traditional prescriptive means of meeting the functional requirements of Part B of the Building Regulations in England and Wales. Whilst fire engineering may be the only practical way to achieve a satisfactory standard of fire safety in some large and complex buildings (Fire Protection Association, 2008) such as airport terminals or sports stadia, questions remain about its appropriate application and regulation, and the potential implications on the commercial property insurance industry (Wilkinson, Glockling et al., 2010).

1.2 Definition

The term fire engineering is often misused and not well understood by those outside the construction profession. It is the opinion of some that fire engineering involves manual firefighting, whilst of others it is prescriptive fire safety code enforcement, as suggested by Lataille (2003), whilst others think that fire engineering is the calculation of pipe sizing for fire sprinkler systems, or the completion of fire risk assessments using simple techniques or checklists.

The Institution of Fire Engineers defines fire engineering as ‘the application of scientific and engineering principles, rules [Codes], and expert judgement, based on an understanding of the phenomena and effects of fire and of the reaction and behaviour of people to fire, to protect people, property and the environment from the destructive effects of fire’ (Chitty, et al. 2003)

The Chartered Institution of Building Services Engineers cites two types fire engineering (CIBSE, 2003):
An investigation into resilient fire engineering building design

- *fire protection engineering*: where the engineer is responsible for design of fire systems such as automatic fire suppression and fire detection systems, and,

- *fire safety engineering*: where the engineer is responsible for design of fire strategies including location and number of stairs, design of smoke control regimes and designed structural fire protection measures.

It is the latter of these two types which is most appropriate for this paper, but it is interesting to examine these definitions further.

The word ‘safety’ is often added to create the term fire *safety* engineering in the United Kingdom. Anecdotal evidence attributes this to the late Professor David Rasbash, the first Professor of Fire Engineering at the University of Edinburgh who observed that at least one university official said that fire engineering sounded like a course in arson (Bickerdike Allen Partners, 1996).

Fire *protection* engineering is a term more often used in the United States. According to the Society of Fire Protection Engineers, fire protection engineering is the application of science, engineering principles and experience to protect people and their environments from the destructive effects of fire. (Richardson, et al. 2003).

The International Standards Organisation Technical Report ISO/TR 13387-1:1999 defines fire engineering as the application of engineering principles, rules and expert judgement based on scientific appreciation of the fire phenomena, of the effects of fire, and the reaction and behaviour of people, in order to;

- save life, protect property and preserve the environment and heritage;

- quantify the hazards and risk of fire and its effects;
evaluate analytically the optimum protective and preventative measures necessary to limit , within prescribed levels, the consequences of fire (Billington, Ferguson et al. 2002).

A similar definition is proposed by Purkiss (1996), however, more succinctly put fire engineering can be described as ‘the provision of fire safety measures reasonable in the circumstances of the case’ (Institution of Fire Engineers. Northern Branch. 1995).

Fire engineering is the design and construction process which, by consideration of the hazards and risks involved and the precautions which are possible, achieves a balanced and acceptable level of fire safety (Stollard, 1996).

2. FIRE ENGINEERING ORIGINS

2.1 Development of prescriptive guidance

Fire safety within the built environment has been a subject of concern for thousands of years. More than 2000 years ago, fires in Rome lead to the development of rules governing the minimum width of roads in order to facilitate fire brigade access and reduce the likelihood of fire spread (University of Salford, Association of Building Engineers, 1994).

Statutory fire safety provision within the UK has evolved slowly over many centuries, largely driven in reaction to major disasters. In London, argues Law (1991), the most significant fire disaster was the Great Fire of 1666, when the major part of the city was destroyed. There was little loss of life, and the rules for rebuilding the city concentrated on reducing the spread of fire between buildings. Controls were placed on materials of construction, on the thickness of walls and on the width of streets, describes Law (1991) and Read (1993). These rules were rigidly prescribed.
In the 19th century, after disastrous industrial fires killed fire fighters and gave major financial losses, further regulations were developed. In the 20th century, experiences of fires during the Second World War were incorporated into the Post-war Building Studies on Fire Grading of Buildings. Malhotra, et al. (1987) suggests that these were seen as landmark documents of their day influencing the technical content of the subsequent Building Regulations. By the time further amendments were made by 1976, the regulations comprised 307 pages, were highly prescriptive, and, in Law’s opinion, understood only by lawyers.

Whilst a detailed review of the development of fire safety legislation is outside the scope of this paper, the following events and corresponding legislation during the 20th century are worthy of note (Loss Prevention Council, 1998):

<table>
<thead>
<tr>
<th>Fire site</th>
<th>Death toll</th>
<th>Act of Parliament</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastwood Mills, Keighley, 1956</td>
<td>8</td>
<td>Factories Act, 1961</td>
</tr>
<tr>
<td>Henderson’s department Store, Liverpool, 1960</td>
<td>11</td>
<td>Offices, Shops and Railway Premises Act,1963</td>
</tr>
<tr>
<td>Rose and Crown Hotel, Saffron Walden, 1969</td>
<td>11</td>
<td>Fire Precautions Act, 1971</td>
</tr>
</tbody>
</table>
Ferguson and Charters (1997) describe how even traditional prescriptive building regulation systems had procedures to oversee significant departures from the standard solution, albeit cumbersome in nature. In England and Wales such relaxations were at one time granted only by central Government, although this process was devolved to local Government.

Despite criticism, prescriptive building regulations have been an important component in the evolution of fire safety in buildings. It is acknowledged that (Hasofer, Beck et al. 2007) prescriptive design has resulted in the achievement of safety levels which the community appears to accept.

2.2 Drivers for a new approach

As a result of the large and rapid increase in innovative and diversified building design, including the expansion of air travel in the early 1970s, prescriptive regulations became demonstrably restrictive and inflexible. By way of example, air travel required airports to start handling large numbers of people, who were unfamiliar with the building, in a pleasant

<table>
<thead>
<tr>
<th>Fire site</th>
<th>Death toll</th>
<th>Act of Parliament</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bradford City FC, 1985</td>
<td>58</td>
<td>Fire Safety and Safety of Places of Sport Act, 1987</td>
</tr>
<tr>
<td>King’s Cross Underground Station, 1987</td>
<td>27</td>
<td>Fire Precautions (Sub-surface Railway Stations) Regulations, 1989</td>
</tr>
</tbody>
</table>

Table 1: Significant fire events (Loss Prevention Council, 1998)

A historic perspective of fire engineering in the UK
and efficient way. Designs based on the prescriptive standards of the time simply couldn’t cope with this new design requirement. Some engineers and scientists saw the possibility of applying scientific research directly to the design of individual buildings (Charters, 2006). These issues were discussed at the time of the design of Stansted Airport by Law (1985). One important issue relating to this airport design was the need for large compartment volumes, not permitted under Building Regulations without obtaining a relaxation. Law collected a range of data from experiments, surveys and fire statistics to illustrate how various measures could compensate for lack of fire resisting construction, known as compartmentation.

Others, including Ramachandran (2000), argued that prescriptive rules are highly empirical and could lead to costly over-designs, particularly for large buildings, thereby strengthening the case for an alternative approach.

The commitment of UK Government to deregulation and to reduce the burden on industry led, in 1985, to the introduction of new functional building regulations, i.e. the Building Regulations 1985 (American Society of Civil Engineers, et al. 1995).

The requirements for fire safety of buildings given in the 1985 regulations were set out in four functional requirements. Cooke and Deakin described the regime as thus. Designers were free to provide any solution that could be shown, to the satisfaction of the regulatory enforcement authority, to fulfil the functional requirements. Technical support to the regulations set out traditional approaches that were ‘approved’ by the Secretary of State as one way of satisfying the requirements. However, the functional nature of the regulations provided greater opportunities for the adoption of fire engineered approaches to fire safety design.
Interestingly, Billington, Ferguson et al. (2002) reported that, with the introduction of the 1985 regulations, the property protection issue was deliberately set aside because the legislators’ role has been seen as being in life safety matters only.

Butcher (1992) added another note of caution regarding the use of fire engineering approaches immediately following the introduction of the 1985 regulations. Whilst he was very much in favour of the concept, he doubted whether the level of knowledge at the time could produce a genuine fire engineered solution. He identified that a vast amount of information was available in archives, research reports and studies of fire incidents which needed to be extracted and collated. He recommended a comprehensive research programme so that fire engineered calculations could be based on experience rather than vague theory (Butcher, 1992). Bullock agrees with this assertion, stating that the fire engineer requires data in order to provide a quantifiable judgement and that sufficient empirically derived data and relevant analytical methods do not exist (Bullock, 1997).

It was suggested by Cooke that the traditional prescriptive technical guidance accompanying the functional regulations would continue to be used for the majority of simple buildings, and that fire engineering would be used for large, complex buildings where the benefits were sufficient to justify the cost of the study (ASTM, 1995).

3. THE DEVELOPMENT OF FIRE ENGINEERING

3.1 A fire engineering code

Whilst formal recognition and acceptance of the use of fire engineering had been given in England and Wales within Approved Document B, no guidance was given. The pressure for guidance and a structure for the application of fire engineering principles to the design of
buildings came from designers and an initiative by the British Standards Institution (BSI) to provide a Code of Practice on the subject.

In 1989 a format and list of contents for a comprehensive Code of Practice on the application of fire engineering principles to fire safety of buildings was presented to BSI. As described by Cooke (International Council for Building Research, Studies and Documentation. Working Commission 14: Fire Safety Engineering, et al. 1993), it was intended that the proposed code would cover general principles, life safety considerations, property safety considerations, mitigation of socially unacceptable events and reduction of economic loss. By the end of 1990, Cooke describes, a small panel of fire safety engineers was formed with the support of Warrington Fire Research Centre, to undertake a three year contract, administered by BSI, which would culminate in a Code of Practice giving a framework for the fire engineering design of buildings. The panel first met in March 1991 and decided the following objectives for the code;

- The code should be analytical, with the acceptance that design could not always proceed entirely by quantification because some intuitive judgement might be necessary.

- The code should state acceptable levels of life loss.

- The code would be aimed principally at fire engineers. Whilst this means that only suitably qualified and experienced individuals might be able to undertake the analytical work, it would not necessarily mean that other members of the design, construction and building approval team would not be able to use the code.

- The code would identify, allow and encourage the use of appropriate zone and field models.
• Data and the methodology should have a high degree of transparency, i.e. the ability to trace where all the information came from.

• The principles and methodology should ideally be applicable to ‘any bounded space in which people might be present or nearby and where a fire might occur’.

Deakin (1999) described the resulting draft Code of Practice as the most important document produced in the UK in support of the use of more fundamental approaches to fire safety design. It provided the designer and the regulatory enforcement authorities with an overview of what was considered to be necessary. Deakin attempts to simplify the very complex design process and describes the way the code is divided into sub-systems. Importantly, it indicates that there are gaps in the knowledge, and that much has still to be achieved by the use of engineering judgement. Deakin comments that the ability to trace where the information within the code has come from, as described in the objectives above, focussed an unjustified emphasis on requiring demonstration of the validity and scope of the application of the relationships cited. Interestingly, he concludes that the document has been viewed in a prescriptive manner, with focus on the theory rather than the framework for design.

The draft Code of Practice was published as a Draft for development DD240 by BSI in 1997 (Billington, Ferguson et al. 2002). Since then, the format and content were reviewed leading to, in 2001, BS7974 *Code of Practice on the Application of Fire engineering Principles to the design of Buildings* being published. This code is supported by eight Published Documents, replicating the sub-systems defined in the draft, which contain detailed technical guidance on different aspects of fire engineering from background information to quantitative risk assessment (Charters, 2006).
3.2 Use of fire engineering

By the mid 1990s, it was possible to gauge how the use of the fire engineering was developing. Ferguson and Charters (1997) described the results of their review, twelve years after the introduction of the functional approach. They reported a pressure on Government to refine and update guidance documentation to address the inevitable questions relating to the new regime. Professional associations of building control officials set up closer links between their geographic areas in order to promote consistency of enforcement and agree answers to some frequently asked questions. The Ferguson and Charters paper highlighted that most construction projects involve a certain degree of variation from standard prescriptive design and that few projects, if any, are completely based on a fundamental fire engineering approach. They reported that the acceptance of fire engineered solutions is easier in some places, and for some things, than others. They argued that the reason for this relates to the skills within, and the policy of, the local authority Building Control department and the sensitivity of the project. They reported increasing concern of the qualifications required to practice fire engineering and the fear in some quarters that people acting outside their sphere of competence could mislead uninformed officials into accepting a scheme on spurious arguments.

Lucht (Institution of Fire Engineers. Northern Branch. 1995) outlined other barriers to the use of fire engineering. He identified eight key issues;

- Lack of design goals; a leading barrier to the use of emerging fire safety design methods.

  It was felt that codes and standards do not specify the overall level of safety that each is trying to achieve in the public interest.
• Resistance to change; an attitudinal barrier. It was suggested that prescriptive codes are simply easier to use than performance based methods.

• Education; the level of specialised technical education needed to implement prescriptive ‘choices’ is not nearly as high as that required to perform detailed engineering calculations, analyses and evaluations to achieve performance goals.

• Technology transfer; work is needed to translate research results into tools that practitioners can easily understand and enforcing authorities can trust.

• Economics; fire engineering design requires significant input from specialist consultants early in the conceptual development stage of building design.

• Legal barriers; the fear of liability and law suits make engineers reluctant to use invalidated design methods.

• Institutional barriers; established methods of ‘doing business’ can stand in the way of accepting new techniques. Codes and standards organisations are often slow to accept new methods.

• Technological base- the creation of effective fire safety design tools is an extremely complex problem from a scientific perspective and there are gaps in knowledge.

3.3 Stakeholders

One of the barriers to the use of fire engineering identified by Lucht, above, was discussed in greater detail by Dalloway(1995). Building Control officials enforce national building regulations in the UK, and are often cited as being resistant to change. Dalloway argued that the principal concerns of the building control surveyor was the ability to verify sources of
An investigation into resilient fire engineering building design

information and validate emerging fire engineering models and formulae. Whilst he concluded that generally building control surveyors could cope with fire engineering submissions, he stated that if it was identified that, on particular projects that they couldn’t, they should seek specialist advice. Sugden (1998) argued a similar point regarding building control officials, stating that in their training, those officials who are responsible for the approval of buildings do not have a detailed knowledge of the arguments and calculations to be used by the fire engineer. He extended this argument to include the site control the construction of fire engineered buildings. He asks is site control adequate? Do we need to make greater use of certified products and accredited installers?

Sugden (1998) also identifies one further stakeholder - the client. He suggests that there are two core motivations when considering the use of fire engineering. Firstly, fire engineering is chosen to design the fire safety when a proposed structure is of a novel design or use that does not easily fit in with existing prescriptive legislation, or, secondly, it is chosen to reduce the cost of fire protection below the anticipated cost of meeting the prescriptive rules. The potential for cutting corners and safety in this scenario is obvious, argues Sugden, and he concludes that understanding the client’s motivation will throw light on fire engineering proposals made.

Another important stakeholder group in the fire engineering process is the fire and rescue service. Butler (Institution of Fire Engineers. Northern Branch. 1995) explained the contribution that the fire and rescue services can make to the advancement of fire engineering. One of the bodies most directly concerned with fire safety in buildings is the fire and rescue service. They protect their citizens in different ways and at different levels depending on national and local arrangements, by fighting fires, enforcing fire safety legislation, conducting fire safety education and influencing national standards and law. Butler recognised that there
is an increasing need for operational fire-fighters to have an understanding of fire engineering in order to make dynamic risk assessments and judgements about fire-fighter safety at incidents. In addition, fire and rescue services are in an ideal position to thoroughly and systematically investigate fire events with a view to enabling greater understanding of the whole fire scenario and feed back into the fire engineering design process. Concerns about competency of fire engineering practitioners were also raised by Butler. He suggests that the professional institutions must resolve this so that enforcers can be confident that the individual they are dealing with is suitably qualified and can recognise the limits of their expertise. Townsend (2000) takes the view of the fire and rescue service further. He talks about how fire and rescue services responded to the development and use of fire engineering by educating their own officers. With fire and rescue service enforcement officers holding fire engineering qualifications, Townsend reported greater a consistency of approach and a feeling of a collaborative approach between the architects, consultants, engineers and enforcing authorities when working on fire engineered building projects.

Insurers are an often overlooked stakeholder in the fire engineering design process. The insurer of the construction development may not be the insurer of the building when in use, and different insurers (or groups of insurers or re-insurers), are likely to be responsible for providing cover for the building itself, the contents and perhaps business interruption insurance. This was highlighted by Young (Institution of Fire Engineers. Northern Branch. 1995) as he explained the insurers’ views of fire engineering. Young explained the need for a fire engineering Code of Practice and progress made on the draft code, but recommended that some five additional factors needed to be addressed in order to make the code of use to insurers.
• Definition of a minimum standard for a ‘fire safe’ building; in the UK, the minimum standard for fire safety is usually equivalent to the fire safety provided by the application of Approved Document B. Young argues that this is a lower than desirable standard in many respects from an insurer’s viewpoint.

• Definition of a fire engineer and their competency; Young asks what qualifications and experience should they have? Should they be registered or regulated? Who judges them?

• Composition of Qualitative Design Review (QDR) team; Young argues that, when conducting the QDR- the initial stage of a fire engineering study, the input from insurers is essential. It is important that someone is able to contribute with regard to potential damage costs of both fabric and business interruption. If these factors are not properly addressed in the early stages of design, either high costs will be carried for later alterations, or unnecessarily high insurance costs carried for the life of the building.

• Objectives and scope of QDR; Young suggests some further design objectives and limits including- What fire frequency is acceptable? What is the financial limit of loss? What about disruption of local community (loss of key amenity, etc)?

• Outputs from QDR; whilst the draft code listed eight points to be covered in the report, Young suggests that these might not be enough for the insurance community. One key output should be the financial assessment of losses in each compartment in the event of fire relating to building reinstatement, contents loss and business interruption.
4. FIRE ENGINEERING TODAY

4.1 Overview

It is generally agreed that in a modern society, traditional prescriptive design techniques can hinder innovation and creativity, and are difficult, if not impossible to apply sensibly to buildings with special functions, such as sports stadia, high-rise developments and transportation termini. Fire engineering, as a means of satisfying the requirements of building regulation, is an approach which has freed up building design, whilst at the same time providing suitable levels of safety. Many of the exciting buildings currently being enjoyed in the UK have engineered fire safety and could not have been built under the previous prescriptive regime (Hopkinson, 2001).

Fire engineering, as an ever evolving discipline, is now responding to new challenges which require a greater depth and breadth of experience.

One new area where fire engineering is starting to make an impact concerns business resilience. Scott (2006) explains that, in a ‘post 9/11 and 7/7’ world, resilient design objectives are being explored more frequently, including the safety of public, commercial flexibility, market share and brand protection, security of information and robustness in response to attack. He argues that fire engineers have long recognised that adherence to prescriptive codes often does not produce a successful commercial building and the main thrust of fire engineering has been to enable buildings to open up, increase their flexibility and commercial value and, at the same time, improve the safety of the building occupants. Hence, resilient design further improves the function and adds long term value to a project.

It is also apparent that, whilst fire engineering was originally the pioneering method of enabling the successful design of buildings such as airports and enclosed shopping centres,
such buildings are now commonplace. The new frontier for fire engineering design includes the design of very tall buildings. Projects such as those described by Hannah, Daniels et al. (2003), Lam (2007) and Kennett (2007) demonstrate innovative designs incorporating the use of elevators for rapid evacuation of occupants during a fire, the use of a ventilation system to protect common escape routes and the incorporation of a sprinklered single stairway, respectively, all in tall residential and office buildings.

Another area where fire engineering is beginning to make an impact concerns the sustainable construction agenda. Charters (Interscience Communications Ltd. 2007) suggests that fire safety in buildings contributes to all aspects of sustainability and can help address the balance between protection of the environment and prudent use of natural resources. However, he states that more research and guidance is required.

4.2 Concerns

Concerns exist as to whether the fire engineering design community has the knowledge, data and tool sets required to undertake advanced fire safety analysis. By way of example, Galea (Interscience Communications Ltd. 2004) argues that, although there are numerous computation tools available, without exception all models have limitations. In the case of evacuation models, he explains that current levels of model sophistication and application reflect our current understanding of human behaviour and evacuation conditions. However, as architects design more innovative structures and regulators strive to maintain, or improve safety standards, the fire engineer is expected to demonstrate performance in ever more complex and demanding evacuation scenarios. This increases the demands on model capabilities which in turn challenge our understanding of human behaviour in evacuation scenarios.
Galea argues that, if computational fire engineering (i.e. the use of computational models in performance based design) is to play a useful role in the design of safer structures, further targeted research is needed to generate the data required by complex modelling applications. Without this constant research, he suggests, fire engineering could eventually become as inappropriate as prescriptive codes.

Furthermore, the motivations for using fire engineering are increasingly being questioned. Ham (2007) warns architects against trying to buy their way out of problems they have created through poor design with complex technology and inappropriate fire engineering arguments. Dix (2003) also cites examples where fire engineering is used to justify designs which are, in certain circumstances, unsafe. He states that there is increased evidence of the emergence of performance justified engineering. This is where a decision is made with respect to an aspect of design and then the techniques of performance engineering are used to explain why this otherwise inappropriate outcome is appropriate. The use of fire engineering in this way constitutes a significant threat to the credibility of its use as a design tool.

It is recognised that it is common practice for the fire engineer to be instructed to concentrate solely on life safety and evacuation because these are the elements mandated by the building regulations process. Although life safety is most importance, a solution which focuses exclusively on life safety may have a detrimental effect on property and business protection in comparison to a prescriptive code compliant solution (Fire Protection Association, 2008). Glockling and Barnett (2004) identify that a fire engineered approach might be chosen as a means of reducing the cost of fire protection by a design-and-build contractor and the building owner might not be aware of the potential differences in business protection that these changes might give.
They also give a warning about the validity of fire engineering strategies throughout the life of a building. When a building is new, the fire engineered design and management should be in harmony with the activities conducted within it. Over time the prosperity and nature of the activities or processes employed may change and there is a potential for the original design concept to be lost. Therefore, there is a fear, warns Glockling, that these changes will lead to a degradation in fire protection in excess of that which may be expected from prescriptively designed solutions.

This concern is echoed by Dix (2003) when he states that regulators must acknowledge that using performance based engineering as a basis for design approval also requires ongoing inspection to ensure that assumptions used in the development are still applicable.

6. CONCLUSIONS

By thoroughly reviewing the wide range of literature available, this paper has outlined and documented the emergence of fire engineering as an engineering profession in the United Kingdom.

The literature review has discussed both the gains and the concerns voiced by a full range of industry stakeholders during the profession’s early development, and discussed how fire engineering principles are used in contemporary construction projects.

Whilst it has been accepted that fire engineering is a necessary process which brings many benefits to the creative architectural community, and is further developing to address new design challenges, many concerns still exist.
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APPENDIX B  HAS FIRE ENGINEERING LIVED UP TO EXPECTATIONS?


Abstract

As an engineering discipline within the United Kingdom, fire engineering is relatively young, having been established as an alternative means of meeting the functional requirements of the Building Regulations since the publication of the 1985 edition of Approved Document B, in England and Wales. This paper provides a critical review of the introduction of fire engineering and its growth to the present day and establishes the successes of the discipline as well as short comings and more significant concerns.

The origins of fire engineering as a professional engineering discipline within the UK are described and the motivations of Government, the construction industry and the engineering profession at the time leading up to the acceptance of fire engineering as a valid contribution to the UK Building Regulations process are reviewed. It also reviews the development of the profession over the intervening decades, and establishes whether fire engineering has lived up to the expectation at inception.

This paper builds upon a detailed literature review and includes knowledge elicitation gained by interviewing key stakeholders.

Paper type: Conference paper
INTRODUCTION

Background

Fire engineering is increasingly being used as an alternative means of meeting the functional requirements of Part B of the Building Regulations in England and Wales. Whilst fire engineering may be the only practical way to achieve a satisfactory standard of fire safety in some large and complex buildings (1), such as airport terminals or sports stadia, questions remain relating to the appropriateness of its application and supporting regulation, and the potential implications that this creates for insurers.

Definition

The term fire engineering is widely misused and often not well understood by those outside the profession. Some think that fire engineering involves manual fire-fighting, while others think it is prescriptive fire safety code enforcement, or fire sprinkler system design (2).

The Institution of Fire Engineers (IFE) defines fire engineering as ‘the application of scientific and engineering principles, rules [Codes], and expert judgement, based on an understanding of the phenomena and effects of fire and of the reaction and behaviour of people to fire, to protect people, property and the environment from the destructive effects of fire’(3).

Fire protection engineering, a term more often used in the United States, is the application of science, engineering principles and experience to protect people and their environments from the destructive effects of fire, according to the Society of Fire Protection Engineers (SFPE) (4).
Development of prescriptive rules

Statutory fire safety provision within the UK has evolved incrementally over many centuries, largely in response to major disasters. In London, argues Law (5), the most significant fire disaster was the Great Fire of 1666, when the major part of the city was destroyed. Following the fire, controls were placed on materials of construction, on the thickness of walls and on the width of streets, describes Read (6). These rules were rigidly prescribed.

In the 20th century, experiences from fires during the second world war were incorporated into the Post-war Building Studies on Fire Grading of Buildings. Malhotra (7) suggests that these were seen as landmark documents of their day and influenced the technical content of the subsequent Building Regulations. By the time further amendments were made in 1976, the regulations that comprised 307 pages, were highly prescriptive, and, in Law’s opinion, understood only by lawyers (5). Despite the criticism, prescriptive building regulations have been an important component in designing for fire safety in buildings. It is acknowledged that prescriptive design has resulted in the achievement of safety levels which the community appears to accept (8).

Fire engineering origins

As a result of the rapid increase in innovative and diversified building design, including the expansion of air travel in the early 1970s, prescribed regulations became demonstrably restrictive and inflexible. Designs based on the fire safety standards of the time simply couldn’t cope with this new design requirement. Some engineers and scientists saw the possibility of applying scientific research directly to the design of individual buildings (9). These issues were discussed at the time of the design of Stansted Airport by Law (10). Law collected a range of data from experiments, surveys and fire statistics to illustrate how various
measures could compensate for a lack of fire resisting construction, known as compartmentation, within the airport terminal.

Others, including Ramachandran (11), argued that prescriptive rules are highly empirical and could lead to costly over-designs, particularly for large buildings, thereby strengthening the case for an alternative approach.

The commitment of UK Government to deregulation and to reduce the burden on industry led, in 1985, to the introduction of new functional building regulations, (12). The requirements for fire safety in buildings were set out in four functional requirements. Designers were free to provide any solution that could be shown to fulfil these functional requirements. With the introduction of the 1985 regulations, property protection issues were deliberately set aside because the legislators’ role has been seen as being in life safety matters only (13).

Butcher (14) recommended a note of caution regarding the use of fire engineering approaches immediately following the introduction of the 1985 regulations. Whilst he was very much in favour of the concept, he doubted whether the level of knowledge at the time could produce a genuine fire engineered solution. He identified that a vast amount of information was available in archives, research reports and studies of fire incidents which needed to be extracted and collated. He recommended a comprehensive research programme so that fire engineering calculations could be based on experience rather than vague theory. It was suggested by Cooke (15) that the traditional prescriptive technical guidance accompanying the functional regulations would continue to be used for the majority of simple buildings, while fire engineering would be used for large, complex buildings.
The development of a fire engineering code

The pressure for guidance and a structure for the application of fire engineering principles to the design of buildings came from designers and an initiative by the British Standards Institution (BSI) to provide a Code of Practice on the subject.

In 1989 a format and list of contents for a comprehensive Code of Practice on the application of fire engineering principles to fire safety of buildings was presented to BSI. By the end of 1990, a small panel of fire safety engineers was formed to undertake a three year contract, administered by BSI, which would culminate in a Code of Practice giving a framework for the fire engineering design of buildings (16).

Deakin (17) described the resulting draft Code of Practice as the most important document produced in the UK in support of the use of more fundamental approaches to fire safety design. It provided the designer and the regulatory enforcement authorities with an overview of what was considered to be necessary. The Code of Practice was published as a Draft for Development DD240 by BSI in 1997 (12). Since then, the format and content were reviewed and updated leading to BS7974 Code of Practice on the Application of Fire engineering Principles to the design of Buildings being published in 2001. The code is supported by eight Published Documents which contain detailed technical guidance on different aspects of fire engineering from background information to quantitative risk assessment (9).

Use of fire engineering

By the mid 1990s, Ferguson and Charters (18) described the results of a review, twelve years after the introduction of the functional approach. They highlighted that most construction projects involved a certain degree of variation from the prescriptive design standard, and that few projects, if any, were completely based on a fundamental fire engineering approach.
They reported concerns relating to the skills within, and the policy of, local authority Building Control departments. They reported increasing concern of the qualifications required to practice fire engineering and the fear in some quarters that people acting outside their sphere of competence could mislead uninformed officials into accepting a scheme on spurious arguments.

Sugden (19) suggested that there are two core motivations when considering the use of fire engineering. Firstly, fire engineering is chosen to design for fire safety when a proposed structure is of a novel design or where the use does not easily fit in with existing prescriptive legislation, or, secondly, it is chosen to reduce the cost of fire protection below the anticipated cost of meeting the prescriptive rules. The potential for cutting corners and safety in this scenario is obvious, argues Sugden, and he concludes that understanding the client’s motivation will throw light on fire engineering proposals made.

Young (20) explained how insurers are often overlooked as stakeholders in the fire engineering design process. Whilst he welcomed the development of a fire engineering Code of Practice he recommended that additional factors needed to be addressed in order to make the code of use to insurers. These included a definition of a fire engineer and their competency, the composition of the Qualitative Design Review (QDR) team with input from insurers being essential, additional objectives and scope of QDR to address acceptable fire frequency and financial limit of loss, and additional QDR outputs.

**Fire engineering today**

It is generally agreed that traditional prescriptive design techniques can stunt innovation and creativity, and are impossible to apply sensibly to buildings with special functions, such as sports stadia, high-rise developments and transportation infrastructure. Fire engineering, as a
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means of satisfying the requirements of building regulation, is an approach which has freed up building design, whilst at the same time providing suitable levels of safety. Many of the landmark buildings in the UK have been engineered for fire safety as they could not have been built under the previous prescriptive regime (21).

It is also apparent that, whilst fire engineering was originally the pioneering method that enabled the successful design of large and complex buildings such as airports and enclosed shopping centres, it is now widely applied to such buildings. New and challenging applications for fire engineering are in the design of very tall buildings. Projects such as those described by Hannah (22), Lam (23) and Kennett (24) demonstrate innovative designs incorporating the use of elevators for rapid evacuation of occupants during a fire, and other novel features. Another area where fire engineering is beginning to make an impact concerns the sustainable construction agenda. Charters (25) suggests that fire safety in buildings contributes to all aspects of sustainability and can help address the balance between protection of the environment and prudent use of natural resources.

Concerns exist as to whether the fire engineering design community has the knowledge, data and tool sets required to undertake advanced fire safety analysis. By way of example, Galea (26) argues that, although there are numerous computational tools available, without exception all models have limitations. As architects design more innovative structures the fire engineer is expected to demonstrate performance in ever more complex and demanding evacuation scenarios. This increases the demands on model capabilities which in turn challenges our understanding of human behaviour in evacuation scenarios. Without this constant research, he suggests, fire engineering could eventually become as inappropriate as prescriptive codes.
Furthermore, the motivations for using fire engineering are increasingly being questioned. Ham (27) warns architects against trying to buy their way out of problems they have created through poor design with complex technology and inappropriate fire engineering strategies. Dix (28) also cites examples where fire engineering is used to ‘justify’ designs which are, in certain circumstances, unsafe. He states that there is increased evidence of the emergence of ‘performance justified engineering’. The use of fire engineering in this way constitutes a significant threat to the credibility of its use as a design tool.

It is recognised that it is common practice for the fire engineer to be instructed to concentrate solely on life safety and evacuation, because these are the elements mandated by the building regulations process. Although life safety is of utmost importance, a solution which focuses exclusively on life safety can have a detrimental effect on property and business protection when compared with a prescriptive code compliant solution (29). Glockling and Barnett (30) identify that a fire engineered approach might be chosen as a means of reducing the cost of fire protection by a design-and-build contractor and the building owner might not be aware of the potential differences in business protection that these changes might provide. They also give a warning about the validity of fire engineering strategies over the lifecycle of a building which is a concern echoed by Dix (28) when he states that regulators must acknowledge that using performance based engineering as a basis for design approval also requires ongoing inspection to ensure that assumptions used in the development are still applicable.

**RESEARCH METHODOLOGY**

Following the literature review, further knowledge elicitation was gained by interviewing key stakeholders.
Method

As described by Sutrisna (31), there are three major dimensions that need to be considered when choosing a research methodology, namely the research philosophy, reasoning of the research, and data.

In order to elicit knowledge from a range of disparate, yet complementary stakeholders, an interpretive epistemology was needed. That is, as one person’s reality, derived by observations and perceptions, is likely to be different from another’s, the truth is a social construct, rather than existing independently (32). Therefore, the researcher needs to determine the reality from the participants’ collective perspectives; to see things through their eyes. Following this philosophy, the reasoning of the research was considered. This study employed inductive research methods, which tend to learn about the issues under investigation by applying a less structured methodology to gain richer and deeper information. Finally, on the data level, as this paper focuses on qualitative information.

In addition to an extensive literature review, other qualitative research methods have been utilised, plus substantial data analysis. In order to fully understand current practice relating to the use of fire engineering, stakeholder groups have been identified and questioned in a series of two stage knowledge elicitation sessions. This included communicating with the selected stakeholders from each group to give background information to the nature of the research and then, once consent had been obtained, the comprehensive questioning was undertaken via a mixture of face-to-face meetings and a self-administered internet based semi-structured questionnaire.
Data collection and analysis

There are three interview techniques to consider when designing a research method; face to face, telephone and self-administered. Bradburn’s study (33) concluded that no data collection method is superior to all other methods for all types of probing questions. Therefore, a face-to-face interview method was employed for the main data collection with nineteen stakeholders. Supplementary data was gathered by a self-administered internet based questionnaire to which ten stakeholders responded. Both the face-to-face and the self-administered methods used the same set of questions, making a total survey sample size of twenty nine.

In order to enhance and expeditiously assist the analysis of data gathered during the interview process, computer-aided techniques were employed. Computer-aided qualitative data analysis (CAQDAS) offer techniques for the management and analysis of textual data in qualitative research, as textual database management systems for the automatization of manual coding, indexing and sorting operations (34). It is important to choose a CAQDAS software package that fits with the method and methodology being employed. Weft QDA was chosen as it provides the basic ‘code and retrieve’ features in a simple, easy to comprehend interface, without being encumbered by complex options and tools. Weft QDA was designed on the principle that this activity is a generic interpretive strategy and makes this activity straightforward (35).

Interview design

An ‘open-ended’ (36), semi-structured approach was chosen, using just a few key open, non-judgemental questions. Open questioning has the advantage of allowing freedom and spontaneity of answers, and gives the interviewer the opportunity to probe. However, as
described by Oppenheim (37), open questions are time consuming to analyse, costly in interviewer time and demand more effort from the respondents. The questions used are listed in Appendix A.

The UK fire engineering community is relatively small. It was necessary to constrain the sample to an appropriately manageable number. Stratified sampling was used to select the stakeholder sample. Stratified sampling (32) is considered appropriate where the population is spread over distinct groups, or strata. Ideally, the differences within each group or stratum should be small relative to the differences between strata. Each stakeholder chosen was selected for their expert status in their particular specialism, giving confidence in the reliability of the data.

The stakeholder groups interviewed were identified as;

- Academics; Those involved with the teaching and equipping the fire engineers of the future, and also those involved in research; pushing the boundaries of knowledge in the field. The sample included experienced Professors engaged in directing research and teaching programmes in UK universities respected for excellence in fire engineering.
- Designers; Those architects and others, involved with the design of buildings and facilities, often as ‘principal adviser’ to the client. Those who are responsible for translating the client’s requirements into a brief, creating the architectural concept, and coordinating the other design professionals. The sample included influential architects from leading UK practices who are involved in the design of prestigious developments and active on committees of the Royal Institute of British Architects (RIBA).
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- **End users;** Those who either commission buildings, or are responsible for operating them. The sample included managers responsible for safety within, and the maintenance of complex buildings, including the tallest building in the UK.

- **Enforcers;** Those authorities having jurisdiction (AHJ) for approving building designs against the requirements of the Building Regulations, within Building Control functions and Fire Authorities. The sample included serving building control professionals, leaders of the industry’s professional body the Association of Building Engineers (ABE), and experienced serving fire safety officers.

- **Practitioners;** Those engineering consultants and designers who assist the building design process by advising on fire safety matters, to varying degrees. The sample included senior engineers working in leading fire engineering consultancies who are regularly involved in complex fire engineering projects.

- **Insurers;** Those insurers and brokers who are responsible for insuring property and businesses, and advising their clients on risk management issues. The sample included experienced senior surveyors and managers working in the leading UK insurance companies and brokers.

- **Policy Makers;** Those responsible for determining Ministerial priorities, monitoring and affecting changes to Regulations, etc. The sample included those responsible for fire safety building regulations within the UK Government’s Department of Communities and Local Government.

- **Institutions;** Trade bodies and professional institutions that have a role in informing, developing and/or regulating a membership. The sample included the leaders of a trade body representing manufacturers and installers of passive fire protection products.
RESULTS

Introduction

Nineteen experts were interviewed and ten additional responses were received via an internet based questionnaire. The Weft QDA software has been used to assist in analysing the interview transcripts. The following comments, issues and trends were identified.

Background

A high proportion of interviewees arrived at their role in fire engineering from a background in another discipline. The two most popular routes to fire engineering out of the people questioned are by formal qualifications in Physics or Civil Engineering. This is perhaps not surprising as many of the interviewees undertook their higher education and training at a time before dedicated fire engineering qualifications existed.

Many interviewees described their relationship with fire engineering as being multi-faceted; for example, some practitioners of fire engineering also play an active role in developing the profession by participating in code or guidance authoring activities or fundamental research. This confirms the premise that, as the profession is young, key individuals are relatively few in number and each of these individuals is involved in a wide variety of activities.

Drivers for fire engineering

When asked why they thought fire engineering exists as a profession or discipline, the overwhelming views of the interviewees related to its ability to facilitate architectural design freedoms, in terms of form and materials of construction. It is described as existing to support creative architecture that would otherwise be restricted by prescriptive design standards. This very positive opinion is shared universally by all stakeholder groups alike, suggesting that
customer demand has been a driver for fire engineering developments. Comments were made describing buildings as getting ever more complicated and clients want more fire engineered buildings to allow business to work in surroundings that support their processes. Similarly, a view held by many interviewees is that fire engineering is the result of a natural progression away from prescriptive design, keeping apace with other developments in architecture and construction. It has also been suggested that this evolution was initiated as a response to the UK Government’s drive for self-certification during the early 1980s and that fire engineering provides a way of simplifying a complicated regulatory process.

More controversially, the second most frequent comment made in response to this question about why fire engineering exists centred on the issue of fire engineering enabling the reduction of construction project costs. Some practitioners of fire engineering saw this as a positive contribution, citing cost effective, risk appropriate fire safety measures. However, many more interviewees raised concerns about fire engineering being used primarily for cost saving reasons. In addition, many of the policy makers and enforcers felt that fire engineering is used as a method of legitimising deviations from what would otherwise be code-compliant building designs, and even that fire engineering enables the abuse of these rules, giving developers the opportunity to avoid compliance. Numerous examples were cited where developers or architects have stated that they want to fire engineer the building because they can’t make it work in accordance with the prescriptive code.

**Competence and data**

The vast majority of interviewees considered themselves to be completely equipped, sufficiently equipped or at least felt competent to undertake their work. Being adequately equipped means having the foundation of a relevant educational background, the acquisition of meaningful experience as well as access to appropriate tools and data. Several
interviewees identified gaps in certain of these elements, including; data/models, currency of research and educational qualifications. It was felt that there is a shortage of good data from which one can draw correlations, and test theories, and even where good data exists; obtaining access to latest research and wider opinion is sometimes difficult. It was emphasised that whilst fire engineering is a relatively young discipline, the tools are even younger. The profession, as a whole, lacks experience in applying these tools and lacks a life-cycle way of looking at the buildings that have been designed using these tools and these approaches. When discussing modelling tools the shared view was that we don’t know everything there is to know about fire dynamics. We certainly don’t have the data to characterise materials and how they burn so that we can use them correctly in our computer simulation tools, and we don’t understand enough about the human dynamic and human behaviour. Whilst some interviewees recognised that they didn’t necessarily hold directly relevant qualifications, there was some scepticism relating to the quality of the engineers graduating from certain of the UK universities teaching fire engineering. Several interviewees felt that their extensive experience and good judgement filled any gaps there might have been with their education. Many respondents added that successful fire engineering requires teamwork where support from colleagues and others, sometimes externally sourced, is essential. This sentiment is not restricted to the practitioners of fire engineers, but was equally expressed by the enforcers.

**Development of fire engineering**

When discussing how fire engineering, or its impact has changed over the past decades, and how it is envisaged it might change in the future, some interrelated issues emerged. It was widely accepted that the profession has matured, evolving from a pursuit for academics, to a situation today where it is emerging as a recognised, separate professional discipline. Interviewees agreed that fire engineering is becoming more accepted in the UK and there has
been a wider global acceptance of fire engineering by clients and authorities worldwide. The interviewees have also seen a change in how fire engineering has been applied to construction projects, or rather, the types of buildings that fire engineering is now being applied to, recognising that it is more frequently applied to more mundane projects.

The assertion that nearly all new commercial buildings contain an element of fire engineering analysis to save on cost and to justify departure from the prescriptive codes, leads to another important point raised by a significant number of interviewees. As one enforcer put it, there is a proliferation of designs for buildings which don’t comply, but have been labelled as ‘fire engineered’ as it enables them to put forward an argument as why it doesn’t need to comply. There is agreement with this opinion from other practitioners who state that there are very few buildings that have a full performance based approach carried out on them. Perhaps one reason for this is that there has been a ‘deskilling’ of the architectural profession over the last decade. It is suggested that fire engineers now do a lot more of the duties the architects used to do and the architect is now merely a project manager of expert consultants. One of the significant consequences of this, as described by a practitioner, is that the demand for fire engineering has outstripped the capacity of fire engineers. As an enforcer added, a lot of people call themselves engineers but are not.

One common comment made by interviewees from all stakeholder groups is that fire engineering has been able to be used more widely because the tools now available are far more sophisticated, which is an indication of a maturing discipline. A practitioner adds a note of caution with the widespread, commonplace use and misuse of models without the fundamental understanding of when a mistake is made. An academic adds that not only is the misuse of modelling tools a concern, but the very proliferation of tools is an even greater concern. He warns of the existence of many fire and evacuation simulation tools that have not
been validated, tested, nor described in peer reviewed literature, yet are being used blindly and accepted by enforcers.

An academic who gave an international perspective from regions where fire engineering or performance based engineering is more mature, notes that the first phase of failure has been recognised and comments that there is now an attempt for regulatory regimes to put resources into reviewing fire engineering design proposals, as opposed to just accepting them. With a similar theme, many interviewees predicted that fire engineering failures, or examples where fire engineering has been incorrectly used within a building project, could come to light in the near future. A practitioner predicted that there will be a serious fire in a fire engineered building that will show the failings of practitioners of fire engineering. An academic is equally concerned suggesting that a disastrous fire in a fire engineered building which is later shown to be the cause of dubious fire engineering could set back the whole discipline.

**Future developments**

Other opinions concerning how fire engineering may develop in the future included an overwhelming thought that fire engineering will become more accepted, more sophisticated and be used more widely. This was stated by interviewees from all stakeholder groups. In terms of how the profession might develop, practitioners and academics suggest that fire engineering will develop to reflect modern methods of construction and environmental and sustainability issues. Two practitioners of fire engineering posed a change which is considered necessary to enable the discipline to be better applied. They described the need for fire engineering input throughout all stages of a building’s life-cycle, developing a fire safety ‘circle’, and making sure that operational fire safety is a key part of the early design process. The concept of the fire engineering ‘circle’ was repeated by other interviewees, and
the need for fire engineering input at all stages of a building’s life cycle, from design to demolition, was compelling.

The need for further research to expand the pool of data available to support fire engineering concepts was discussed at length. Practitioners commented how research is needed to keep pace with new fire safety developments, such as research into human behaviour to inform the use of lifts for evacuation. Additionally, an academic raised the issue of keeping data current and appropriate, citing an example where a researcher has asked for his material to be removed from an international fire engineering guidance document because he was concerned that the data was no longer valid.

An interesting point or concern about how fire engineering, or fire engineering codes and standards might develop in the future was raised by two practitioners. The issue concerns reconciling the very definition of performance based engineering with the necessity to provide a standardised methodology. It was hoped that fire engineering doesn’t become ‘too prescriptive’.

**Perceptions**

The most controversial part of this knowledge elicitation exercise involved asking the interviewees about their perception of the roles of the other stakeholders involved in fire engineering. Analysis of the responses shows clearly that interviewees had more critical comments than positive when describing their fellow professionals in the industry. The four stakeholder groups attracting the most criticism were architects/designers, enforcers, insurers and practitioners.

Whilst the input from academics is widely valued, it was felt that they are disconnected, or removed from the real world. This disconnection was felt, both in terms of teaching and
research, as their industrial experience is perceived to be limited and they struggle to keep up to speed with change.

The work of building designers and architects was described as mostly well intended; however, they received much criticism from the interviewees for not understanding fire safety issues, and not understanding how to use fire engineers. The issue of architects loosing skills was again raised, as well as many interviewees criticising what they consider to be inadequate fire safety related training within architectural training. Examples cited included one academic who recalled contributing to architectural degrees of five or seven year duration which contain merely four hours on fire safety. The way architects use fire engineering was again criticised, an academic described fire engineering as the ‘new liquid paper’, enabling their mistakes and omissions to be conveniently endorsed. Further comments of building designers and architects was a criticism of their lack of understanding of their clients’ needs, and the poor way in which they attempt to define the objectives of the design.

The criticism of end users within the fire engineering process can be summed up as a lack of engagement when the building is designed and then falling short of their responsibilities during operation. Again, a disconnection was described between the designers and practitioners, and the end user stakeholder group, which, one academic commented is being addressed by the Regulatory Reform (Fire Safety) Order. A practitioner stated that often end users don’t even know that they’re in fire engineered buildings, because of a lack of information transfer from the practitioner, through the construction company, to the client. These issues were echoed by many of the interviewees, practitioners, enforcers, academics alike, with the importance of good dialogue and transfer of knowledge to the end users being emphasised. A differing view was posed by an academic, who suggests that, actually the end
users shouldn’t know that there has been a fire engineer involved at all. If the fire engineering is done well they shouldn’t have to worry about anything.

Whilst some encouraging comments were made about the competency and actions of enforcers, both Building Control body and Fire Authority based, far more critical statements were made. A common feeling was that the quality of enforcement varies dramatically across the UK, with consistency of approach really lacking. A specific criticism of the skills base within the Building Control enforcement community was made by a practitioner, questioning their skills and experience, simply accepting fire engineering submissions without any third-party validation. An academic commented similarly, that the enforcers don’t know what to look for, and they don’t know how to challenge. Also it was stated that Building Control enforcers do not inspect on-site installations. There was agreement that the enforcers need to be trained as well as, if not better than, the engineers, and to work in a performance based environment.

Practitioners of fire engineering, i.e. those consultants who use fire engineering methods, received significant criticism from their colleagues. Comments ranged from criticising their perceived intentions, to their working practices and the commercial pressures that practitioners often work under.

Insurers receive a similar level of criticism. It is thought that insurers do not play an active role in the fire engineering process, and when they do, their poor levels of knowledge and understanding precludes any meaningful interaction. An academic comments that fire engineering is not used by insurers since few can assess the risks, and a practitioner adds that insurers simply don’t have a role at all in fire engineering, adding that most of the time they simply wait until the building is completed and then decide whether or not to insure it. Many practitioners’ perception of insurers is that they rely solely on sprinklers as a form of fire
safety. This message was echoed by a different practitioner who said in relation to an industry event he had attended, that their only message seemed to be ‘Put in sprinklers’. Further comments concerned the commercial nature of insurance. Some advice was given by some stakeholders, to those within the insurance community urging them to engage in the design process, having an input into the objective setting and then determining the premium according to those objectives. A counter-argument, given by an insurer is that the insurance industry would welcome being more greatly involved, but the opportunities presented to insurers are few and far between, in his view. He suggests that they are only asked to be involved after the design stage has been agreed.

Manufacturers of building products that support fire safety strategies, and enable fire engineering, are needed and welcomed in the UK. As one practitioner described, without them, we wouldn’t have many of the products that are available to us as part of the armoury of measures available to deploy in designs. However, it became clear that the interviewees have also experienced manufacturers who disregard fire safety when they are developing their building products. An enforcer described how his organisation had experienced poor quality materials originating from the Far East being used in construction projects. Aligned to product manufacturers are product installers, and an important problem identified is the quality of workmanship on site. Criticism was levelled at the lack of supervision and checking of on-site construction so that the ability to deliver high quality in accordance with the specification is limited. This fact poses a problem for fire engineering as when designs become more and more sophisticated, the room for a margin of error in terms of the workmanship diminishes.

The criticism of policy makers focussed on the slow nature of policy change. They also discussed the way policy makers prioritise, and how they interpret the financial cost of action,
or inaction. Comments about perceived attitudes were made such as current political focus on environmental and climate change issues.

Institutions and trade bodies are seen as vital within the fire engineering process as they are the groups who translate research into practical every day advice. However, the Institution of Fire Engineers (IFE) received much criticism from interviewees. Many practitioners feel that the role the IFE plays in fire engineering is inadequate. It was stated that the IFE has moved away to some extent from being a predominantly fire and rescue service organisation, but it was felt that it hasn’t moved far enough yet. Two interviewees gave examples of similar large membership professional organisations that the IFE could aspire to be like. The Institution of Occupational Safety and Health (IOSH), the Chartered body for health and safety professionals and the British Medical Association (BMA), the doctors’ professional organisation in the UK are both respected organisations who train and regulate their members well, acting as governing bodies for their respective professions. It was thought that the IFE is not taking that task on very responsibly. An academic adds the IFE needs to be pushing good practice, and coming up with guidelines and cited the Society of Fire Protection Engineers (SFPE) as an organisation taking a much more pro-active stance in developing guidelines and informing its members.

**CONCLUSIONS**

Has fire engineering lived up to expectations? The answer has to be Yes.

This investigation has shown that the common expectation across all stakeholder groups was that fire engineering would facilitate architectural design freedoms and support creative construction allowing the UK, and more specifically London, to continue to develop its reputation as a city of world-class importance.
London now has many prestigious and innovative buildings, worthy of a global financial centre. Along with equally impressive airports and public entertainment venues, a message of innovation, good design and prosperity is given to all visitors.

However, it has also become evident that since fire engineering has become more accepted, significant concerns have been raised regarding various elements of the design process including,

- The appropriateness of application of fire engineering to some design issues and misuse of the term ‘fire engineering’ to describe simple code-deviation design,
- The motivations of the client and design team for using fire engineering techniques on some projects, which are often economic motivations, or to address a design error or omission.
- The ability of building control professionals to approve designs, and of fire and rescue service personnel to contribute to the process,
- The ability of the construction industry to select high quality materials and to ensure the high standards of installation workmanship which is crucial for successful fire engineering,
- The involvement of the insurer and the ability to champion objectives other than life safety,
- The ongoing validity of fire engineered solutions during the building’s life-cycle, and the continued input of fire engineers from design to demolition,
- The limitations of the knowledge, data and tools that support fire engineering design concepts,
- The ability of professional institutions to guide and regulate practicing fire engineers.
All these issues need to be addressed if fire engineering is to enjoy continued growth as a profession, and continued acceptance as a legitimate contribution to the building design process.

**APPENDIX 1**

**Interview questions**

1. Please give a brief description of your educational and career history.

The objective of this question was to understand the background of the interviewee and how their experiences have shaped their opinions, in order to appreciate the various routes into the profession and its allied disciplines.

2. What is your relationship with fire engineering?

The objective of this question was to understand how the interviewee is involved in the building design process and to what extent they come into contact with fire engineering, and to categorise whether they are Developers, Users, Beneficiaries, Regulators/Appraisers of fire engineering.

3. Why do you think fire engineering exists as an engineering discipline/profession?

The objective of this question was to understand the interviewee’s opinion regarding why the profession has developed, flourished and become established in the UK.

4. Please describe how adequately you consider yourself equipped to undertake your role in respect to your interface with fire engineering.
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The objective of this question was to establish how the development of methods, tools and training has kept pace with the profession, and whether access to the same is deemed adequate.

5. How has fire engineering or its impact on your organisation, changed during your career?

The objective of this question was to appreciate, from the interviewee’s perspective, how fire engineering and its application has developed since inception.

6. How do you envisage fire engineering changing in the future, from you perspective?

The objective of this question was to gain an insight of how fire engineering will continue to develop.

7. What is your perception of the role of other stakeholders in fire engineering?

The objective of this question was to test the stereotypical opinions that certain stakeholder groups have of others and to understand the reasons for those views.

8. Anything else?

The objective of this question was to collect thoughts that may have been inspired by giving the interviewee the opportunity to consider these prior questions.

**APPENDIX 2**

**Further work**

This paper is part of an Engineering Doctorate which is investigating the application of fire engineering in the UK. Further work will be undertaken to understand the role of the insurer
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in the fire engineering process, understand how fire engineering can be used as a tool for business and property protection, and develop methods to assist in insuring fire engineered buildings. The intended purpose of this research programme is to influence significant change within the UK building regulations system, to publish best practice guides for use by commercial property insurers, fire engineering practitioners and enforcers, and to contribute to the development of BS7974 to reflect aspects of this research.

APPENDIX 3

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APPENDIX C  INSURER INVOLVEMENT IN THE FIRE SAFETY ENGINEERING DESIGN PROCESS


Abstract

As an engineering discipline within the United Kingdom, fire safety engineering is relatively young, having been established as an alternative means of meeting the functional requirements of the Building Regulations since the publication of the 1985 edition of Approved Document B, in England and Wales. This paper provides a brief critical review of the introduction and growth of fire safety engineering. It then concentrates on investigating the role of the commercial property insurer and the underwriting process, within the context of the fire safety engineering design process. It outlines the intended role of insurers within the qualitative design review (QDR) objectives setting process of BS7974 and then establishes whether this happens in reality, together with the reasons for any variation.

This paper builds upon a detailed literature review and includes knowledge elicitation gained by conducting a case-study investigation.

Paper type: Conference paper
INTRODUCTION

The Institution of Fire Engineers defines fire safety engineering as

the application of scientific and engineering principles, rules [Codes], and expert
judgement, based on an understanding of the phenomena and effects of fire and of the
reaction and behaviour of people to fire, to protect people, property and the
environment from the destructive effects of fire. (Chitty, 2003).

A more succinct definition is

the use of engineering principles for the achievement of fire safety. (British Standards

As an engineering discipline, fire safety engineering is relatively young, and it has been
accepted as an alternative means of meeting the functional requirements of the UK Building
Regulations (Great Britain, 1985a) since the publication of the 1985 edition of Approved
Document B (Great Britain, 1985b).

Research suggests (Wilkinson, Glockling et al. 2010) that fire safety engineering design
methods have facilitated architectural design freedoms and supported creative construction
allowing the UK, and more specifically London, to continue to develop its reputation as a city
of world-class importance. However, it has also become evident that since fire safety
engineering has become more accepted, significant concerns have been raised regarding many
various elements of the design process including the involvement of the insurer and the ability
to champion objectives other than life safety. Furthermore, fire safety engineering almost
inevitably leads to a reduction of both active and passive fire protection installed in buildings,
which can significantly impact on insurance. This paper investigates the role played by commercial property insurers in the building design process.

**FIRE SAFETY ENGINEERING IN THE UK**

**Origins**

Statutory fire safety provision within the UK has evolved incrementally over many centuries, largely in response to major disasters. In London, argues Law (1991), the most significant fire disaster was the Great Fire of 1666, when the major part of the city was destroyed. Following the fire, controls were placed on materials of construction, on the thickness of walls and on the width of streets, describes Read (1993). These rules were rigidly prescribed.

In the 20th century, experiences from fires during the second world war were incorporated into the Post-war Building Studies on Fire Grading of Buildings. Malhotra (1987) suggests that these were seen as landmark documents of their day and influenced the technical content of the subsequent Building Regulations. By the time further amendments were made in 1976, the regulations that comprised 307 pages, were highly prescriptive, and, in Law’s opinion, understood only by lawyers (Law, 1991). Despite the criticism, prescriptive building regulations have been an important component in designing for fire safety in buildings. It is acknowledged that prescriptive design has resulted in the achievement of safety levels which the community appears to accept (Hasofer et al. 2007).

As a result of the rapid increase in innovative and diversified building design, including the expansion of air travel in the early 1970s, prescribed regulations became demonstrably restrictive and inflexible. Designs based on the fire safety standards of the time simply couldn’t cope with this new design requirement. Some engineers and scientists saw the possibility of applying scientific research directly to the design of individual buildings.
An investigation into resilient fire engineering building design

(Charters, 2006). These issues were discussed at the time of the design of Stansted Airport by Law (1985). Law collected a range of data from experiments, surveys and fire statistics to illustrate how various measures could compensate for a lack of fire resisting construction, known as compartmentation, within the airport terminal.

Others, including Ramachandran (2000), argued that prescriptive rules are highly empirical and could lead to costly over-designs, particularly for large buildings, thereby strengthening the case for an alternative approach.

The commitment of UK Government to deregulation and to reduce the burden on industry led, in 1985, to the introduction of new functional building regulations, (Sanayei (Ed) 1995). The requirements for fire safety in buildings were set out in four functional requirements. Designers were free to provide any solution that could be shown to fulfil these functional requirements. This can be deemed the time of the emergence of formal fire safety engineering in the UK.

**Today**

It is generally agreed that traditional prescriptive design techniques can stunt innovation and creativity, and are impossible to apply sensibly to buildings with special functions, such as sports stadia, high-rise developments and transportation infrastructure. Fire safety engineering, as a means of satisfying the requirements of building regulation, is an approach which has freed up building design, whilst at the same time providing suitable levels of safety. Many of the landmark buildings in the UK have been engineered for fire safety as they could not have been built under the previous prescriptive regime (Hopkinson, 2001).

It is also apparent that, whilst fire safety engineering was originally the pioneering method that enabled the successful design of large and complex buildings such as airports and
enclosed shopping centres, it is now widely applied to such buildings. New and challenging applications for fire safety engineering are in the design of very tall buildings. Projects such as those described by Hannah (2003), Lam (2007) and Kennett (2007) demonstrate innovative designs incorporating the use of elevators for rapid evacuation of occupants during a fire, and other novel features. Another area where fire safety engineering is beginning to make an impact concerns the sustainable construction agenda. Charters (2007) suggests that fire safety in buildings contributes to all aspects of sustainability and can help address the balance between protection of the environment and prudent use of natural resources.

**Concerns**

Concerns exist as to whether the fire safety engineering design community has the knowledge, data and tool sets required to undertake advanced fire safety analysis. By way of example, Galea (2004) argues that, although there are numerous computational tools available, without exception all models have limitations. As architects design more innovative structures the fire engineer is expected to demonstrate performance in ever more complex and demanding evacuation scenarios. This increases the demands on model capabilities which in turn challenges our understanding of human behaviour in evacuation scenarios. Without this constant research, he suggests, fire safety engineering could eventually become as inappropriate as prescriptive codes.

Furthermore, the motivations for using fire safety engineering are increasingly being questioned. Ham (2007) warns architects against trying to buy their way out of problems they have created through poor design with complex technology and inappropriate fire safety engineering strategies. Dix (2003) also cites examples where fire safety engineering is used to ‘justify’ designs which are, in certain circumstances, unsafe. He states that there is increased evidence of the emergence of ‘performance justified engineering’. The use of fire
safety engineering in this way constitutes a significant threat to the credibility of its use as a design tool.

It is recognised that it is common practice for the fire engineer to be instructed to concentrate solely on life safety and evacuation, because these are the elements mandated by the building regulations process. Although life safety is of utmost importance, a solution which focuses exclusively on life safety can have a detrimental effect on property and business protection when compared with a prescriptive code compliant solution (Fire Protection Association, 2008). Glockling and Barnett (2004) identify that a fire engineered approach might be chosen as a means of reducing the cost of fire protection by a design-and-build contractor and the building owner might not be aware of the potential differences in business protection that these changes might provide. They also give a warning about the validity of fire safety engineering strategies over the lifecycle of a building which is a concern echoed by Dix (2003) when he states that regulators must acknowledge that using performance based engineering as a basis for design approval also requires ongoing inspection to ensure that assumptions used in the development are still applicable.

**METHODOLOGY**

This research resulting in the remainder of this paper involved two stages. Firstly, an extensive literature review was conducted to understand the background to the topic as well as the present day issues. Secondly, in order to fully understand current practice relating to the involvement of the insurance industry within the fire safety engineering design process, a case study investigation was undertaken. The investigation involved a combination of face-to-face meetings and site visits where the individuals were observed undertaking their professional role. The following people were involved in the case study investigation;
Table 1. Case study investigation participants

This investigation involved a small but high quality cohort, united by their relationship with fire safety engineering of an iconic property portfolio, which represents an interpretive epistemology employing inductive research methods as discussed by Fellows and Liu (2008). It followed a less structured methodology in order to gain richer and deeper information, with the interviewees commenting on their personal experiences. Such commentaries are acceptable as scientific data, as asserted by Brown and Sime (Brenner (Ed.) 1981).

RESULTS

Insurance and Reinsurance

Insurance is one method that businesses can reduce the financial impact of a risk occurring. Whilst holding an insurance policy does not remove a risk, it provides some security should the worst happen (Dickson, 1997). In simple terms, the concept of insurance works as follows. The insurer, a business that provides insurance, agrees to take on a risk on behalf of the insured. It does this by providing the insured with a policy, an insurance contract. Within
the policy, the insurer states what risks it has agreed to insure against and what it will pay the insured if the risk happens. The insurer receives a fee from the insured, known as an insurance premium. To be included in an insurance policy, a risk must be capable of being measured in monetary terms. It must also be something that is not certain to happen, and the insured must have a direct interest in any loss (Lloyd's of London, 2008a).

Actuarial risk theory is concerned with the application of probabilistic techniques and models to the risk process involved in the operation of an insurance business. The risk arises due to the fact that an insurance company agrees to meet the claims of its policy holders to compensate their losses due to the occurrence of events they insure. The insurer would face ruin during a period if the total claim amount to be paid by the insurer during that period exceeded its assets, consisting of free reserves (capital) and total premiums received (Ramachandran, 1998).

Insurers manage the risks they take on through the process of reinsurance. Reinsurance is an extension of the concept of insurance, in that it passes on part of the risk for which the original insurer is liable. Reinsurance contracts are similar to insurance policies, with the insured being the direct insurer, or the reinsured. A contract of reinsurance is between the insurer and the reinsurer only. There is no direct link between the original insured and any reinsurer (Lloyd's of London, 2008b). Reinsurance allows insurers to protect against large claims, such as catastrophic events like earthquakes, as well as increasing the capacity of the direct insurer. There are two basic methods of reinsurance:

1. Facultative Reinsurance- specific reinsurance covering a single risk. The reinsurer is reinsuring one insured on a specific policy. Each facultative risk is submitted by the insurer to the reinsurer.
2. Treaty Reinsurance- a method of reinsurance requiring the insurer and the reinsurer to formulate and execute a reinsurance contract. The reinsurer then covers all the insurance policies coming within the scope of that contract.

**Fire insurance**

Fire insurance provides financial compensation for damage due to and consequent on a fire to the owners or occupiers of the premises where this occurred. The compensation is normally for direct material damage (MD) by the fire itself, by heat or smoke from the fire and by water and other agents used to control and extinguish the fire. In addition, business interruption (BI) insurance provides financial compensation for such consequences as loss of orders due to late delivery, loss of key facilities and cost of reorganisation. The extent of these consequential losses may exceed the direct losses (Institution of Fire Engineers, 1989).

Fire insurance in Europe has two roots. In northern Europe, the rise of co-operatives and guilds during the Middle Ages generated the need for mutual protection, and the duties of co-operatives included providing mutual assistance in the event of fire. The idea of sharing the economic consequences of fires across a risk community of property owners was first developed in Denmark (Galey, Kuhn, 2009). The Mediterranean provides the commercial roots for marine insurance which also branched out into property insurance on land, and thus into fire insurance. As early as the 14th century, marine insurance contracts were arranged in exchange for payment in Italian seaports. This is confirmed by the oldest known insurance document- the Genoa policy drawn up in 1347 (Gruss, 1982).

In the UK, the first insurance companies offering cover for property damage and financial losses were set up as a result of the Great Fire of London in 1666. The fire swept rapidly through medieval wooden houses and raged for five days, destroying more than 13000 homes...
(Read, 1993). By the end of the 17th century, three companies were engaged in providing fire insurance. These London based companies conducted business through a network of local agents, insuring virtually all types of buildings from residential properties to industrial sites. These early insurers set up their own fire brigades to protect the properties they insured (Galey, Kuhn 2009).

Today, fire insurance is provided by insurance companies and by Lloyd’s underwriters, known as a leading market for specialist insurance. Insurance may be placed directly with a company, or through an intermediary, usually an insurance broker. When a new insurance policy is proposed to an insurer, a fire surveyor will normally visit the premises to be insured to evaluate potential risk from fire and to advise the insured on fire prevention and protection. The fire surveyor prepares a report for consideration by the insurer’s underwriter. The underwriter decides on the acceptability of the insurance and the premium to be charged according to the conditions described by the fire surveyor (Institution of Fire Engineers, 1989). This process is described in greater detail below.

**Underwriting**

Insurance underwriters evaluate the risk and exposures of potential clients, decide how much coverage the client should receive and how much they should pay for it. Underwriting involves measuring risk exposure and determining the premium that needs to be charged to insure that risk. Essentially, underwriting is the process of issuing insurance policies. The acceptance or rejection of risk is based on a prescribed capacity concept and is normally performed in accordance with organisational guidelines (Galey, Kuhn 2009). Fire underwriters perform a task which Galey (2009) describes as difficult, extensive and important, especially in industrial and large-risk business. He identifies the following individual responsibilities;
1. Gathering background information at the enquiry stage, with site survey from a specialist risk engineer, if appropriate;

2. Scrutinising insurance application;

3. Checking objective risk features such as type of operation, type of construction, separation, fire protection measures, exposure to natural perils, etc;

4. Understanding the subjective risk aspects, such as claims history, reputation, etc;

5. Checking the technical insurance conditions, sums insured, limits, deductibles, warranties, exclusions, etc;

6. Basic accept or reject decision;

7. Determining the costing for the insurance policy, in order to maintain a self-supporting risk portfolio, i.e. aggregate premiums exceed claims expenditure and costs in that year.

Two loadings are generally imposed on the risk premium when calculating the total premium payable by the insured. The first is known as a safety loading and the second is an administrative loading to cover the insurer’s operating costs which include profits, taxes and administrative expenses. The premium rate should also be adjusted for any self-insurance (deductible) agreed between the insurer and the insured. When a deductible is introduced in an insurance contract, the insured is expected to take greater interest in adopting loss prevention and reduction measures. With adequate fire protection, particularly sprinklers, the insured can take the risk of accepting a large deductible which will minimise the total cost of insurance and protection. In order to promote this concept, it is necessary for the insurance company to establish statistically sound rebates on insurance premiums for different levels of
deductibles, taking sufficient account of the reduction in loss due to a fire protection measure (Ramachandran, 1998).

It is customary to use estimates of expected loss under different conditions in data for estimating premiums. Some definitions of loss expectancy are listed in Table 1 (Rasbash, Ramachandran et al. 2004). The association of the loss with the failure of items of fire safety defence allows quantification of the probabilities of the loss occurring.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Maximum possible loss</td>
<td>Financial loss that would occur under catastrophic or extremely unfavourable conditions (failure of two or more protection systems, active and passive)</td>
</tr>
<tr>
<td>Maximum probable loss</td>
<td>Maximum financial loss under normal conditions, for example one protective system failing.</td>
</tr>
<tr>
<td>Estimated maximum loss</td>
<td>Usually expressed as percentage of value of building under consideration; see full definition below.</td>
</tr>
<tr>
<td>Normal loss expectancy</td>
<td>Financial loss under average operating conditions— all protective systems operational.</td>
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Table 2. Loss expectancy definitions. Adapted from Rasbash, et al (2004)

Estimated Maximum Loss (EML) is the loss expectancy definition commonly used in the UK. The London Insurance and Reinsurance Market Association define EML as an estimate of the monetary loss which could be sustained by insurers on a single risk as a result of a single fire or explosion considered by the underwriter to be within the realms of probability (Rigby-Smith, 1995).

During the case study investigation interviews, it was confirmed that underwriters are interested in five key issues when writing insurance policies;

1. EML- the calculated worst case scenario,
2. The materials the building is constructed from,

3. The attitude of the insured to risk improvement, and housekeeping,

4. Hazards to which the building is subjected, including external exposures such as deliberate fire setting,

5. Protection measures included within the building.

It is also understood that the geographical proximity of other properties being insured by the company is considered so as to limit their exposure within a defined area. However, it is the EML calculation is the most important factor for the underwriter. Within the firm investigated, surveyors will comment on EMLs as part of the survey and provide a percentage EML for buildings, contents, and business interruption where requested by underwriters. However, the final decision on the percentage EMLs to use to calculate exposures rests with the underwriter, although the underwriters must assess the EML on the information provided by the Risk Adviser. Where in the opinion of the underwriter, the EML is significantly different than that suggested by the Risk Adviser; the underwriter would discuss their rationale with the surveyor for agreement. It was suggested that the fundamental reasons for calculating the EML of a risk are:

- To ensure that the firm underwrite to their maximum capacity, which would not necessarily be the case if acceptance was based purely on the sum insured.
- To avoid over-exposure, i.e. writing above the firm’s acceptance level.

Surveyors often express EML as a percentage. An increase in sum insured will generally not alter the percentage unless there is a significant change in the risk. However, a simplified list of factors to be taken into consideration when assessing EML, as defined by the Insurance
Institute of London (Rigby-Smith, 1995), now part of the Chartered Insurance Institute is as follows;

- Size, height and shape of area potentially exposed to a single fire or explosion.
- Construction of roof, walls and floors.
- Presence of combustible linings to walls, roofs, ceilings and partitions.
- Nature, distribution and combustibility of contents (fire load).
- Use of hazardous processes and substances and their degree of separation.
- Susceptibility of contents to damage by smoke, heat and water.
- Risk of explosion from any source.
- Hazards arising from gases or corrosive materials.
- Concentrations of values within a small area.
- Standards of management and housekeeping.

Similarly, the Insurance Institute of London (Rigby-Smith, 1995) defines factors which should NOT be taken into account when assessing an EML;

- Any horizontal separations.
- Fire resisting doors.
- The absence of any normal source of ignition.
- The existence or installation of fire detection, prevention or extinguishment arrangements including sprinklers and the adequacy or otherwise of Fire Brigade facilities.

Insurance EML is also of importance to reinsurers. Whilst reinsurers do not impose any underwriting or risk acceptance standards on their insurer clients, they do like to understand the insurer's approach in general terms, such as EML philosophy, and they periodically visit
the insurer to gain a better understanding of the risk management undertaken with the insureds.

**Risk management**

Within the framework of loss prevention, insurers and reinsurers have long been analysing the quality of the risks they insure, and options for improving the quality of the portfolio. Loss prevention has a direct impact on the prices, terms and conditions in the sense of risk-adequate rating and is the basis for profitable business (Schadenspiegel, 2007). In order to assess and control the likelihood and magnitude of these risks, insurers have their own technical standards giving requirements for constructional measures, fire protection equipment and methods of work (Bickerdike Allen Partners, 1996). These standards are often used as benchmarks against which a building and its contents can be assessed. During his interview, the insurance Property Risk Manager revealed that his firm undertake between 35000 and 40000 surveys each year at properties they insure. By discussing the role of the Risk Adviser, it is apparent that insurers have a big commitment to active risk management and loss prevention activities in order to maintain and improve their portfolio of risks.

However, insurance is a profit-generating business and is affected by economic considerations. In a soft insurance market there is much competition between insurance companies for premium income in order to invest the capital profitably on the stock market. This desire for premiums can override the need for stringent risk control, an attitude which in time must result in bad loss experience. This in turn leads to an increased emphasis on loss prevention and risk improvement and then the market hardens, i.e. insurance is more difficult to obtain unless insurers requirements are met, when the stock market is depressed (Bickerdike Allen Partners, 1996). In addition, an insurer may accept bad risks as part of a Broker-presented portfolio.
Fire safety engineering design process

A framework for a fire engineered approach to building design is described in BS7974-0 (British Standards Institution, 2001) and illustrated in Figure 1, below. Clause 4.1 of that Code divides the framework into three stages;

1. Qualitative design review (QDR) where the scope and the objectives of the fire safety design are defined, and where performance criteria are established and acceptance criteria set;

2. Quantitative analysis, where engineering methods are used to evaluate potential solutions; and

3. Assessment against criteria, where the results of the quantitative analysis are compared against the acceptance criteria.

It is suggested in BS7974-0 that the QDR team on a major project might include a representative of the approvals body and/or the insurer. However, the insurance industry sees this as an important stage in the building design phase and suggests that, wherever practicable, the insurer must be invited to join the QDR team (Fire Protection Association, 2008).

The objectives for the fire safety design are discussed and described in the QDR process. Objectives of fire safe building design are defined as life safety, property protection and continuity of operations (Cote, 2004). Life safety objectives are those mandated in the UK Building Regulations (Great Britain, 2006) and are often achieved by providing systems for early warning of fire, extinguishment of a fire and proper egress for prompt exiting from the building. Property protection is not a mandated objective, but is of concern to insurers. It can be achieved by installing fire extinguishing systems, by providing compartmentation features
to confine or limit fire spread within a building, and by constructing the building of materials that resist fire development. Similarly, continuity of operations objectives are not mandated, but of interest to insurers. It considers the specific and unique functions of the building and its contents and is best accomplished through the installation of automatic fire extinguishing systems and by ensuring duplication of the ‘unique’ function, either within the building under consideration, or elsewhere. Within the BS7974-0 framework, support is given to the consideration of property protection and continuity of operations objectives. Clauses 6.3.1 and 6.3.3 state that:

The fire safety objectives that might typically be addressed in a fire safety engineering study [include] loss control…It might be desirable to take measures to reduce the potential for large financial losses…Consideration may be given to minimise damage to the structure and fabric of the building, the building contents, the ongoing business viability, the corporate image. (British Standards Institution, 2001)

Therefore, to meet the requirements of the insurance industry, the fire safety objectives of the QDR must include property and business protection matters, to the extent determined by the agreed acceptance criteria.

**The insurer’s role**

Although the process described in the preceding section describes how a recognised and well used fire safety engineering design process allows for insurer involvement, the reality may be very different. Recent research suggests that insurers do not play an active role in the fire safety engineering process, and when they do, their poor levels of knowledge and understanding precludes any meaningful interaction (Wilkinson, Glockling et al. 2010). The interview with the insurance Property Risk Manager confirmed that his firm do not often get
involved in the building design process, citing less than 10 percent of their property risk portfolio having had insurer input at design stage. Although he believes there is a good understanding of fire safety engineering, and its potential implications to the insurance industry, he explained that there could be numerous reasons why insurers do not appear to get involved. As approximately 90 percent of his firm’s commercial property insurance comes to them via brokers. It could be that the broker hinders good communication between the insurer and the client’s design team.

Further research suggests another reason for poor insurer engagement. It is not the case that insurers don't want to get involved in the fire safety engineering design process but, more often than not, they are not invited to do so, or are only invited to get involved at a very late stage, merely to ‘rubber-stamp’ the design decisions (Barrett, 2010).

Although there is some reluctance from the fire safety engineering design community, there is also evidence that some designers are keen for more insurer involvement. One responsible fire engineer says that they consult with insurers on the majority of their projects (Barrett, 2010).

The insurance company Property Risk Manager was able to list some examples where his firm had contributed in the building design process, and even influenced significant changes in terms of installed fire safety measures. However, these ‘successes’ are often limited to very prescriptive type messages, such as ‘put in sprinklers’, a point echoed by recent research (Wilkinson, Glockling et al. 2010).

The interview with the insured’s Risk and Insurance Manager described how the insurer was recently invited to participate in a QDR process as part of the design of a transport interchange within their site. The fire safety engineering consultants invited the client and the
insurer to discuss the development of a fire strategy for the station design. The insurer was able to convince the client and the fire safety engineers that the addition of fire sprinklers within voids over false ceilings within the retail areas of the station would be a prudent investment, based on the insurers experience of fire related losses. This anecdotal example illustrated good practice where a responsible fire safety engineer had involved an experienced insurer and the result was the inclusion of additional fire suppression features. However, it also illustrated the limitations of insurer involvement as the discussion simply concentrated on the prescriptive solution, rather than discussing any performance-based objectives. The insurer is also aware that if they try to impose their requirements too forcefully, the end-user client, or their Broker, may seek an alternative insurance provider.

The interview with the insurance company’s Risk Adviser and Sprinkler Risk Adviser revealed that when invited to survey fire engineered buildings, insurance risk surveyors are aware of the physical differences when compared to code compliant properties. They described how they give more consideration to potential fire inception hazards, the distribution of fire load and the potential for fire spread, especially when novel construction materials or design features are encountered. However, this approach is reactive, i.e. surveying the constructed building, rather than active, i.e. being an influential part of the design process.

It is clear that even with the best intentions, whether the insurer is involved in the design process or not, the current approach is not effective and the robustness of the fire safety engineering design suffers.

Despite a small number of minor examples, it is clear that the insurer does not play a suitably active role in the building design process, nor do they command sufficient influence. This is due to a number of reasons, including;
- Commercial property insurers are often not identified at the conceptual design stage and are therefore not able to participate.
- If a contract works insurer is appointed, their priorities are quite different with their focus is concentrated on the construction process, rather than the occupied building.
- Insurance brokers acting as the intermediary between insurer and insured can mean that any opportunities to be involved with design are missed;
- In a soft market, insurers are less inclined to insist on costly fire protection measures when they are competing for income premium against other insurers, and are therefore less likely to want to participate in the design process, or fearful of losing the client;
- Fire safety engineering designers are often reluctant to invite insurers into the QDR process for fear of the project incurring costly fire protection features in addition to the mandated life safety requirements.
CONCLUSIONS

This paper involved two research elements, a literature review to understand the concept of insurance, and a case study investigation to discover the involvement and motivations of insurers in the building design and construction process.

It has become apparent that, at least within the largest insurance companies, there is an understanding of the differences between prescriptive, ‘code-compliant’ buildings and performance-based, ‘fire engineered’ buildings. There is an acknowledgement that processes within insurance underwriting for fire engineered buildings should take account of these differences in risk, and examples have been cited.

However, despite a small number of minor examples, it is clear that the insurer does not play a suitably active role in the building design process. This is due to a number of reasons.

Insurers display a big commitment to risk management of the properties they have a financial interest in, but appear to lack the skills, and sometimes the will or authority, to commit the same effort when properties are being designed.

Fire safety engineering is a technique which supports innovative architectural design, vital to sustaining modern Britain. However, the probable inevitable outcome is that more buildings will suffer greater material damage and business interruption without early insurer involvement in the design process. It would be naive to assume this will not have an impact on insuring such buildings.

FURTHER WORK

This paper is part of a wider project that is being conducted as an Engineering Doctorate research topic funded by the Engineering and Physical Sciences Research Council (EPSRC),
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administered by the Centre for Innovative and Collaborative Engineering (CICE) at Loughborough University and sponsored by the Fire Protection Association (FPA). Further projects and papers will focus on;

- Fire safety engineering as a tool for business and property protection. To review current practices for ensuring and to develop better methodologies for ensuring business and property protection objectives are met in the fire safety engineering design process.
- Insuring fire safety engineered buildings. To understand the methods used to calculate EML values for traditionally designed and constructed buildings; to establish methods for commercial property insurers to quantify financial exposure when insuring buildings subject to fire safety engineering design and ongoing maintenance requirements; and to formulate insurance premium calculation tools for fire safety engineered buildings.
- Fire safety engineering: Proposals for change. To propose changes to fire safety engineering methods, codes and regulation; to change the way insurers and post-loss investigators consider and challenge fire safety engineering proposals, buildings and subsequent fires; and to improve engagement between the design community and the commercial property insurance industry.

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APPENDIX D  USING BUSINESS IMPACT ANALYSES TO ENHANCE RESILIENT FIRE ENGINEERING BUILDING DESIGN


Abstract
As an engineering discipline within the United Kingdom, fire engineering is relatively young. It has been accepted as an alternative to traditional prescriptive means of meeting the functional requirements of the Building Regulations since the publication the 1985 edition of Approved Document B.

Performance-based fire engineering design methods have facilitated architectural design freedoms and supported creative construction. However, it has become evident that since fire engineering has become more established, significant concerns have been raised regarding various elements of the design process including the ability to consider aspects other than life safety.

In response to these concerns, this paper introduces novel application of concepts to assist the building design team consider their client’s resilience requirements. This is by utilising business continuity planning methods, specifically business impact analyses within the fire engineering qualitative design review. By using these concepts in this new way, the architectural design team will be able identify those processes which are of greatest
Using business impact analyses to enhance resilient fire engineering building design

importance to their client’s organisation, allowing the most appropriate fire engineering strategy to be established.

**Keywords:** Fire engineering / Resilient building design / Business impact analysis

**Paper type:** Journal paper
INTRODUCTION

Fire engineering is increasingly being used as an alternative to the traditional prescriptive means of meeting the functional requirements of Part B of the Building Regulations in England and Wales, such as Approved Document B (Great Britain, 1985b), or Health Technical Memorandum 05-02 (Department of Health, 2007). Whilst fire engineering may be the only practical way to achieve a satisfactory standard of fire safety in some large and complex buildings (Fire Protection Association, 2008) such as airport terminals or sports stadia, questions remain about its appropriate application and regulation, and the potential implications on the commercial property insurance industry (Wilkinson, et al., 2010a).

It is generally agreed that in a modern society, traditional prescriptive design techniques can stunt innovation and creativity, and are impossible to apply sensibly to buildings with special functions, such as sports stadia, high-rise developments and transportation termini. Fire engineering, as a means of satisfying the requirements of building regulation, is an approach which has freed up building design, whilst at the same time provided suitable levels of safety. Many of the exciting buildings currently being enjoyed in the UK have been designed with engineered fire safety and could not have been built under the previous prescriptive methods (Hopkinson, 2001).

THE APPLICATION OF FIRE ENGINEERING

Background

The Institution of Fire Engineers defines fire safety engineering as ‘the application of scientific and engineering principles, rules [Codes], and expert judgement, based on an understanding of the phenomena and effects of fire and of the reaction and behaviour of
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people to fire, to protect people, property and the environment from the destructive effects of fire.’ (Chitty, 2003).

A more succinct definition is ‘the use of engineering principles for the achievement of fire safety’. (British Standards Institution, 2001, 2003).

As an engineering discipline, fire safety engineering is relatively young, and it has been accepted as an alternative means of meeting the functional requirements of the UK Building Regulations (Great Britain, 1985a) since the publication the 1985 edition of Approved Document B (Great Britain, 1985b).

Whilst fire engineering was originally the pioneering method of enabling the successful design of buildings such as airports and enclosed shopping centres, such practice is now commonplace. The new frontier for fire engineering design includes the design of very tall buildings. Projects such as those described by Hannah (Hannah, et al., 2003), Lam (2007) and Kennett (2007) demonstrate innovative designs incorporating the use of elevators for rapid evacuation of occupants during a fire, etc. Another area where fire engineering is beginning to make an impact relates to the sustainable construction agenda. Charters (2007) suggests that fire safety in buildings contributes to all aspects of sustainability and can help address the balance between protection of the environment and prudent use of natural resources.

Despite these successes, a survey of the literature (Wilkinson, et al., 2010a) revealed that some significant concerns exist regarding the availability of the data and tools required to undertake advanced fire safety analysis. Furthermore, the motivations for using fire engineering are increasingly being questioned. Examples are documented where architects are seen to be trying to find a way out of problems of poor design with complex technology
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and inappropriate fire engineering arguments (Ham, 2007). This is sometimes referred to as performance justified engineering (Dix, 2003).

Concerns over the fire safety objectives used in the design process have also been raised (Fire Protection Association, 2008). It appears to be common practice for some projects to concentrate solely on life safety, because this is mandated by the building regulations process (Glockling and Barnett, 2004). What effect this could have on property and business protection when compared with a prescriptive code compliant solution is yet to be determined.

**Interview-based investigation**

In order to investigate these concerns, research was undertaken (Wilkinson, et al., 2010a) using an extensive series of interviews with key members of fire engineering stakeholder groups. The objectives of the research were to understand the drivers for fire engineering, the respondent's opinions regarding competence and data, establish how the profession has developed and might develop in the future, and understand the perceptions of the roles of the various stakeholders involved in fire engineering. A face-to-face interview method was employed for the main data collection with nineteen stakeholders. Supplementary data was gathered by a self-administered internet based questionnaire to which ten stakeholders responded. Both the face-to-face and the self-administered methods used the same set of questions, making a total survey sample size of twenty nine. An ‘open-ended’, semi-structured approach was chosen (Gillham, 2000), using just a few key open, non-judgemental questions.

The UK fire engineering community is relatively small. It was necessary to constrain the sample to an appropriately manageable number. Stratified sampling was used to select the
Using business impact analyses to enhance resilient fire engineering building design

stakeholder sample. Stratified sampling (Fellows and Liu, 2008) is considered appropriate where the population is spread over distinct groups, or strata. Ideally, the differences within each group or stratum should be small relative to the differences between strata. Each stakeholder chosen was selected for their expert status in their particular specialism, giving confidence in the reliability of the data.

The stakeholder groups interviewed were identified as;

- **Academics;** Those involved with the teaching and equipping the fire engineers of the future, and also those involved in research; pushing the boundaries of knowledge in the field. The sample included experienced Professors engaged in directing research and teaching programmes in UK universities respected for excellence in fire engineering.

- **Designers;** Those architects and others, involved with the design of buildings and facilities, often as ‘principal adviser’ to the client. Those who are responsible for translating the client’s requirements into a brief, creating the architectural concept, and coordinating the other design professionals. The sample included influential architects from leading UK practices who are involved in the design of prestigious developments and active on committees of the Royal Institute of British Architects (RIBA).

- **End users;** Those who either commission buildings, or are responsible for operating them. The sample included managers responsible for safety within, and the maintenance of complex buildings, including the tallest building in the UK.

- **Enforcers;** Those authorities having jurisdiction (AHJ) for approving building designs against the requirements of the Building Regulations, within Building Control functions and Fire Authorities. The sample included serving building control professionals, leaders of the industry’s professional body the Association of Building Engineers (ABE), and experienced serving fire safety officers.
Practitioners; Those engineering consultants and designers who assist the building design process by advising on fire safety matters, to varying degrees. The sample included senior engineers working in leading fire engineering consultancies who are regularly involved in complex fire engineering projects.

Insurers; Those insurers and brokers who are responsible for insuring property and businesses, and advising their clients on risk management issues. The sample included experienced senior surveyors and managers working in the leading UK insurance companies and brokers.

Policy Makers; Those responsible for determining Ministerial priorities, monitoring and affecting changes to Regulations, etc. The sample included those responsible for fire safety building regulations within the UK Government’s Department of Communities and Local Government.

Institutions; Trade bodies and professional institutions that have a role in informing, developing and/or regulating a membership. The sample included the leaders of a trade body representing manufacturers and installers of passive fire protection products.

This investigation concluded that the common expectation across all stakeholder groups was that fire engineering would facilitate architectural design freedom and support creative construction allowing the UK, and more specifically the city of London, to continue to develop its reputation as a centre for world-class developments.

The research also revealed that since fire engineering has become accepted, significant concerns have been raised regarding various elements of the design process including,

- The appropriateness of application of fire engineering to some design issues and misuse of the term ‘fire engineering’ to merely describe deviation from design codes;
• The real motivations of the client and design team for using fire engineering techniques are often economically driven motivations, or a means of addressing design errors or omissions;
• The ability of building control professionals to approve designs, and of fire and rescue service personnel to contribute to the process;
• The ability of the construction industry to select high quality materials and to ensure the high standards of installation and workmanship which are crucial for successful fire engineering;
• The lack of involvement of the insurer and the ability to consider design objectives other than life safety;
• The validity of fire engineered solutions during the building’s life-cycle, and the continued input of fire engineers from design to demolition;
• The limitations of the knowledge, data and tools that support fire engineering design concepts;
• The ability of professional institutions to guide and regulate practicing fire engineers.

All these issues need to be addressed if fire engineering is to enjoy continued growth as a profession, and continued acceptance as a legitimate contribution to the building design process (Wilkinson, et al., 2010a).

FIRE ENGINEERING AND THE ROLE OF THE INSURER

Published framework

A framework for a fire engineered approach to building design is described in BS7974-0, Application of fire safety engineering principles to the design of buildings (British Standards Institution, 2001). As a performance-based fire safety design process, BS7974 is widely used
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globally to varying degrees, but is often considered the framework against which fire engineering proposals are appraised in the UK’s national building regulation approvals process, such as in England and Wales (Department of Communities and Local Government, 2007). The process is described here and illustrated in Figure 1, below.

Figure 1; Fire engineering process

The process is divided into three stages;

- Qualitative design review (QDR) where the scope and the objectives of the fire safety design are defined, the performance criteria are established and acceptance criteria set;
- Quantitative analysis, where engineering methods are used to evaluate potential solutions; and
• Assessment against criteria, where the results of the quantitative analysis are compared against the acceptance criteria.

The objectives of the fire safety in building design are considered and described in the qualitative design review (QDR) process. These are defined as life safety, property protection and continuity of operations (Cote, 2004). Life safety objectives are mandated in the UK Building Regulations (Great Britain, 1885 and 2006a) and are often achieved by providing systems for early warning, extinguishment and prompt egress from the building. Property protection is not a mandated objective, but is of concern to insurers. It can be achieved by installing fire extinguishing systems, by providing compartmentation features to limit fire spread and specifying building materials that resist fire development. Similarly, continuity of operations objectives are not mandated, but of interest to insurers. This considers the specific and unique functions of the building and its contents and is often accomplished through the installation of automatic fire extinguishing systems and by ensuring duplication of the unique function, i.e. ensuring that the function can be carried out elsewhere, either within the building under consideration, or at another location. Within the BS7974-0 framework, support is given to the consideration of property protection and continuity of operations objectives. Clauses 6.3.1 and 6.3.3 state that the fire safety objectives that might typically be addressed in a fire engineering study include loss control. It states that it might be desirable to take measures to reduce the potential for large financial losses and that consideration may be given to minimise damage to the structure and fabric of the building, the building contents, the ongoing business viability, the corporate image. (British Standards Institution, 2001)

Therefore, in order to meet the requirements of the insurance industry and the end-user client, the fire safety objectives of the QDR should include property and business protection matters to the extent determined by the agreed acceptance criteria. In order to consider the fire
engineering design process and establish where the best opportunities for gaining relevant information to inform the QDR, we first have to understand the fire insurance industry.

**Fire insurance**

Insurance is one method that businesses can reduce the financial impact of a risk occurring. Whilst holding an insurance policy does not remove a risk, it provides some security should the worst happen (Dickson, 1997). Fire insurance provides financial compensation for damage due to and consequent on a fire to the owners or occupiers of the premises where this occurred. The compensation is normally for direct material damage (MD) by the fire itself, by heat or smoke from the fire and by water and other agents used to control and extinguish the fire. In addition, business interruption (BI) insurance provides financial compensation for such consequences as loss of orders due to late delivery, loss of key facilities and cost of reorganisation. The extent of these consequential losses may exceed the direct losses (Institution of Fire Engineers, 1989).

Today, fire insurance is provided by insurance companies and by Lloyd’s underwriters, known as a leading market for specialist insurance. Insurance may be placed directly with a company, or through an intermediary, usually an insurance broker. When a new insurance policy is proposed to an insurer, a fire surveyor will normally visit the premises to be insured to evaluate potential risk from fire and to advise the insured on fire prevention and protection. The fire surveyor prepares a report for consideration by the insurer’s underwriter. Insurance underwriters evaluate the risk and exposures of potential clients; decide how much coverage the client should receive and how much they should pay for it. Underwriting involves measuring risk exposure and determining the premium that needs to be charged to insure that risk. Essentially, underwriting is the process of issuing insurance policies. The acceptance or
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rejection of risk is based on a prescribed capacity concept and is normally performed in accordance with organisational guidelines (Galey and Kuhn, 2009).

It is customary to use estimates of expected loss under different conditions in data for estimating premiums (Rasbash, et al., 2004). The association of the loss with the failure of items of fire safety defence allows quantification of the probabilities of the loss occurring. Estimated Maximum Loss (EML) is the loss expectancy definition commonly used in the UK. The London Insurance and Reinsurance Market Association define EML as an estimate of the monetary loss which could be sustained by insurers on a single risk as a result of a single fire or explosion considered by the underwriter to be within the realms of probability (Rigby-Smith, 1995).

Within the framework of loss prevention, insurers have long been analysing the quality of the risks they insure, and options for improving the quality of the portfolio. Loss prevention has a direct impact on the prices, terms and conditions in the sense of risk-adequate rating and is the basis for profitable business (Schadenspiegel, 2007). In order to assess and control the likelihood and magnitude of these risks, insurers have their own technical standards giving requirements for constructional measures, fire protection equipment and methods of work (Bickerdike Allen Partners, 1996). These standards are often used as benchmarks against which a building and its contents can be assessed. However, insurance is a profit-generating business and is affected by economic considerations. In a soft insurance market there is much competition between insurance companies for premium income in order to invest the capital profitably on the stock market. This desire for premiums can override the need for stringent risk control, an attitude which in time must result in bad loss experience. This in turn leads to an increased emphasis on loss prevention and risk improvement and then the market hardens, i.e. insurance is more difficult to obtain unless insurers requirements are met, when the stock
market is depressed (Bickerdike Allen Partners, 1996). In addition, an insurer may accept bad risks as part of a broker-presented portfolio, where assessment of individual properties may be overlooked in order to secure the insurance business of a larger collection of risks.

**Case-study investigation**

Further research (Wilkinson, et al., 2010b) involved a case-study investigation conducted to fully understand current practice relating to the involvement of the insurance industry within the fire safety engineering design process. The investigation involved a combination of face-to-face meetings and site visits where individuals were observed while undertaking their professional role.

<table>
<thead>
<tr>
<th>Job title</th>
<th>Employer</th>
<th>Stakeholder group</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property Risk Manager</td>
<td>Major UK commercial insurance company</td>
<td>Insurer</td>
<td>Senior managerial role overseeing surveyors and influencing company commercial property underwriting strategy.</td>
</tr>
<tr>
<td>Risk and Insurance Manager</td>
<td>Property portfolio with 33 high-rise office buildings.</td>
<td>End-user client</td>
<td>Senior role responsible for insurance procurement, risk transfer and risk management.</td>
</tr>
<tr>
<td>Risk Surveyor and Sprinkler Risk Surveyor</td>
<td>Major UK commercial insurance company</td>
<td>Insurer</td>
<td>Field-based team assessing the acceptability of properties in relation to the insurer’s requirements.</td>
</tr>
<tr>
<td>Associate</td>
<td>Major fire safety engineering consultant</td>
<td>Practitioner</td>
<td>Experienced practicing fire engineer.</td>
</tr>
</tbody>
</table>

Table 1. Case study investigation participants

This investigation involved a small but high quality cohort, united by their relationship with fire safety engineering of an iconic property portfolio, which represents an interpretive
epistemology employing inductive research methods as discussed by Fellows and Liu (2008).

It followed a less structured methodology in order to gain richer and deeper information, with the interviewees commenting on their personal experiences. Such commentaries are acceptable as scientific data, as asserted by Brown and Sime (Brenner (Ed.) 1981).

Although BS7974 (British Standards Institution, 2001) represents a recognised and well used fire safety engineering design process which allows for insurer involvement, the reality appears to be very different. This case-study investigation suggests that insurers do not play an active role in the fire safety engineering process, and when they do, their poor levels of knowledge and understanding precludes any meaningful interaction. The interviews with the insurance Property Risk Manager confirmed that his firm do not often get involved in the building design process, citing less than 10 percent of their property risk portfolio having had insurer input at design stage. Although he believes there is a good understanding of fire safety engineering, and its potential implications to the insurance industry, he explained that there could be numerous reasons why insurers do not appear to get involved. As approximately 90 percent of his firm’s commercial property insurance comes to them via brokers, it could be that the broker hinders good communication between the insurer and the client’s design team. Further research suggests another reason for poor insurer engagement. It is not the case that insurers don't want to get involved in the fire safety engineering design process but, more often than not, they are not invited to do so, or are only invited to get involved at a very late stage, merely to ‘rubber-stamp’ the design decisions (Barrett, 2010).

The insurance company Property Risk Manager was able to list some examples where his firm had contributed in the building design process, and even influenced significant changes in terms of installed fire safety measures. However, these ‘successes’ are often limited to
very prescriptive type messages, such as ‘put in sprinklers’, a point echoed by recent research (Wilkinson, et al., 2010a).

The interview with the insured’s Risk and Insurance Manager described how the insurer was recently invited to participate in a QDR process as part of the design of a transport interchange within their site. The fire safety engineering consultants invited the client and the insurer to discuss the development of a fire strategy for the station design. The insurer was able to convince the client and the fire safety engineers that the addition of fire sprinklers within voids over false ceilings within the retail areas of the station would be a prudent investment, based on the insurers experience of fire related losses. This anecdotal example illustrated good practice where a responsible fire safety engineer had involved an experienced insurer and the result was the inclusion of additional fire suppression features. However, it also illustrated the limitations of insurer involvement as the discussion simply concentrated on the prescriptive solution, rather than discussing any performance-based objectives. The insurer is also aware that if they try to impose their requirements too forcefully, the end-user client, or their Broker, may seek an alternative insurance provider.

The interview with the insurance company’s Risk Adviser and Sprinkler Risk Adviser revealed that when invited to survey fire engineered buildings, insurance risk surveyors are aware of the physical differences when compared to code compliant properties. They described how they give more consideration to potential fire inception hazards, the distribution of fire load and the potential for fire spread, especially when novel construction materials or design features are encountered. However, this approach is reactive, i.e. surveying the constructed building, rather than active, i.e. being an influential part of the design process.
This research concluded that, at least within the largest insurance companies, there is an understanding of the differences between prescriptive, ‘code-compliant’ buildings and performance-based, ‘fire engineered’ buildings. There is an acknowledgement that the insurance underwriting for fire engineered buildings should take account of these differences.

However, despite a small number of minor examples, it is clear that the insurer does not play an appropriate active role in the building design process, and when they do, their poor levels of knowledge and understanding precludes any meaningful interaction. This is due to a number of reasons (Wilkinson, et al., 2010a);

- Commercial property insurers are often not involved at the conceptual design stage and are therefore not able to participate.
- If a contract works insurer is appointed, their attention is usually focused on the construction process, rather than the finished building.
- Insurance brokers usually act as the intermediary between the insurer and the client can mean that any opportunities to be involved with design are missed;
- In a soft market, insurers are less inclined to insist on costly fire protection measures when they are competing for income premium against other insurers, and are therefore less likely to want to participate in the design process, or fearful of losing the client;
- Fire engineering designers are often reluctant to invite insurers into the QDR process for fear of the project incurring costly fire protection features in addition to the mandated life safety requirements.

Insurers have a big commitment to the risk management of the properties they have a financial interest in, but appear to lack the skills, and sometimes the will or authority, to commit the same effort when properties are being designed. Even with the best intentions and
regardless of whether the insurer is involved in the design process or not, the current approach is not effective and the robustness of the fire engineering design becomes questionable. Fire engineering is a technique which supports innovative architectural design, vital for sustaining a modern economy. However, the probable inevitable outcome is that more buildings can suffer greater material damage and business interruption if insurers are not involved in the design process. It would be naive to assume that this will not have an impact on insuring such buildings.

ENSURING RESILIENCE AT BUILDING DESIGN STAGE

Overview

In response to the concerns raised in the previous discussion, it is clear that a new approach to fire engineering objective setting is required. The key step is to actively involve the end-user client, i.e. the organisation that has commissioned the new building and intends to occupy and use the facilities, in order to derive a complete set of design requirements. As research has shown (Wilkinson, et al., 2010b) commercial property insurers, whilst important stakeholders, are not necessarily best placed to inform the building design and fire engineering design processes as their early involvement in the design process cannot be guaranteed.

Therefore, the remainder of this paper describes a process which is used to assess business risks, known as business impact analysis (BIA), and discusses how the process can be utilised to inform the fire engineering objective-setting process. BIA is defined as the procedure for collecting and analysing the urgency of organisational functions or activities, and the organisation’s tolerance of loss. It describes the resources necessary for the activities to be accomplished (Reuvid, 2006). Whilst BIA is a process which is commonplace within business continuity management (BCM) techniques, it is a method of analysis that has not yet been applied within the building design process. It is felt that where the client is able to
conduct a BIA, the protection of company resources associated with the built environment that underpin the conduct of business critical activities, may be added to the fire engineering objectives to inform the qualitative design review (QDR) process, as described in PD 7974-0 (British Standards Institution, 2001).

**Business resilience, interest, responsibility and drivers**

BIA is fundamental to ensuring a successful building design that fully meets the needs of the client. It is also essential for ensuring the continued viability and success of the client organisation. For example, the role of the Managing Director or Chief Executive of an organisation includes the requirement to be accountable for the overall performance of the organisation and for the day-to-day running and management of the organisation, under delegated authority from the Executive. Their specific responsibilities include (Prospectus, 2004):

- Implementing the Executive’s policies and strategies;
- Managing the day-to-day operations of the organisation;
- Managing resources efficiently and effectively to achieve the organisation’s objectives;
- Ensuring that appropriate internal audit processes and procedures are in place;
- Developing and implementing a risk management plan; and
- Ensuring that there is a succession plan in place.

The analysis of business vulnerabilities and the appreciation of the benefits of good business continuity planning are at the heart of many of these responsibilities and as such business continuity initiatives need to start at the top of an organisation and promulgate downwards.
Indeed, it is stated in the Companies Act (Great Britain, 2006b) that a director of a company has a duty to act in the way he considers, in good faith, would be most likely to promote the success of the company for the benefit of its members as a whole, and in doing so have regard (amongst other matters) to:

- The likely consequences of any decision in the long term;
- The interests of the company's employees;
- The need to foster the company's business relationships with suppliers, customers and others;
- The impact of the company's operations on the community and the environment;
- The desirability of the company maintaining a reputation for high standards of business conduct; and
- The need to act fairly as between members of the company.

Therefore, the responsibility to ensure a business’ long-term viability rests at the very top of the organisation. A business that fails following a major event, such as fire, has demonstrated a fragility that results from poor management.

**Business continuity management**

Business continuity management (BCM) is a business-driven process that:

- Establishes a strategic framework that improves an organisation’s resilience against the disruption to its ability to achieve its key objectives;
- Provides a reliable method of restoring an organisation’s ability to supply its key products and services to an agreed level within an agreed timescale after a disruption; and
- Delivers a proven capability to manage a business disruption, protecting the organisation’s reputation and brand (British Standards Institution, 2006)
BCM requires a process to be planned, implemented and improved on a regular basis, and BS 25999-1 introduces the concept of a BCM lifecycle.

Any business activity is sometimes subject to disruptions caused by technology failure, denial of access and fire. BCM provides the capability to adequately react to operational disruptions while protecting welfare and safety. Some of the benefits of an effective BCM (British Standards Institution, 2006), are that the organisation;

- Is able to proactively identify impacts of an operational disruption;
- Has in place an effective response to disruptions which minimises the impact on the organisation;
- Maintains the ability to manage uninsurable risks.
Central to BCM is the identification of critical activities and the resources upon which they depend. Resources are often grouped into categories such as people, plant, premises and infrastructure, and where the built environment is a part of the provision of these resources, there is clearly a need to take advantage of these analyses and consider the information during the building design phase.

**FIRE ENGINEERING SOLUTIONS TO BUSINESS CONTINUITY ISSUES**

**Business impact analysis**

Whilst the protection of resources that underpin critical activities with fire suppression systems goes some way towards reducing the likelihood of critical damage from fire, no system is infallible, and as such no contribution is made in ensuring critical activity availability when such systems fail (British Standards Institution, 2012). Business continuity solutions ensure that there is always adequate provision for the continuity of critical activities irrespective of the type and scale of the event behind the loss of resource.

As such, solutions relevant to the built environment where fire engineering tools may be used include (British Standards Institution, 2012);

- Duplication of assets;
- Splitting and separation of assets;
- Protection of assets;
- Early detection of threat.

The effects of fire are only some of the causes of disruptions that would be identified and managed within a holistic business continuity plan. However, by identifying these fire-related disruptions and potential consequences at the design stage of a building or plant, it is possible to incorporate design features designed to reduce property loss, assist in ensuring business
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continuity and provide resilience against the effects of fire. For the fire safety engineer, the BIA process will (British Standards Institution, 2012);

- Identify those activities critical to the end user client’s organisation;
- Identify the resources needed to support the activities; and
- Identify the fire safety objectives necessary to protect the resources.

The BIA describes;

- The importance of business activities to the company in delivering its strategic plan;
- The timescales upon which the activity must be recovered before the company sustains critical damage;
- The resources upon which the activity depends;
- The percentage loss of resource deemed tolerable; and
- How the organisation will need to resume over time, from the minimum staffing of the emergency team to the full reinstatement of all services (Reuvid, 2006).

Using this information to augment the mandated life safety objectives the fire safety objectives for consideration could contain activity specific requirements such as;

- Fire must be detected and extinguished before reaching x kW in size
- Compartment / equipment must be recovered in 7 days
- Business Stream must be operational in 14 days

Whilst fire safety engineering alone will be unable to, or not be the most appropriate means to achieve these aims, some building elements could be instrumental in meeting these goals.
Use of business impact analysis within qualitative design review

Qualitative design review (QDR) was described earlier as one of the initial stages in the fire engineering design process. Whilst the QDR is essentially a qualitative process, it can often be useful to carry out simple calculations to resolve a difference of opinion between team members or to establish the most significant scenarios for detailed quantification.

The main stages in the QDR are defined as (British Standards Institution, 2001):

- review of architectural design and occupant characteristics;
- establish fire safety objectives;
- identify fire hazards and possible consequences;
- establish trial fire safety designs;
- identify acceptance criteria and methods of analysis; and
- establish fire scenarios for analysis.

The fire engineer, architectural design team and insurer should endeavour to fully understand the end-user client’s organisation in terms of its objectives, stakeholder obligations, statutory duties and the environment in which the organisation operates. By including the information derived from a BIA, within the traditional QDR process, the fire safety objectives can be informed from a business resilience point of view, as shown in Figure 3.
**BIA/QDR process**

The data gathered from the organisation’s continuity and recovery strategy, and BIA will identify mission critical activities and the timeframe within which they must be recovered (the maximum tolerable outage, or recovery time objective), and will be used as a means to establish dependencies and relationships between business processes and supporting infrastructures.

As described by Sharp (2008), Hiles (2007) and others, the BIA is an integral part of an organisations business continuity plan. Therefore, it is a document already in existence, undertaken by the end-user client organisation. Where a BIA is not available, or documented, the fire engineer or architectural design team could facilitate a BIA on behalf of the client. However, there is little purpose in undertaking a BIA unless the management of the end-user client’s organisation understand the requirement and are willing to act on the findings. For a BIA to be undertaken successfully, its purpose must be appreciated and supported by senior management in advance of the process commencing. Before a BIA is undertaken, a clearly
stated commitment to the wider goals and objectives of business continuity management should be sought from senior management within the client’s organisation. This commitment should include the organisation’s appetite to invest in the solutions that result from the use of a BIA to help define the design requirements.

Figure 4 shows the three steps in the BIA process, should it be required to undertake one (British Standards Institution, 2012). The first step in the BIA process is to address the scope of the analysis. This will largely be influenced by the scope of the building or plant being designed, however, a new facility being constructed within an existing site, will require a BIA
which analyses the entire site, or facility in order to fully understand the influences and dependencies within the new building.

The second step involves data collection and requires a collaborative approach to be taken, but it is essential that the end-user client is responsible for undertaking the analysis. The client’s insurer, or insurance broker will often have a good understanding of the organisation, the hazards, and business interruption consequences, however, it is the only the end-user client who can convey the full picture. The senior management team should be asked to consider the organisation as a whole and provide a ranking for key products or services and the point at which the maximum tolerable period of disruption (MTPD) occurs. This team will also need to set the timescale for resumption within the MTPD, which is called the recovery time objective (RTO). The outcome of this data collection is to determine the critical activities across the organisation that is needed to deliver these products and services (Sharp, 2008).

The third element of the BIA is to subject the findings to a moderation process, rather than simply accepting the findings at face value. Moderation is best conducted by senior managers within the client’s organisation so they can give the global perspective, but other various methods to moderate the BIA data include (Hiles, 2007);

- comparison of output with findings of earlier reviews, or across other divisions, or with internal expectations;
- use of peer review with other BCM experts;
- use of a senior figure within the client organisation (or panel) to assess the initial findings.

Once the BIA has been completed, the process undertaken and the findings should be documented in such a way that it;
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- provides a meaningful input into the fire engineering objective setting within the QDR,
- feeds back into the wider client organisation’s business continuity management plan,
- provides sufficient evidence of the process to satisfy later audit.

The incorporation of such a BIA, or the interpretation of the end-user client organisation’s BIA, into the QDR and objective setting process will then allow the fire engineer to establish scenarios for quantitative analysis utilising appropriate fire protection tactics (Figure 5), resulting in resilient building designs.

![Figure 5: BIA to QDR](image-url)
A STANDARDISED APPROACH FOR USE OF BUSINESS IMPACT ANALYSIS IN FIRE ENGINEERING QUALITATIVE DESIGN REVIEW

Developing the approach for use of BIA

Modern fire engineering design is an integral part of the entire building design process from the conceptual phase onwards (CIB W014, 2001). Typically, the architect makes a draft design based on his interpretation of the end-user client’s objectives. As the building design evolves, with the input of the structural engineer and the building services engineer, the fire engineer selects and designs appropriate components to satisfy the functional fire safety objectives. However, in order to inform the objective setting process as outlined earlier, there is a requirement for business resilience objectives to be explored at the earliest opportunity. Therefore, in order to promote the concept of utilising BIA discussed in the previous sections of this paper and ensure that an organisation’s resilience objectives are considered in the building design phase, the process needs to be embedded within the established fire engineering design framework.

As already outlined, an established framework for a fire engineered approach to building design is described in BS7974-0 (British Standards Institution, 2001). As a performance-based fire safety design process, BS7974 is widely used globally to varying degrees, but is often considered the framework against which fire engineering proposals are appraised in the UK’s national building regulation approvals process, such as in England and Wales (Department of Communities and Local Government, 2007).

FSH/024 is the Technical Committee within the British Standards Institution (BSI) that under the direction of the Standards Policy and Strategy Committee is responsible for the development and maintenance of standards for fire engineering in buildings. It represents the UK on European and International standards organisations and it drafted the standard BS7974.
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Code of Practice on the Application of Fire engineering Principles to the design of Buildings which is supported by eight Published Documents each containing detailed technical guidance on different aspects of fire engineering from background information to quantitative risk assessment. (Charters, 2006).

During 2010, the author discussed the issues identified by the research discussed previously with FSH/24 Technical Committee who quickly gave their support. The Committee appreciated the requirement to promote business resilience objectives within the fire engineering QDR process and the author established, and then led a working party, known as a Panel, to develop some initial ideas. The Panel comprised members of FSH/24 who brought experience from various fire engineering stakeholder groups, including practitioners, insurers, academics and approval bodies. In November 2010, the Panel met for the first time to review ideas and discuss potential output, including the idea of creating a new published document in the BS7974 series to describe and standardise the BIA process. A business case was developed and presented to BSI and once approved, the Panel continued to meet at regular intervals. It began to draft a guidance document which is to be known as PD7974-8 Application of fire safety engineering principles to the design of buildings – Part 8: Property protection, mission continuity and resilience (British Standards Institution, 2012). Starting by agreeing a structure for the document, the Panel quickly developed the text and individuals volunteered to concentrate on certain elements, such as describing the process, developing worked examples, etc. In September 2011, an initial draft document containing PD7974-8 was presented to the FSH/24 Technical Committee for discussion and approval. Since then, a Content Developer was appointed by BSI to assist with formatting of the draft PD7974-8 and after several reviews, the draft PD7974-8 has been issued for public comment.
Structure of document

The draft PD7974-8 has been developed in accordance with the established protocol for all British Standard codes, and follows the requirements of BS0, A Standard for Standards (British Standards Institution, 2011).

It begins by describing the relationship of PD8 with other publications in the BS7974 series. It introduces the concepts, terminology and drivers for adopting the approach outlined in the document and then defines the scope. As PD8 is intended to supplement the existing design process as established within BS7974, PD8 sets out clearly when fire engineering design objectives are considered. It describes the established QDR process and how PD8 should be used to incorporate the clients’ resilience objectives.

The main body of the document describes the BIA process, how a BIA can be interpreted for fire engineering purposes and then details numerous examples of resilience objectives and fire safety tactics to meet these objectives. Case study examples of how the process in PD8 can influence fire engineering design are presented from a wide spectrum of building occupancies, a school, a food manufacturing site and a nuclear power station. Appendices include background information in relation to business continuity management as described in BS25999 (British Standards Institution, 2006) and example BIA formatting with typical BIA data.

Evaluation

The draft PD7974-8 document has been released as a Draft for Public Comment (DPC) where comments are invited from all interested parties. At the time of writing, only a small quantity of comments had been received, indicating general approval from the industry. In addition, the document has been exposed to various fire engineering stakeholder groups during a range
of dissemination activities, including the commercial property insurance community, fire engineering practitioners and building user client groups. On each occasion, the discussions have generated positive feedback and support for the approach.

However, in order to evaluate the practicality of the methods described within PD7974-8 in greater detail, a desk-top pilot study was undertaken. The pilot study involved a detailed discussion with a commercial property insurer, evaluating a recent fire engineering project they had been involved with. The pilot study involved an established small-scale snack food producer and their plans to expand production capabilities to meet a significant increase in sales including substantial plans to develop an export market. It was described both in terms of a ‘conventional’ fire safety design where life safety objectives were considered, and in terms of an approach considering objectives gleaned from a BIA-type study. In more detail, the site being studied was described as compact, comprising an office building, a production building and a storage building. The storage building can house up to 7 days’ worth of product, so essentially the business operates a “just in time” manufacturing philosophy. The production building is a converted farm building which houses frying ranges, protected with automatic fire suppression local to the ranges. The ranges are provided with a single feed from the bulk oil storage tank.

The client and their team originally chose the most cost-effective option of expanding the original production building by building a simple extension, thereby providing the space to locate additional frying ranges, etc. This option met all Building Regulation requirements and met with approval from the Building Control body. However, after conducting a BIA, the following business resilience issues were taken into account in order to adjust the fire safety objectives.
Using business impact analyses to enhance resilient fire engineering building design

- With fruition of successful business development, loss of production for more than 2 days is unacceptable.

- The original expanded building designs represents a large “single and communicating risk”, which would be considered by insurers as an estimated maximum loss (EML) of 100%. For many insurers, this EML would be too high to cover and would require reinsurance, increasing costs for the client.

- The client is the largest employer in the surrounding rural area and therefore the loss to the community resulting from a disruptive fire is large.

- The business is owned by a venture capitalist organisation, which is keen to look after its investment and acts as a vocal Board member.

- Having identified these issues, to proceed as planned, would mean the MD would be falling short of an MD’s responsibilities.

Following the BIA process and after discussions with their insurer, the client chose to convert the existing warehouse into a new production facility, separated by more than 20 m from the original production building. A new warehouse is planned which will be sprinklered which means that the client will now have two separate production lines operating in parallel, both protected by high-pressure fog fire suppression, giving protection of production operations, with a new sprinkler protected warehouse giving additional business resilience. The new arrangements will attract the maximum discount from their insurers.

Without following the process as described in the draft document PD7974-8 (British Standards Institution, 2012), such business resilience objectives may have been missed within the building design phase, allowing an inferior package of fire protection measures to be incorporated into the development. PD7974-8 now provides a standardised method for building designers and fire engineers to fully appreciate their client’s requirements.
Potential concerns

Some initial concerns have been derived from informal feedback where the draft document has been exposed to various fire engineering stakeholder groups during a range of dissemination activities. These exercises have included the commercial property insurance community, fire engineering practitioners and building user client groups. Some feedback has indicated a potential concern regarding the involvement of the fire engineer in the building design process. Confirming a conclusion of previous research (Wilkinson, et al., 2010a) in many building design projects where a fire engineer is employed, their appointment is for a limited role only, often to purely address a specific issue. This means that a fire engineer may not be appointed at the earliest conceptual design stage and therefore the opportunities to utilise a fire engineering guide may be limited or delayed. Therefore, the proposed guide needs to be communicated to the wider architectural community in order to maximise the benefits to the building user client. Another potential concern regards the lack of business continuity planning undertaken in UK businesses. It is thought that, as few organisations have thorough and effective business continuity plans in place, it is going to be less likely that an organisation has a BIA in place for use in the process described in the guide. This reinforces the need for the guide to include enough information to allow the building design team to facilitate a BIA with their clients when necessary.

CONCLUSIONS

This paper has outlined recent research investigating how performance-based fire engineering techniques are used within building design. The literature review described concerns regarding the motivations for applying fire engineering techniques to building design. The survey research suggested that greater input is required from commercial property insurers at the building design stage in order to champion property protection and business resilience.
objectives and then the subsequent case-study investigation, however, concluded that for a number of reasons, it is impractical to expect the insurer to influence the design team to the extent desired.

Therefore, in response to these various research activities, the concept of business impact analysis has been introduced to ensure that property protection and business continuity objectives are at the forefront of new building design, whether the insurer is involved in the process or not.

In order to help consulting fire engineers, and architectural design teams, incorporate business protection objectives in their fire safety designs, there is a requirement for the established British Standard which defines a fire engineering procedure, to be enhanced. This idea gained support from the Technical Committee within BSI responsible for maintaining the Standard, and PD 7974-8 Application of fire safety engineering principles to the design of buildings-Part 8: Property protection, mission continuity and resilience (British Standards institution, 2012) has been drafted.

The new Standard embeds the use of a business impact analysis as an integral part of the qualitative design review process. Without following the BIA process as described in the draft document PD7974-8, business resilience objectives may be missed within the building design phase, allowing an inferior package of fire protection measures to be incorporated into building developments. For the first time, this new document will enable the building designer to be fully cognisant of their client's critical processes and the resources required to support these processes. It will therefore enable the appropriate fire safety measures to be incorporated into the building design to enhance business resilience.
An investigation into resilient fire engineering building design

Initial evaluations of this guide though various stakeholder dissemination activities and a public consultation process has been positive. The potential concerns that the evaluations have raised regarding the role of the fire engineer throughout the building design phase, and regarding the prevalence of BIA within organisations will be addressed in the guide and the way it is publicised upon its launch.

REFERENCES


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APPENDIX E INTERVIEW QUESTIONS AND STAKEHOLDER INTERVIEWEES

Questions used when interviewing in Work Package 1

- Please give a brief description of your educational and career history.
- What is your relationship with fire engineering?
- Why do you think fire engineering exists as an engineering discipline/profession?
- Please describe how adequately you consider yourself equipped to undertake your role in respect of your interface with fire engineering?
- How has fire engineering, or its impact on your organisation, changed during your career?
- How do you envisage fire engineering changing in the future, from your perspective?
- What is your perception of the role of other stakeholders in fire engineering?
- NB: For the purposes of this survey, the stakeholder groups which have been identified include academics, architects/building designers, end users/operators, enforcers, practitioners/consultants, insurers, policy makers, product manufactures and other interested parties.
- Please make any other comments you have in relation to this study.
Table 6.1: Stakeholder Interviewees

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Organisation</th>
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<tbody>
<tr>
<td>John Purkiss</td>
<td>Professor of structural fire engineering</td>
<td>Aston University</td>
</tr>
<tr>
<td>Ed Galea</td>
<td>Professor of computational fire engineering and modelling</td>
<td>University of Greenwich</td>
</tr>
<tr>
<td>Jim Shields</td>
<td>Professor of fire safety engineering</td>
<td>University of Ulster</td>
</tr>
<tr>
<td>Arnold Dix</td>
<td>Adjunct professor of engineering</td>
<td>Queensland University of Technology</td>
</tr>
<tr>
<td>Peter Caplehorn</td>
<td>Technical Director</td>
<td>Scott Brownrigg Architects</td>
</tr>
<tr>
<td>Paul Roberts</td>
<td>Fire Policy Lead</td>
<td>Department of Health</td>
</tr>
<tr>
<td>Paul Coster</td>
<td>Fire and Life Safety Manager</td>
<td>Canary Wharf Management Ltd</td>
</tr>
<tr>
<td>David Gibson</td>
<td>Chief Executive</td>
<td>Association of Building Engineers</td>
</tr>
<tr>
<td>David Clements</td>
<td>District Surveyor</td>
<td>City of London</td>
</tr>
<tr>
<td>Name</td>
<td>Role</td>
<td>Organisation</td>
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<tr>
<td>Dennis Davis</td>
<td>Former Her Majesty's Chief Inspector of Fire Services</td>
<td>Home Office</td>
</tr>
<tr>
<td>Steve Robinson</td>
<td>Head of Fire Safety</td>
<td>Cambridgeshire Fire and Rescue Service</td>
</tr>
<tr>
<td>Martin Shipp</td>
<td>Technical Development Director Fire Safety</td>
<td>BRE</td>
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<tr>
<td>Peter Bressington</td>
<td>Director</td>
<td>ArupFire</td>
</tr>
<tr>
<td>Eric Marchant</td>
<td>Consultant</td>
<td>Edinburgh Fire Consultants and University of Edinburgh</td>
</tr>
<tr>
<td>Peter Jackman</td>
<td>Technical Director</td>
<td>International Fire Consultants</td>
</tr>
<tr>
<td>Margaret Law</td>
<td>(retired) former Technical Director</td>
<td>Ove Arup and Partners</td>
</tr>
<tr>
<td>Howard Morgan</td>
<td>Senior Consultant</td>
<td>International Fire Consultants</td>
</tr>
<tr>
<td>Mick Green</td>
<td>Partner</td>
<td>Buro Happold</td>
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<tr>
<td>Andy Nicholson</td>
<td>Associate</td>
<td>Buro Happold</td>
</tr>
<tr>
<td>Name</td>
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<tr>
<td>Richard Morgan</td>
<td>Managing Consultant</td>
<td>Marsh</td>
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<tr>
<td>Peter Brierley</td>
<td>Director</td>
<td>General &amp; Commercial Insurance Services Limited</td>
</tr>
<tr>
<td>Roy Watkinson</td>
<td>Technical and Commercial Underwriting</td>
<td>AXA Insurance</td>
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<td></td>
<td>Director</td>
<td></td>
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<tr>
<td>Dougie Barnett</td>
<td>Head of Customer Risk Management</td>
<td>AXA Insurance</td>
</tr>
<tr>
<td>Dave Sibert</td>
<td>Fire Safety Advisor</td>
<td>Fire Brigades Union</td>
</tr>
<tr>
<td>Wilf Butcher</td>
<td>Chief Executive</td>
<td>Association of Specialist Fire Protection</td>
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<tr>
<td>Stuart Kidd</td>
<td>Secretary General</td>
<td>British Automatic Fire Sprinkler Association</td>
</tr>
<tr>
<td>Bill Parlour</td>
<td>Technical Officer</td>
<td>Association of Specialist Fire Protection</td>
</tr>
<tr>
<td>Mike Larking</td>
<td>Fire Policy Lead</td>
<td>Department of Communities and Local Government</td>
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