A Model of the Role of Management in Construction Fire Safety Failure Scenarios

By

Marie-Cécile Puybaraud

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Heriot-Watt University

Department of Building Engineering & Surveying

Edinburgh

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ABSTRACT

This research is aimed at identifying and proposing a managerial model to prevent and control fires during construction works. The research was based on an extensive review of relevant literature and an in-depth analysis of major fires in the UK and France. The outcomes and research findings enabled the development of a managerial model highlighting the implementation of safety systems throughout the project life cycle. Critical analysis of professional interviews enabled the author to develop an in-depth qualitative review of current practices. This was significant in establishing the managerial model. Through the post analysis of relevant cases of fires originating during construction activities, a comparison is made between recognised good and bad practice, and a Fire Safety Management Model (FSMM) is developed to meet the requirements for fire prevention. This Model addresses the requirements of practitioners, their needs and their concerns regarding the possible effect of a fire during construction activities. The FSMM has been validated and tested by two Expert Panels (one in France and the other in the UK). These panels were formed by representatives of the construction industry and experts in the field of fire safety. A guideline for review and analysis were proposed and these formed the basis of the validation exercise for each member of the Expert Panel.

The Fire Safety Management Model considers a global approach towards fire prevention on construction sites and for a given organisation. The set of requirements highlighted in the Model is generic and will be refined and adapted by the organisation using it. However the framework proposed in this research must be considered in full, from the conception of the project, its construction and finally throughout subsequent stages of the life cycle including maintenance and refurbishment. It was an iterative Model, flexible and adaptable to change.

1 INTRODUCTION:

This research emerges from a need to consider the economics impact of fires on construction sites, a problem for too long ignored by members of the construction industry. In the UK, the total cost of premium reach £100m per year, and it is estimate that 60-70% of this amount is claimed every year. Within the last ten years, major fires with excessive losses (above £100m) forced insurers, clients and contractors to investigate the problem and evaluate this risk of fire.

Marchant (1976) was one of the first researchers to investigate the problem in the UK in the 1970s. A major ICE Conference in 1992 gave rise to a series of informative papers (Abbott, Kidd, Smith, Toone, Rimmer, Barber, Evans) on the fires on construction sites but didn't provide outstanding pieces of work to eradicate the problem. In 2001 it is still impossible to accurately assess the real quantities of fires on construction sites and their impact. The work of Puybaraud & Barham (1997a, 1997b, 1999) and Hinks & Puybaraud (1999) were leading in identifying the real threats of fires during construction activities and pointing out the devastating impact on the business as a whole. The increasing pressure of insurers and reinsurers to raise awareness of the problem and their leading industrial research in the field (Munich. Re, 1987, 1998; Swiss Re, 1993, 1998; Ebner, 1994) forced the construction industry to change their approach and implement a proactive fire safety process for sites. As a result, over the last decade, we witnessed a cultural change in health and safety on construction sites encompassed by the implementation of fire safety management approach to support the prevention of fires during construction activities on sites or in occupied facilities (refurbishment works, maintenance operations).

A construction site presents very specific characteristics and the typical site environment (including waste, construction activities, storage areas and materials stores) could contribute to a rapid development and spread of fire, major damages and often an uncontrolled situation. The unusual engineering aspects in such a fire scenario is important to consider to built a good understanding of the mechanism of development on site. A quantitative and engineering approach to this problem was difficult as access to a reliable set of data on fires, their causes and consequences for a large sample was impossible. The author orientated her research around a qualitative research based on the assessment of construction site fire safety failures post analysis and identified where the managerial system failed and the reason why.

The overall approach is based on the concept that the JCOP did not provide a satisfactory level of control over the construction works, and that **a managerial framework needed to be developed in parallel to support a free fire environment** on site and address the fire safety management during the complete life cycle of the project: conception, execution and exploitation. The **implementation of a fire safety management system needed to be encompass by a cultural change** in organisation to support the full and successful integration of a total fire safety concept.

The methodology followed to complete this research comprises four different stages (Chapter 5 and 6). The initial formulation of basic ideas through the development of the research proposal, the specification of research design after the literature review, followed by the fieldwork (site investigations), then the data processing and analysis and finally the preparation of the final research report.

Following an extensive review of the current literature available on the research subject (Chapter 2 to 4), the author identified some weaknesses and problems arising from the analysis of specialist documents. Amongst the main areas of problems, the availability and access of reliable statistics on the number, cause and consequences of fires during the construction was first identified. Furthermore, the lack of economical data on the subject, a lack of understanding by the parties (contractors/clients...), poor prevention measures on site, no detailed guidance offered to contractors on the problem of fire on sites, a pressure from insurers to reduce the number of fires incident during construction works and a reactive approach towards the problem by the government, professional bodies (LPC, FPA, Home Office...) and parties (contractors/ clients) were later assessed as major weaknesses within the research process.

In order not to keep the research solely orientated on UK data, the author decided to keep a broader approach and analysis practices in other European countries. A review of legislative and regulatory provisions in the six major European countries (France, Spain, Italy, Germany, Belgium, and Netherlands) was developed. The objectives of this review was to identify best practice models overseas and how they could be transferred or implemented in the UK in view of a future harmonisation of the regulation within the EU. Following the possible formulation of a European approach, a parallel will be draw with the North American approaches (US/Canada). The author identified similarities between the way the Canada and US developed their legislative systems and the forthcoming development of European legislation/regulation for fires on construction sites.

The pilot study revealed a need to emphasis on certain questions and to develop ideas and research hypotheses rather than to gather facts and statistics. In this case the interview becomes exploratory and an in-depth interview. This later helps in the formulation of the research problem, in the articulation of the dimensions and hypotheses and in the details of instrument building.

The scope of the FSMM highlighted **the need to consider a global approach towards fire safety**, rather than a project specific approach. In fact, considerations for the complete project cycle and its relationship to the organisational and managerial strategy were essential to built up an appropriate concept and implement the procedure. As such considerations for the integration of the Recovery and Continuity Systems were essential to appropriately manage the risks of fire during construction works.

The uniqueness of this research demonstrated the dearth of research in fire safety on construction sites. Limited publications could be identified in this area and forced the author to wider the scope of the research to other industries. The robustness of the data collected through the qualitative research and analysis demonstrated the validity of the research concept and how a qualitative approach could solve managerial problems and contribute to build the managerial approach.

1.1 Overview Chapter by chapter.

This thesis is divided in ten chapters from an introduction (present chapter 1) to the conclusions and formulation of recommendations (chapter 10). The introduction defines the relation of the thesis to other work in the same field and refers appropriately to any findings, propositions and new discoveries contained in this thesis. The first three chapters after the introduction present the results of the literature review and the analysis of major publications in the field of fire safety on construction sites and related papers.

In chapter 2 the author analyses the legislative fire safety framework in the UK and France as well as in a selected number of Member States of the EU. The aim is to identify any weaknesses or strengths within the Member State Fire Safety Frameworks. Such investigations raised a number of issues that were developed in forthcoming chapters.

Chapter 3 aims to provide an overview of the characteristics of a construction site, its definition and a detail survey using an engineering approach. In the second part of this chapter, an attempt is made to quantify the fires on construction sites and their losses. A review and discussion of major literature published on the subject was presented. Finally the author looks at current practices and the construction companies response to a fire safety situation. This chapter indicates a dearth of research in the evaluation of fire safety on construction sites. Additional avenues of investigations were presenting themselves. These include a review of the process of organisational change and its management for effective fire safety on site incorporating factors such as culture, communication, and adopting new management philosophies. The clear need for a study of fire safety during the construction process is identified in this chapter. The chapter concludes by planning a thorough investigation of the problem in depth, through a series of field-based.

Chapter 4 examines the characteristics of risk in construction site fires and how to develop a sound project safety case to control and manage the risk of fire during construction activities. The risk of fire is spread throughout the complete life cycle of the facility from its conception and construction through its life and occupation and maintenance, and finally through its demolition. The emphasis, in this chapter, is on the importance of the early consideration of the possibility of a fire during the construction phase. The fire safety cases demonstrates:

i. the importance of having an operational Emergency Plan to protect employees
ii. the general public; the potential value of Training of and Awareness in (primarily) employees and the workforce, (and also the general public/customers for their own safety);
iii. the potential usefulness of a Fire Safety Action Plan (FSP) which develops and embraces both by the Client/Owner and the Contracting Company;
iv. The value of advance liaison with the Fire Services in the unfortunate event of a fire occurring; and of particular relevance to the Facilities Management context of the

indirect business process –the interface between the business continuity and the temporary site operations- hence the need for Business Continuity Planning (BCP) to ensure minimum interruption to the normal business operations.

The research methodology chapters are split in two. Chapters 5 details the research concept and set the ground for developing empirical research and site investigations to support the development of a managerial model. Chapter 6 focuses on a critical analysis of the research methodologies and the validity of a qualitative method against a quantitative approach. A series of PhD schematic structures is prepared and spread throughout the thesis. They contribute to link the research findings to the development of the fire safety management model. The objective of chapter 6 is to explore and compare and contrast various research methodologies suitable for this project, i.e. quantitative and qualitative. A literature survey of current and past research in the field of quantitative and qualitative research identifies a need to consider both methodologies at different stage of the research.

The chapter 7 investigates current practices and attempts to present a real picture of the industry and the state of art in fire safety on construction sites. The qualitative analysis and design of the FSMM contributes to identify significant findings and based on this primary but not definitive analysis, to generate recommendations and conclusions for this research.

The chapter 8 analyses the developing process of a managerial model and reviewed the strengths and weaknesses of existing safety models and systems. The second part of this chapter introduces the concept of the fire safety management model developed by the author and based on the research findings. Three different model are presented (Model A, B and C) and each version offered for review to two Expert Panel in France and the UK. The results of the Expert review are presented and discussed in the following chapter.

The last two chapters 9 & 10 propose a discussion of the results and the formulation of a conclusion with major recommendations. The discussion's chapter intends to summarise and discuss the research findings and explored future development works to enhance the use of the proposed fire safety management model. The author explores the depth of knowledge covered in this PhD and how the project contributed to knowledge. The views of the Expert Committees is related on the steps forward and the applicability of the FSMM as a component in executing a broader client and contractor-oriented push towards better fire safety on site and managerial attitudes. Also discussed are a retrospective vision of the research and the interpretation of the main findings. The final chapter concludes the thesis and provides recommendations for future works.

2 Fire Safety Legislative Frameworks

2.1 Introduction

The risk of fire increases during construction or refurbishment of buildings because large quantities of combustibles are combined with numerous potential ignition sources. Of 618 construction fires in 1993 in the UK, 59% were probably deliberate. The FPA confirmed in 1999 that fires in construction industry escalate, and that 50% of serious fires occurred in buildings which were under conversion. Financial losses were considerable and, although insured, eventually must be met by society. Many of these fires could have been prevented - or the damage limited - by developing and implementing effective fire-safety plans and fire safety management systems which were strictly enforced from the outset of the procurement process. Fire management systems on construction projects reduced the risk of fire and its consequences.

The existing legislative documents addressed this problem through a set of regulations, most commonly known as the Building Regulations 1991, Part B: Fire Safety, first published in 1985 and updated in 2000. We can trace the first legislative incentive to William the Conqueror in Middle Ages. The legislative attempt appeared in the London Assize of 1189. However one specific disaster accelerated the process: The Great London fire in 1666 which destroyed 80% of the City. Early attempts at fire insurance were made in 1635 and 1638 by a mutual Friendly Society. Edinburgh was highly placed in the scene with an "Act regulating the Manner of Building within the Town of Edinburgh", passed in 1698 in Mary's reign. This Act required that in future no building should exceed five storeys. Many other events in England and Wales affected the evolution of the legislation throughout the eighteenth and nineteenth centuries. The first Fire Prevention acts was passed in the town of Liverpool in 1843 and 1844. Already in 1867, a Select Committee "inquire into the existing legislative provisions for the protection of life and property against fires in the UK, and as to the best means to be adopted for ascertaining the causes and preventing the frequency of fires." They recommended that a single Building Act for all towns in the UK should be placed. The UK legislation was reactive. Unfortunately, deaths needed to occur to get the system to advance and improve requirements. In 1897, the LCC reacted to the death of 124 people in the fire of a Paris Charity Bazaar, in 1881 450 people died in the Ring Theatre Vienna, 1903, 566 in the Iroquois Theatre in Chicago, 70 children were suffocated and crushed in the Glen Cinema Paisley in 1929, in Liverpool 10 people were trapped in a four storey department store in 1960; the Stardust Disco in Dublin in 1981, The Bradford City Football ground fire in 1985 killed 56 people; The King's Cross fire in 1987, the Dusseldorf Airport fire in 1996 which killed 16 people. And one of the last to date The Mont Blanc Tunnel which killed 39 people.

The first British Standard (BS) Code of Practice on "precautions against fire" was published in 1948 and concerned houses and flats of no more than two storeys.

In 2000, the UK legislation is still under the Fire Precautions Act 1971, but separate regulations apply in England & Wales, Scotland and in Northern Ireland:

- The Building Regulations, Edition 2000.
- The Building Standards (Scotland) Regulations
- The Building Regulations (Northern Ireland)

Recently, fire safety regulation was reinforced by the publication of the Fire Precautions (Workplace) Regulation 1997, amended in 1999; the draft BSI (1997) Fire Safety Engineering in Buildings: Part1. Guide to the application of fire safety engineering principles, the Loss Prevention Council Code of Practices which may be applicable to satisfy higher and different/additional standard of construction.

Also European Directives are now being implemented by the UK government such as:

- The Framework Directive, Council Directive 89/391/EEC, on the introduction of measures to encourage improvements in the safety and health of workers at work, coming into force 31st December 1992;

- The Workplace Directive, Council Directive 89/654/EEC, concerning the minimum safety and health requirements for the workplace, with a deadline for implementation of this legislation in the Members State of 31st March 1995.
- The 92/57/EEC directive concerns the Temporary and Mobile construction sites and reinforced the implementation of minimum safety and health requirements.

Over the centuries, thousands of fires in buildings have been chronicled. These range from domestic fires to wholesale destruction of large and complex buildings such as the International Exhibition Centre at Brussels in 1910 and the Pavilion "Age of Discoveries" of the EXPO '92 in Seville. As technology became more and more complex, so the cost of building fires increased. What was of particular concern was the substantial rise in the cost implications of fires during the construction process, which were occurring with increasing regularity both on new-build sites and during refurbishment. **The approach to fire safety in construction was unquestionably in need of review.** Such a review was precipitated, primarily, as a result of the recent opening of the internal borders of Europe and, secondly, as a result of the enormous due to fires in almost completed buildings. Changes in work methods and attitudes in the construction process have been identified as a major factor and both fire precautions and management practices, urgently, to be re-assessed.

The objective of this chapter was to analyse the legislative fire safety framework (Figure 3.1) in a selected number of Member States of the EU. The aim was to identify any weaknesses or strengths within the Member State Fire Safety Frameworks. It was anticipated that such investigations would raise a number of issues that would be developed in forthcoming chapters.

2.2 Fire Safety Legislation and Regulation

In the UK, new regulations (CDM 1994) required the preparation and implementation of a Health & Safety Plan in every building site. However, there was a need to address fire safety as a fundamental requirement of such a plan. Our preliminary researches (Rullier, 1992) suggested that, certainly in the UK, France and Spain, there has been little appreciation within the EC before 1997 to address the problem of fire safety as fundamental legislated and it suggested that a similar situation could be encountered outside Europe and, possibly, world-wide. Pressures from the European Parliament (DG III: Industry) in 1994 suggested that the problem of fire should have been investigate where it was currently costing countries of the European Union approximately 1% of GDP (Geneva Association, 1997). For most European Countries, the cost of direct fire losses did not go above 0.40% of GDP (for Belgium) (Geneva Association, 1997). The UK is below this figure and therefore European Directives have not been identified as immediate and urgent measures for the European Union. However, the European Parliament urged the Council of Ministers to make a public announcement **stating their concern over the level of fire costs in the EU**, but directly towards the problem of fire on construction site. The Parliament also called the European Commission to establish a Working Party of fire experts whose terms of reference would be to recommend ways of tackling the fire problem. In 1996 one of the twenty proposed Motions put forward by a MEP to the Environment Committee stressed that fire resolution should "be recognised to be an issue of great importance", but it was first refused and the problem remains not addressed.

For the purpose of this research, seven European countries were selected: France, United Kingdom, Spain, Belgium, Germany, Italy and Netherlands. The analysis will cover three issues: Management, Implementation and Control within the European Fire Safety Framework, in comparison with the contemporary UK Fire Safety Framework. The approach towards Fire Safety in various EU Member State was thereafter compared with the Canada. Canada had a decentralised system which may offer further advantages upon comparison. It was anticipated that by the end of this investigation, the researcher would be able to address the problem and identify weakness and strength within the European Framework, and ultimately suggested areas of improvement and further developments.

2.3 The UK legislative framework: detailed review of legislative requirements in the UK.

The problem of fire safety awareness was often exacerbated by the plethora of different regulations. For example, in the UK, a document, (P5) Standard Fire Precautions to be Taken by Contractors Engaged on Building and Engineering Works and Maintenance for the Department of the Environment, had been published in 1972 and a similar document to the Joint Code of Practice (on the Protection from Fire of Construction Sites and Buildings undergoing Removals) was published in 1980 by the Home Office. These last two documents contain many similarities and the Joint Code of Practice is mainly an improved version of P5. But, at the time of its publication, the later document was not viewed as a necessity, and its importance was not recognised until 1992.

The UK fire legislation, as mentioned before, has to date been largely reactive. This means that almost every piece of legislature was the consequence of a serious fire incident. Only recently have new regulations been proposed or introduced pro-actively; but even these have been, in some circumstances, a result of European Commission Directive.

Arrangements for the prevention of fires on construction sites should be integrated in the Passive Fire Protection system in the primary stage of construction and, at a later construction stage, there should be Active Fire Protection (refer to Figure 2.1). These points have been discussed later in this thesis. The regulations were implemented through a set of Standards, Approved Documents and Statutory instruments (refer to Figure 2.2). Concern was that in the UK fires on construction sites were only considered in one non-mandatory document, the Joint Code of Practice. The Building Regulations and their associated Approved Documents, and the Standards were applied during design and related only to the Fire Safety of the finished product. Nothing in these documents addressed the problem of fire prevention on construction sites.

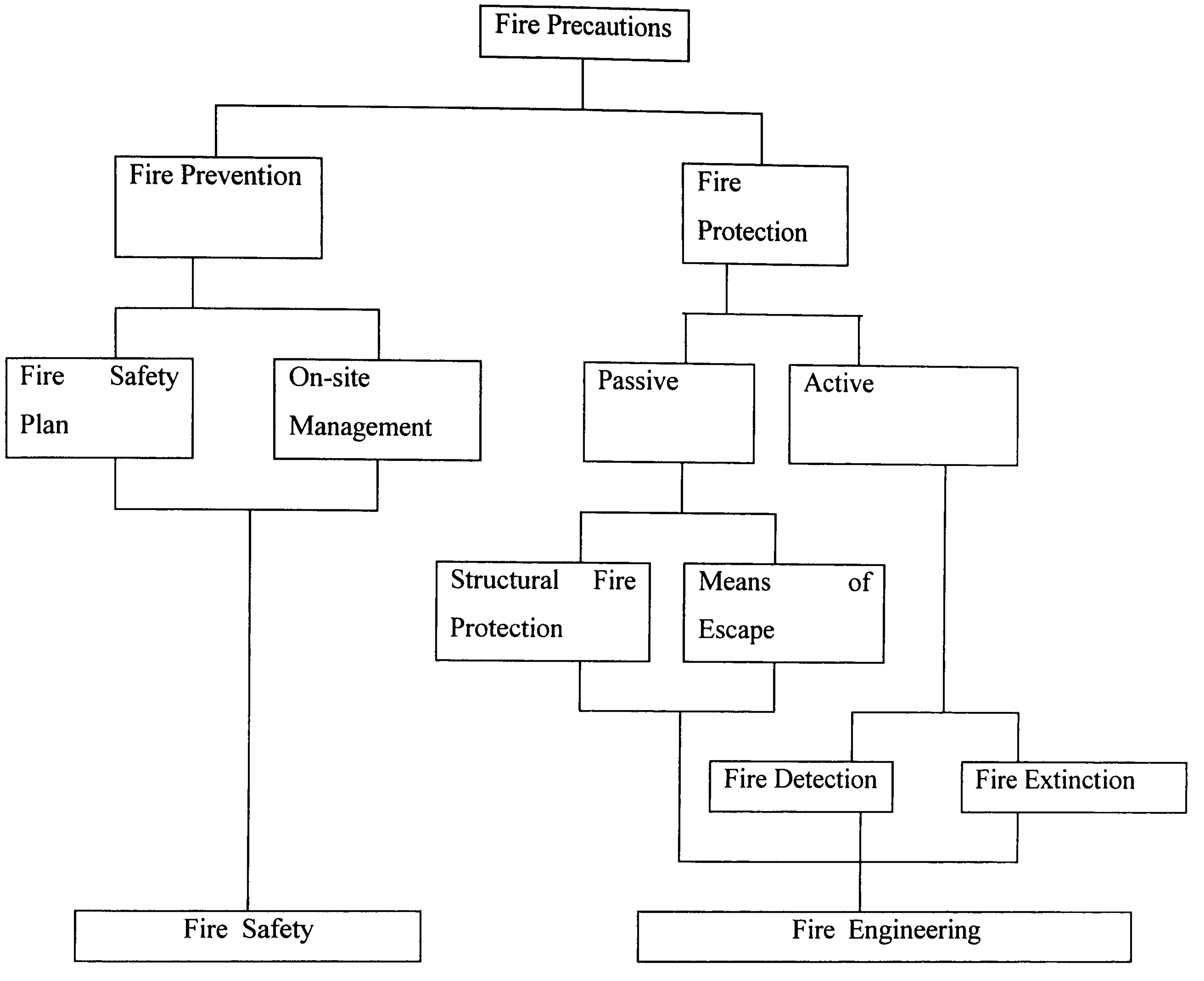

Figure 2.1: General Fire Safety Framework

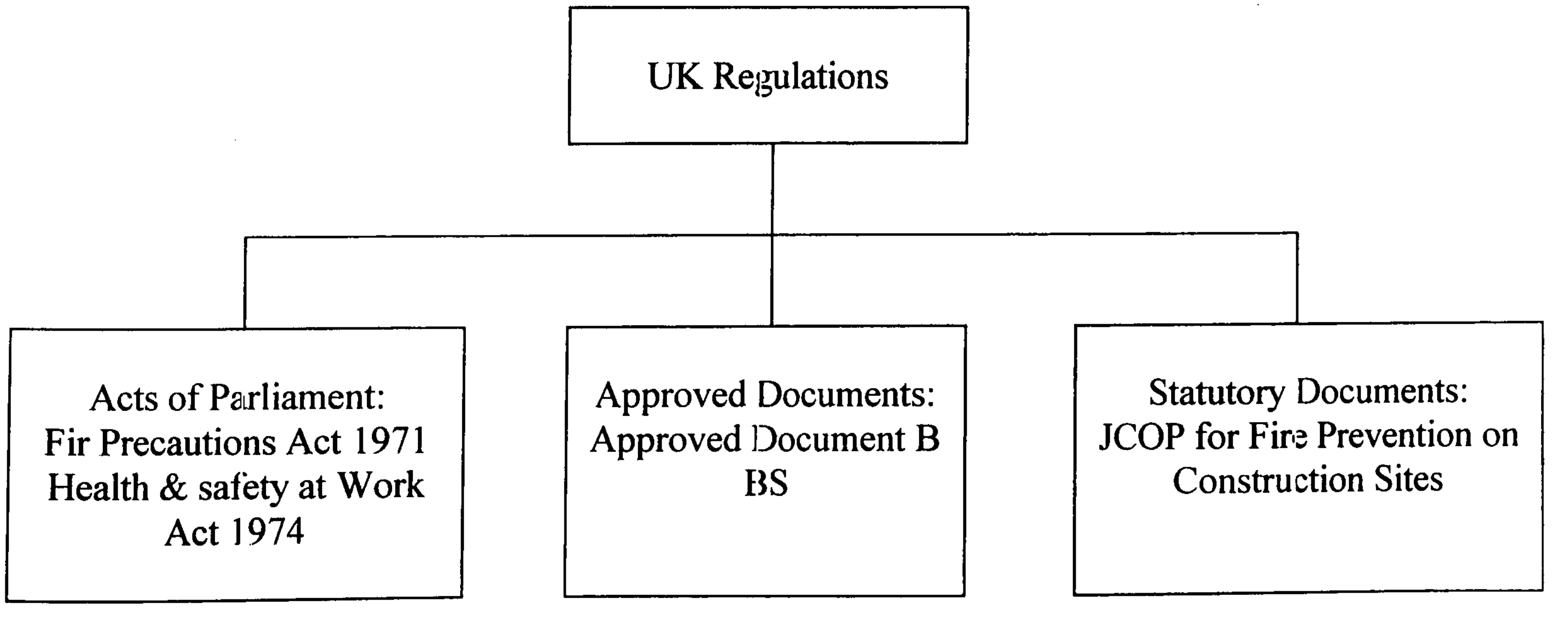

Figure 2.2: The UK Regulations

The problem of fire safety awareness was often exacerbated by a plethora of different regulations in many States. For example, in the UK, the legislative framework was contained within some forty-one general Acts of Parliament, five health and safety Acts, twenty-nine local Acts and a collection of some thirty-two sets of Regulations. To these must be added a further twenty-one general acts and over fifty sets of Regulations, Statutory Instruments and Designation Orders, all of which covered or impinged upon fire safety. This set of legislation was desperately in need of simplification (without, in so doing, causing an erosion of standards); it needed to place duties and responsibility on the right shoulders; it needed to inculcate, and to build on, good working practices and, above all, it should not have been a burden on either the enforcing authorities or on those expected to comply.

Perhaps, in this review, minimum mandatory arrangements for the prevention of fires on construction sites should be introduced. However, they would not really be any substitute for good management practice, e.g. integrating the Passive Fire Protection system into the primary stage of construction and, at a later construction stage, ensuring Active Fire Protection systems were available. These points were discussed later in this thesis.

2.3.1 Fire Safety Regulation for construction sites:

The division of responsibility was beginning to be understood by the British government and, following a series of fire incidents, was stressed by the recent publication of a new set of regulations relating to Health & Safety:

- The *Joint Code of Practice for Fire Prevention on Construction Sites* first published in 1992 is now at its fourth Edition in 2000.
- The consultative draft *British Standard Code of Practice for the Application of Fire Safety Engineering Principles to Fire Safety in Buildings* in 1997 (discussed in Section 3.2)
- *The Construction (Design & Management) Regulations* in April 1994

The Construction (Design & Management) Regulations (CDM) imposed requirements and restrictions only with respect to design and management aspects of construction work. They gave effect to *European Council Directive 92/57/EEC* on the implementation of minimum safety and health requirements at temporary or mobile construction sites. These regulations applied to, and are in relation to, construction work. Regulation 10 dealt with the start of the construction phase and states that every client shall ensure, so far as is reasonably practicable, that the construction phase of any project does not start unless a Health & Safety Plan complying with regulation 15(4) has been prepared in respect of this project. Regulation 15 described the requirements relating to the Health & Safety Plan and Regulation 16 the requirements on, and powers of, principal contractors. However, although seen as innovative and stringent, the CDM Regulations make no specific reference to Fire Precautions or Fire Safety.

Document related to health and safety in construction and especially fire safety were fairly recent. The first published document on fire prevention on construction site was the P5: Standard Fire Precautions P5 by Department of Environment Property Services Agency, Directorate of Building Development. The P5 Guide recommends a set of standard fire precautions to be taken by the contractor engaged in building and engineering works and maintenance for the Department of the Environment Property Services Agency. In 1992, major bodies representing the construction industry for fire safety published a Code of Practice, the Joint Code of Practice for Fire Prevention on Construction Sites (BEC/LPC, 1992).

2.3.2 The Legislative situation in the UK: Discussion

For the past ten years, the UK went through a long phase of review of its Fire Safety Framework. The Interdepartmental Review Team carried out the first Fire Legislation Review, "Fire Safety Legislation and Enforcement" (Home Office, 1997) published in June 1994. The legislation the Review Team was asked to examine has two main strands: building control legislation and fire precautions legislation. The main theme of their findings was that the current system of fire legislation would benefit from rationalisation and simplification. The Review Team also issued a number of recommendations and main changes.

Nevertheless, Fire Safety measures taken in the UK were limited by the use of many modern techniques in engineering and architecture that have been widely developed by researchers for the past ten years. To overcome the inconstancies caused by the current approach to fire engineering, the British Standard Institute (BSI) prepared a draft document in 1991 "BS Code of Practice for the Application of Fire Safety Principles to Fire Safety in Buildings" (BSI, 1996). This draft Code of Practice intends to provide standard way for building designers to depart from traditional fire safety concepts, providing they can demonstrate that the building will still achieve an acceptable level of fire safety. This approach has been also developed in other European Member States and it will be described later in this paper. A Working Party reviewed the draft Code of Practice and decided to keep it as a draft version, following a number of modifications.

In 1994, there was much speculation about the weakening of fire safety regulation under the deregulation initiative. Two years later, Mr. John Heppell on the 11 December 1996 suggested to the House of Commons that a Bill that would consolidate all fire safety legislation and would replace in part or in total more than 54 pieces of legislation on the statute book and put fire legislation into one single Bill (House of Commons Hansard, 1996) The Bill as proposed would be flexible enough to incorporate all future European legislation.

One year later in November 1997, following a review, the Government published a consultation document entitled *Fire Safety Legislation for the Future* (Home Office, 1997). The consultation document sets out proposals for a new fire safety regime based on the main principles included in the Fire Safety Bill which in turn applied many recommendations of the June 1994 Interdepartmental Review of Fire Safety Legislation and Enforcement (Crichley et al., 1994). The proposed new regime should enable rationalisation and consolidation of existing legislation.

This new legislation simplifies the existing law, repealing and consolidating existing legislation where appropriate and takes full account of European Community obligations. The main trends of this new fire safety approach is to give more power at a local level, i.e. to decentralised the control of fire safety in buildings through the increasing involvement of Fire Authorities to ensure satisfactory arrangements for inspections. This new regime enforces the duty of Fire Authorities at a local level and community level. Another important feature of the new regulations is that they are goal-based rather than prescriptive. This fire safety engineering oriented approach is clearly considered under §15 "...if employers wish to achieve compliance by other means, it is open to them to do so." (Home Office, 1997). Five main streams have been identified throughout the new proposal:

i. Duties on the "responsible person", i.e. owner or occupier.
ii. Obligation to attend Fire Precautions.
iii. Requirement to maintain adequate Fire Precautions, i.e. to review and to maintain in satisfactory order.
iv. Freedom to chose the adequate fire safety solutions.
v. All categories of premises would be covered unless exempted, i.e. single dwellings.

Responsibility for fire safety in the UK was shared among a wide amalgam of interests, i.e. Government, Local Authorities and independent and professional bodies and their trade associations. Within the past 25 years with the implementation of the Fire Precautions Act 1971, UK went through a series of enforcement of the fire safety Framework, and since the beginning of the 1990s three different reviews. However, it should be noted that, even now, fire safety is not explicit in the third of this document, the only one which has official regulatory status! Much progress has been done to integrate a fire safety approach within the UK framework. The edition of the JCOP in 1992, amended 4 times with the latest publication in 2000 (4^{th} Edition) and its recognition in the JCT Forms of Contract published in 1998 made it a statutory requirement and non compliance under JCT a breach of contract. It took 10 years to implement the concept of fire safety on construction site and make it a statutory requirement.

UK has a centralised system. Figure 3.3: UK Fire Safety Framework provides an overview of the Framework. The Government has been writing all Acts, Building Regulations and Codes of Practice and Local Authorities have no power to enforce the Law and Regulations. The Secretary of State has the authority, under section 8 of the Building Act 1984, to relax or entirely dispense with the requirements of a particular Regulation in specific cases. This authority has also been delegated to the local authorities. While this might seem to be very wide sweeping power, in practice it hardly occurs at all. The reason being that almost all Regulations was now couched in terms requiring work to be "adequate" or "to a satisfactory level".

Centralised System:

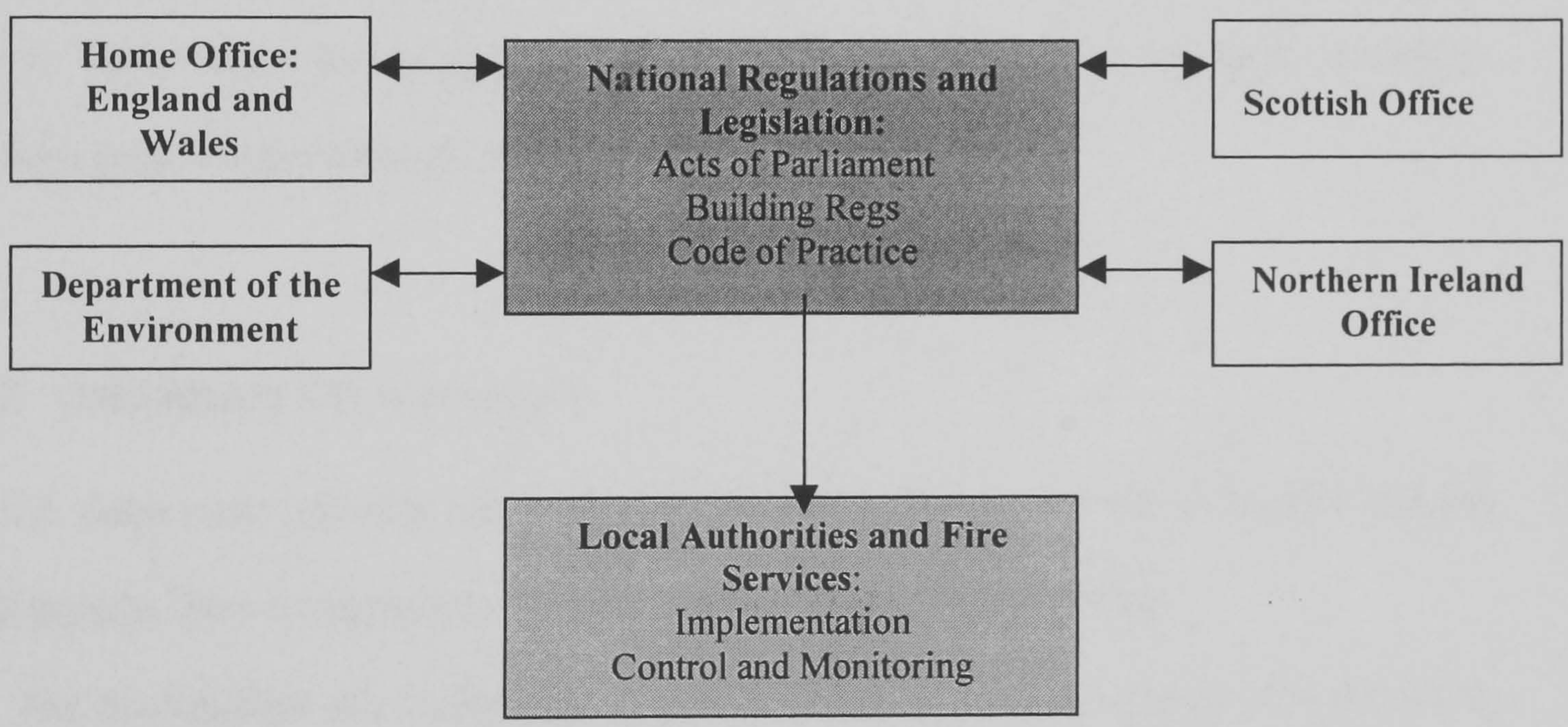

Figure 2.3: UK Fire Safety Framework

All those investigations have the same objective: reduce fire losses and improve fire safety in buildings. Table A in Appendix A gathered information published by the *Geneva Association World Fire Statistics Centre* (Geneva Association, 1997) in their September 1997 bulletin 13 and two other sources of information for the Canada (Institut de Recherche en Construction, 1998; Human Resources Development Canada, 1998). It provided international fire costs comparisons and especially a comparison between EU countries and the Canada and USA. The cost of Direct Fire Losses for the UK was estimated to be 0.16% of GDP, which is below the EU average (0.231% of GDP). Compare with other EU countries, the UK is in a very good position and over the last reduced the cost of Direct Fire Losses from £1,300m in 1991 to £950m in 1994. This clear reduction could have been explained by the Government initiative to improve the UK Fire Safety Framework and the series of reviews to improve the Fire Legislation. A lack of regulation for fire safety in dwellings and at home, and it was not a problem which had been fully addressed by the Government in its last investigation as single dwellings are again excluded from the categories of buildings. In 1999 the Home Office was asked to review the current fire safety strategy (Gately, 2000). The Approved Document B (Fire Safety) was reviewed to better address the needs for an improved level of safety in dwellings. The document was published in January 2000 and took effect from 1 July 2000. Gately (2000) comments on a fundamental need for future legislation to adopt an all-embracing approach and the need for society to develop a greater understanding of fire.

2.3.3 Conclusion UK framework:

The UK framework provided many strengths and compared to the rest of the EU and the world benefits from a long history. The strengths of the system lied within:

i. The development of a separate set of regulation for fire safety on construction sites: The Joint Code of Practice for Fire Prevention on Construction Sites (1992 and 2000).
ii. The JCOP was a requirement of Insurers and Clients and a specific clause of the Insurance contract. Compliance with the JCOP was compulsory and the insurers were engaged to inspect sites to check compliance and advice contractors and clients.
iii. Under the terms of the contract (JCT Forms of Contract 1998) the Fire Code (JCOP) was a requirement and non-compliance is a contractual breach.

iv. The health and safety regulation was developed separately and thanks to the publications of the CDM Regulations in 1994, more emphasis is put on safety at a design stage.

v. Some weaknesses must also be highlighted:

vi. No requirement for systematic risk assessment.

vii. Compliance with JCOP was not a requirement under other forms of contract to JCT: New Engineering Contract/ICE, FIDIC, Government Contracts…

viii. A strong policy of risk inspection was required to support the implementation of fire safety principles on site.

ix. Lack of recording of fire incidents didn't provide any evidence to support a possible improvement and reduction of fires on construction sites.

2.4 The Legislative situation in France:

Although the French system is not Federal and is centrally controlled by National Regulation and Codes there was scope for local variation through the powers of Mayors in towns and cities (Council) and the Prefect of a *Département* (Region).

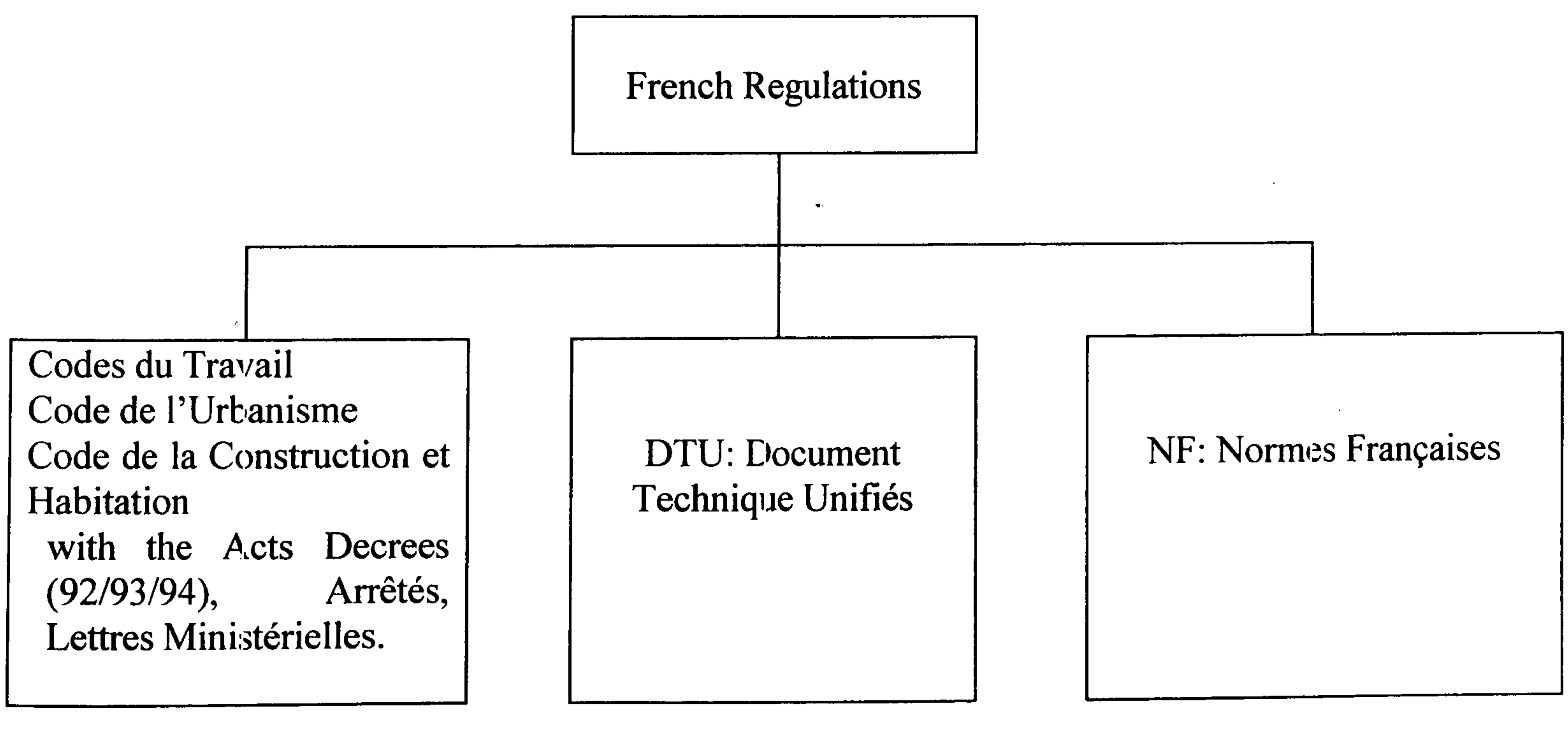

Figure 2.4: The French Regulations

The World Fire Statistics Centre (Geneva Association, 1997) reported that the cost of direct fire losses in France is estimated at 0.25% of GDP (1992-94 statistics). The APSAD (1997) estimated that in 1996, 145 fires cost more than 5mFF and nearly for 12% of them fire losses were estimated to be superior to 50mFF. The government and its different ministers have been regulating fire safety in France. The French system was not Federal and was centrally controlled by national regulations and codes that came into force in 1978. Any contractor owner or developer was obliged, both during the construction and the use of building to respect the measures of prevention and maintenance of the property to ensure the safety of the persons. These measures are described under a set of Codes:

i. Code de l'Urbanisme (Code of Urbanism)
ii. Code de la Construction et de l'Habitation (Construction and Building Code): this was the main code which provided requirements for Fire Safety for four different types of buildings: Dwellings (*Habitation*), Public Buildings (*Etablissement Recevant Public*), High Rise Construction (*Immeuble de Grande Hauteur*), and any Industrial and listed Buildings (*Bâtiment Industriel et Installations Classées*).
iii. *Code du Travail* (Code of Work) which dealt with the requirements for places of work and gave details about Fire Safety Measures in the workplace.
iv. Further technical requirements are listed under a set of regulations called *Documents Techniques Unifiés (DTU)* and a number of Norms or Standards called *Normes Françaises (NF).*

The fire protection regulations were implemented through the *Arrêté* from the 31.01.1986 (OJ 1540 and 1603) and detailed in the *Code de l'Urbanisme* and the *Code de la Construction et de l'Habitation.* The Fire Safety Philosophy in France could be summarised in three points:

i. Prevention of Fires,
ii. Emergency and Evacuation Plan,
iii. Fire Fighting Plan

Health and safety regulations have been implemented through the Code du Travail which registered all acts and regulations in the workplace in France. One Act, two Decrees (*Décret*) and one *Arrêté* detailed the regulatory requirements applying to construction sites and safety:

- The 1993 Act of 31 December 1993, amending the provisions of the Code du Travail applicable[1] to building and civil engineering operations, to protect the health and safety of workers. The European Directive 92/57/CEE of June 1992 on the Temporary and Mobile Construction Sites Directive was transposed in this Act. The 1993 Act was divided in 4 sections: general principles, the prevention and coordination of construction operations (nomination and role of the planning supervisor), integration of safety in the design, sub-contractors works with a specific a reference to penalties clauses.
- The Decree of 8 January 1965 (*Décret 1965*) which applied to organisations where[2] employees carrying out, even in exceptional circumstances, some foundation works, construction, demolition, maintenance, refurbishment / renovation, cleaning, any other construction activities applying to different types of facilities and their use, as described in the Decree 1965.
- The Decree of 20 February 1992 (Decret 1992): The Code du Travail provided specific regulatory requirements[3] for construction works carried out in any facilities in use by an external organisation (contractor/sub-contractor). The Section 1 (General Principles), Article 237-1 required that when the employees of one or several organisations, named external organisations, executed a construction activity or participated to a construction

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[1] Afin d'assurer la sécurité et de protéger la santé de toutes les personnes qui interviennent sur un chantier de bâtiment ou de génie civil, le maître d'ouvrage, le maître d'oeuvre et le coordonateur mentioné à l'article L.235-4 doivent, tant au cours de la phase de conception, d'étude et d'élaboration du projet que pendant la réalisation de l'ouvrage, mettre en oeuvre les principes généraux de prévention énoncés dans l'article L.230-2 (Loi n. 93-1418 du 31 Décembre 1993).

[2] Le décret de 1965 s'applique aux entreprises "dont le personneleffectue, même a titre occasionel, des travaux de terrassement, de construction, d'installation, de démolition, d'entretien, de réfection, de nettoyage, toutes opérations annexes et tous autres travaux prévus par le présent décret, portant sur des immeubles par nature ou par destination" (D. 8 Janv. 1965, art 1).

[3] Lorsque une ou des entreprises, dites entreprises extéreiures, font intervenir leur personnel aux fins d'executer une opération ou de participer à l'execution d;une opération, quelle que soit sa nature, industrielle ou non, dans un établissement d'une entreprise, dite utilisatrice, ou dans ses dépendances ou chantiers, le chef d'entreprise utilisatrice et le ou les chefs des entreprises extérieures sont tenus de se conformer aux dispositions du présent chapitre.

activities, whatever their definitions, industrial or not, in the facilities of another organisation, named user organisation, or within any of their facilities or sites, the owner of the user organisation and the owner(s) of the external organisations must comply with the requirements set out in the Decree 1992.

- The Arrêté of 19 March 1993 fixed, in compliance with the article R.237-8 of the Code du Travail, a list of works at risk for which a plan of prevention was required. The list details 21 construction and work activities classified as "dangerous" and with a risk: electrical works, welding and cutting, demolition works, maintenance activities on specific equipment...

The coordination on construction sites is regulated by two Decrees:

- The 1992 Decree, establishing the responsibilities of the external organisation carrying out work activities in a facility in use and/or owned by the facility user.
- The 1994 Decree, more specific and limited to construction and civil engineering works.

Both decrees couldn't be applied for the same construction activity. However several distinct activities could be carried out on site or in a facility and each under the scope of one decree, either 1992 Decree or 1994 Decree, depending on the nature of the activity.

2.4.1 The Legislative situation in the France: Discussion

Fire Safety Regulation and legal requirements are mainly centralised under the Government directive. Several Ministries are responsible for the implementation of the Fire Safety Regulation in different areas. The Government and Parliament develop Laws and the Ministries concerned elaborate settlements that were applied to the whole national territory. Powers are given to the Mayors and the Prefect (*Le Préfet*, one per *Département*). A Safety Commission was implemented under the direction of the Ministry of Interior and sub-divided in departmental commissions responsible for the control and the compliance of fire safety measures implemented into the building. Figure 2.5 described the French Framework.

The handover of the building was a detailed process involving the issue of the Certificate of Conformity (*Certificat de Conformité*). The French Fire Authority was involved in the design and construction of Buildings but the Fire Service Authorities were only involved in Committees especially dealing with the Construction of High Rise Buildings (IGH) and Public Buildings (ERP).

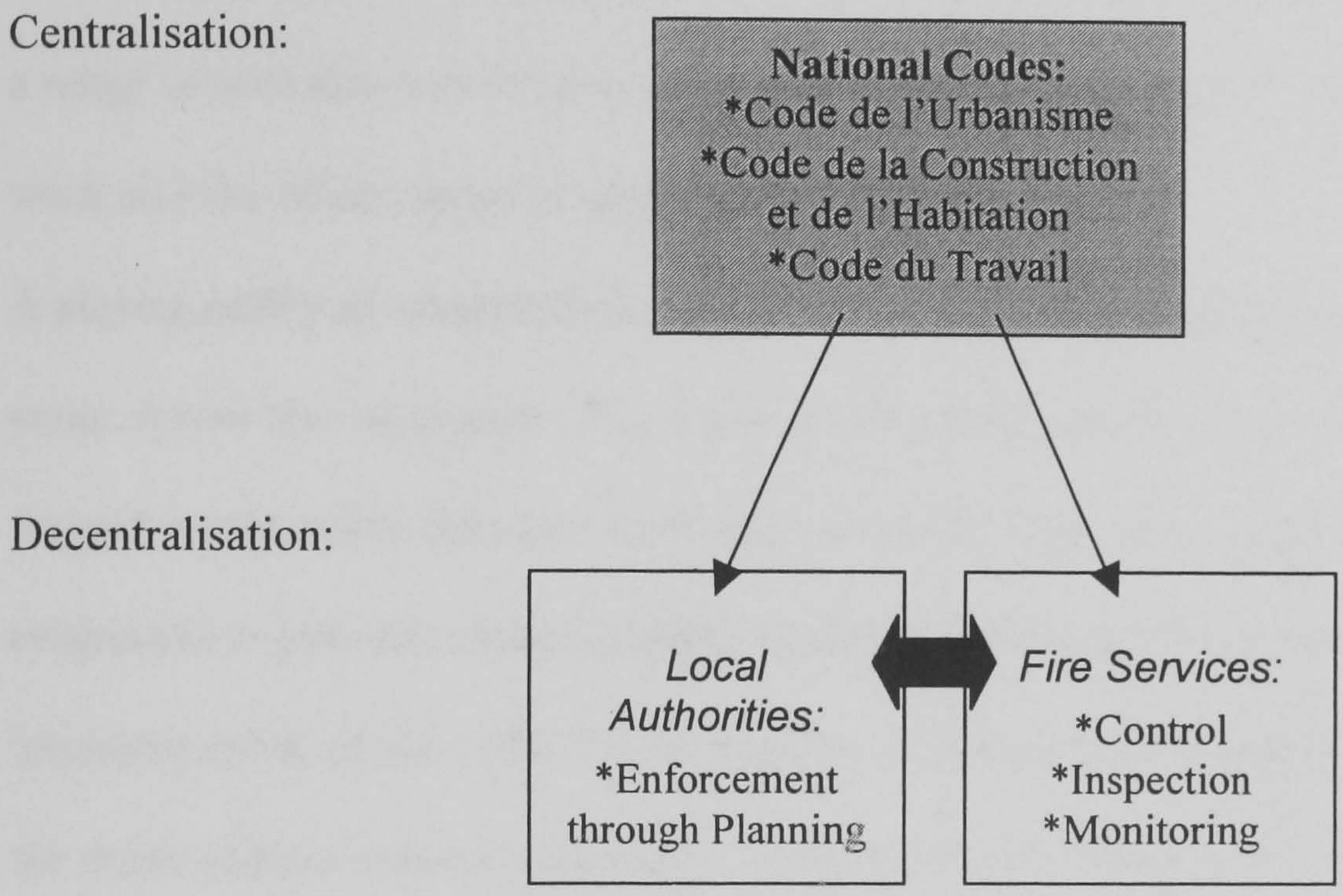


Figure 2.5: French Fire Safety Framework

The operation of a local fire safety committee implied more co-ordination between departments than in the UK where the building control officers did not have formal links with the fire service.

The French law and regulations applying to fire safety and health and safety in construction activities was much more detail than the UK system. The depth of requirements as detailed in the Code du Travail and regarding health and safety in the workplace, considered a site as a workplace.

The definition of a construction activity was broader in the Code du Travail than in the UK regulation, taking into account activities of construction and demolition, but also maintenance, cleaning, refurbishment and renovation works.

The coordination of risk prevention activities on building and civil engineering sites was translated through the 1993 Act of 31 December 1993 and the 1994 Decree. Inter alia the Act provides for the **integration of safety at the work design stage**, the organisation of site coordination and the application of health and safety legislation to self-employed workers. This law was comparable to the CDM Regulations in the UK and provided in depth requirements for health and safety in general. However, there were no specific requirements for fire safety, as it appeared to have been integrated under health and safety. **However fire was recognised as a risk** and the 1993 *Arrêté* listing dangerous activities taking into account a range of activities involving a naked flame, welding work and hot work, as well as electrical work and the maintenance of technical equipment.

A **strong policy of cooperation** between contractor and client or facility users and/or owners came across the regulation. *The Code du Travail* (Article L.235-10) explained than when several construction activities were carried out by several contractors, **all contractors must cooperate to prevent risks resulting from the overlapping of construction activities**. The implementation of the 1992 Decree required a permanent exchange of information: between the organisations owners (contractors / subcontractors / client), between the organisations and the external institutions controlling the construction work activities (work inspectors, health and safety executives bureaux, social security...) and between each organisation and their staff committees. A risk inspection carried out prior to start the construction works was mandatory for all organisations participating in the project. **This risk analysis aimed to assess common risks and define technical choices and preventative measures to implement on site**. A prevention plan is required when the construction activities cover more than 400h per year and when the operations are considered as dangerous works described in the 1993 *Arrêté*.

The **extensive requirements in the French regulations and laws for health and safety were much more developed than in the UK**. However, there is no regulation to enforce fire safety on construction sites. Pressure to apply fire safety principles at a design stage is clear but aimed to protect facilities once they are completed. The fire safety of workers on site is regulated in the *Code du Travail* under the general health and safety requirements. Fire is still considered as a dangerous activity and its prevention is addressed in the prevention plan.

2.4.2 Conclusion French framework:

In conclusion a list of specific issues are worth mentioning:

i. A clear definition of construction sites taking into account construction, demolition, maintenance, cleaning, refurbishment/renovation works.

ii. A strong health and safety law to protect workers on construction and civil engineering projects

iii. Need for specific fire safety regulation for the prevention of fires on construction sites, apart from the recognition of dangerous operations like welding and cutting, electrical operations.

iv. Maintain the promotion of cooperation between organisations participating to the construction process and its operations, through the development of a common risk assessment and prevention plan.

2.5 Comparison between European / Canadian and US Approaches:

By comparing the Canadian and US approach with the European approaches, it was interesting to note major difference in terms of the objectives of the Fire Safety Framework. The objective of the Canadian Fire Code was to improve public fire safety, and especially safety in the home (Fire Code will require smoke alarm in homes built before 1976. Newer homes had already required to have smoke alarm installed). Emphasis on prevention and public education was strong. In most European Member States, fire safety in home was a great concern but there remains no regulation to minimise the number of fires in home. In the UK the last fire safety proposal excluded single dwelling from the categories covered by the regulation. The last fire statistics review revealed an increase in the number of fires (2%) and an increase of 16% in fire death over the period 1993-94 (Home Office Statistics, 1995). Canada had a drop of 60% of fire fatalities within the past 25 years (Canada NewsWire, 1997c) and a decrease of 10.61% from 1993 to 1994 (Fire Prevention, 1998).

For more than 100 years, the NFPA has been developing and updating codes and standards concerning all areas of fire safety. Currently there are more than 300 NFPA fire codes and standards used throughout the world. NFPA 1, Fire Prevention Code addressed basic fire prevention requirements necessary to establish a reasonable level of fire safety and property protection from the hazards created by fire and explosion. **NFPA's code and standard-making process began in 1896** when a small group of concerned professionals met in Boston to address inconsistencies in the design and installation of sprinkler systems. The NFPA (2001) commented that "**one of the unique things about the code and standards making process is that it is truly an open, consensus-based process**." The legal procedure for adopting a code or standard differed from one jurisdiction to another. **The sense of decentralisation and adaptation of the regulation** was stronger in the US and allowed for a lot of flexibility. The NFPA argued that the adoption of the fire safety documents, along with increased public awareness of fire safety practices, has resulted in significant reductions in the loss of life and property damage due to the effects of fire. The NFPA Journal (1995) argued that between 1937 and 1956 a number of significant fires led to changes or development in NFPA codes and standards. Some of the elements and requirements covered in the UK JCOP are covered in law in the US. The OSHA (Occupational Safety and Health Administration) of the United States Department of Labor, in the Occupational Safety and Health Standards for the Construction Industry, argued for a earlier installation of fire protection systems during the construction process and demolition and alteration of facilities. NFPA standards on fire risk during the construction process existed since 1930s and a major emphasis on the risk of hot works in confined space (roof, ships, basement, parking...) has long been recognised as a major risk.

In respect of fire safety in the home, the UK Government on the 7 April 1998 accepted a separate report of the Community Fire Safety Task Force (Home Office, 1997). This report proposed a two-year strategy plan in order to reduce significantly the incidence of fire in the home. In 2000 the Home Office published an updated version of the Approved Document B (Fire Safety) (2000) and considers the fire safety of dwellings. The main idea of the new regime presented by the UK Government seemed to be orientated around the idea of decentralisation of the authority and decision making process related to Fire safety in buildings at a Local level rather than National. This should be achieved through a higher involvement of the Fire Authorities at the Community Level. It was also an attempt to put more pressure and responsibilities on the "responsible person" so far defined as the owner or occupier of the property concerned. This last point tends to join the CDM approach and philosophy.

The UK decentralisation movement was not unique in Europe. France, Spain and Germany decentralised decision-making and organise control at the Local level. Local Authorities may have the power to modify or enforce the fire safety regulation either through planning or direct enforcement, and organised its implementation and control through inspections.

Whilst the Canadian approach may not have been the optimal solution, Decentralisation within the Fire Safety Framework would certainly appear to have offered benefits for the European Member States Legislative Frameworks. Providing Autonomy to Local Authorities, Provinces / Regions would answer a number of issues raised in this chapter and would be more user oriented.

It was still too early to evaluate the impact of the Canadian new framework. But recommendations could be made at a Member State level to consider a more flexible approach to fire safety through a decentralisation process. By giving more power to the Regions and Local Authorities and organising feedback between the different level of Government (National / Regional / Local), the existing fire safety framework could have been improved: a better control framework, a strict inspection programme with an increasing involvement of the Fire Services. General regulations and standards could be agreed at a National level (Inputs), thereby creating a legislative framework and adoption scope by the regions and Local Authorities which would have the power to enforce the existing framework to adapt it to a particular property (Outputs). The following model is proposed: Figure 3.13: Proposed Fire Safety Framework.

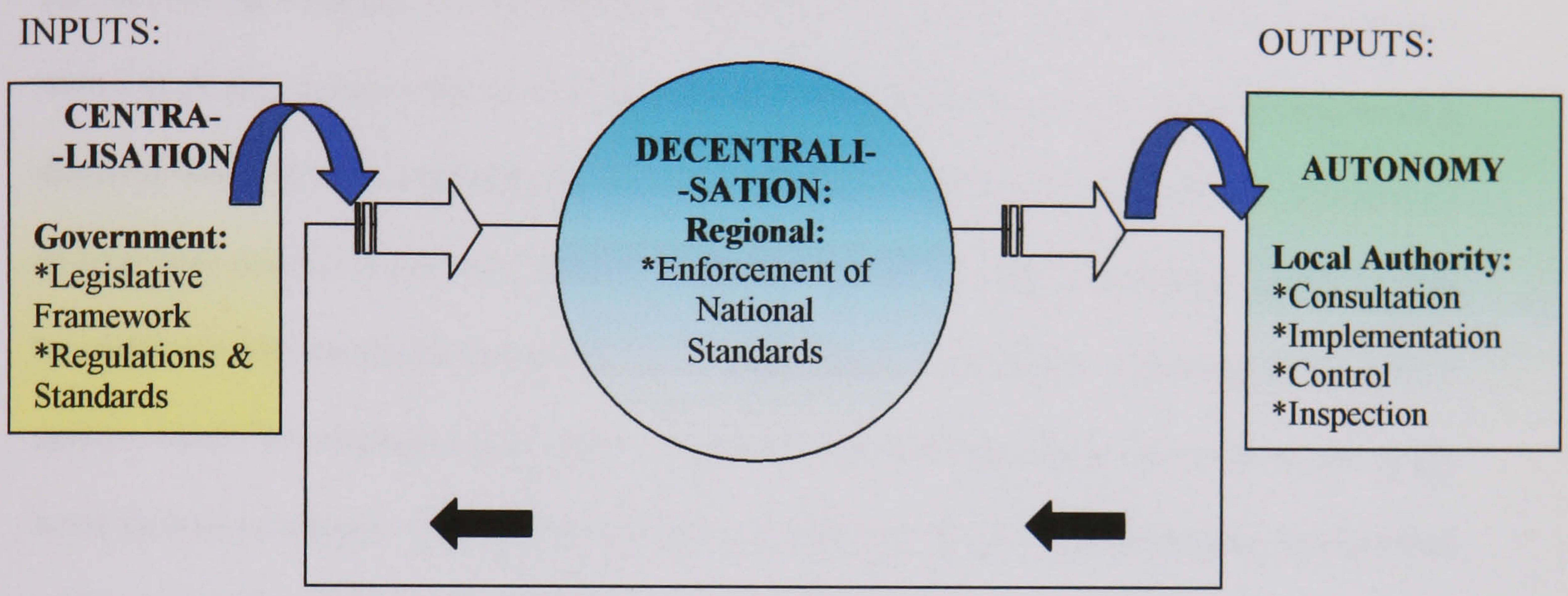


Figure 2.6: Proposed Fire Safety Framework

The Canadian experience indicated that by giving too much power to the Local Authorities, that is to permit the direct adoption of National Regulations, the system was not efficient. This approach was abandoned in Canada in 1975 and more support was given to facilitate the application of National Regulations at either a Regional or Local level of government.

One major weakness has been identified in the various European Fire Safety Legislative Framework: the **problem of Control and Feedback between the Government levels**. The new Canadian strategy clearly addresses this problem. The whole structure might need to be reviewed in the majority of Member States, but too often mistakes are repeated. Those mistakes could be avoided if a **clear control and feedback system** was to be systematically adopted and supported by regular reviews. It is evident that we have been learning from mistakes and therefore we shouldn't ignore them. The Proposed Fire Safety Framework (Figure 3.13) clearly addresses this issue.

The second major point that this proposed model suggests was the **idea of Consultation**. Throughout the first part of this chapter with the comparison of EU Fire Safety Framework, Germany and the Netherlands presented a similar pattern: at a local level, decision-making was carefully made between three parties: Owner, Fire Service and Insurance Company (The Netherlands) or Building Surveyor (Germany). France presented a similar pattern between the Fire Service, the Owner and the Local Authorities at a design and completion phase.

By identifying strength in each separate framework the author have been able to propose a new Fire Safety Framework model that would further facilitate the UK trend **to decentralise decision-making and increase the power** of Regional and Local Authorities. But also by giving more executive power to Region and Local Authorities, the Government would be able to **reinforce the control procedure**. At a Local level, Consultation between at least three parties would be emphasised in order to improve the standard and answer the needs of the users (Users-oriented). The final focus of the model was **to provide Feedback** from Region and Local Authorities to the Government. The objective of this new approach was first to **monitor progress** and secondly, to **improve and adapt the general requirements**, adopted at a National level, to the needs of the users and the Communities.

2.6 European Directives: Fire Safety on Construction Sites in the UK and France.

Pressure from the EU to implement a new set of construction directives forced European countries to review, update, modify and sometimes implement new measures regarding health & safety in general and fire safety in building. Among the Members State active regarding fire safety, France and the UK are two majors driving force. This chapter intended to review fire safety measures in France and the UK for construction sites and presented a comparative study of legislative requirements.

The construction sector provided 7% of all workers in the community. For 15% of all industrial accidents, 30% of all fatal accidents occur in this sector (OJ, 1991)

The rates of fatalities in Member States of the EU revealed a large number of disparities between France and the UK. The Government Statistical Service (1997) concluded that Great Britain fatalities were one of the lowest in Europe and lower than in the USA. A detail of fatalities by industries showed that 8.9/100,000 employees were victims of fatal accidents in construction in the UK against 17.6/100,000 in France in 1993 (Government Statistical Service, 1997). In 1993 (Commission of the European Communities) revealed that the cost of accident on construction sites in the EC was equivalent of ECU15,000 million for 1987 (direct and indirect costs).

The Commission of the European Communities (1993) also revealed that 90% of the total cost of construction accident (ECU15,000 million) was carried throughout the site or execution phase. Fire and explosions count for 3% of the main types of accidents on construction sites in the EC, therefore approximately costing ECU450 million during site execution. Fortunately, fires were not the main cause of these accidents and few construction workers were fatal victims. Nevertheless, severe damages to the facilities and high economic losses demonstrated the catastrophic consequences of fire during the construction / demolition / refurbishment in general, of buildings.

These figures gave rise to a lot of concern about the reduction of accidents on sites and measures to implement to decrease the number of accidents. The answer of the EC emerged through several Council Directives between 1989 and 1992. An important body of Community legislation in the area of health and safety at work was developed and made a significant contribution to workplace working conditions. Prior to the 92/57/EEC Directive, the EC developed two major pieces of legislation:

- The Framework Directive, Council Directive 89/391/EEC, on the introduction of measures to encouraged improvements in the safety and health of workers at work, which came into force 31st December 1992;

- The Workplace Directive, Council Directive 89/654/EEC, concerning the minimum safety and health requirements for the workplace, with a deadline for implementation of this legislation in the Members State of 31st March 1995.
- The 92/57/EEC directive concerns the Temporary and Mobile construction sites and reinforced the implementation of minimum safety and health requirements.

The table 2.1 below provided a summary of the aims and objectives of the new Directives and their deadlines for implementation.

Council Directive	**Title**	**Aims and Objectives**	**Deadline for Implementation**	**Comments:**
89/391/EEC	Framework Directive	The introduction of measures to encourage improvements in the safety and health of workers at work.	31/12/92	General measures for health and safety at work.
89/654/EEC	Workplace Directive	To provide the minimum safety and health requirements for the workplace.	31/12/92	First directive within the meaning of Article 16(1) of the Directive 89/391/EEC.
92/57/EEC	Temporary and Mobile construction sites Directive	The implementation of minimum safety and health requirements at temporary or mobile work sites.	31/12/93	Eighth individual directive within the meaning of the Article 16 of Directive 89/391/EEC.

Table 2.1: Summary of Council Directives 89/391/EEC, 89/654/EEC, 92/57/EEC.

These Directives addressed the problem of health and safety at work in very different way. It was the duty of each individual Members State to implement every Directive. Individual countries interpreted and translated the legislative document, according to the level of provisions in their existing legislative documents (regulation, standards, code of practice, etc.) and their willingness to improve current level of health and safety.

The intention of this section was to review, first of all, the European Directives and to analyse in details the Framework Directive related to general health and safety provisions in the workplace and the temporary and mobile construction sites directives which directly and specifically covered fire safety measures for construction works.

In a second time, the author compared and contrasted the UK and French legislative frameworks and how these Directives have been interpreted and implemented in each Members State, highlighting the strengths and weaknesses.

2.7 Fire safety requirements within the Council Directives:

The **Framework Directive 89/391/EEC** related to fire safety measures under the article 8, and required the employer to provide adequate fire fighting facilities and means of escape at the workplace and liaison with the emergency services internally and externally. This Directive introduced general health and safety requirements at the workplace. However **the Directive did not provide a clear definition of a 'workplace' and excludes a construction site as a workplace**. The provision of Article 16 referred to the application of other directives for specific purposes within which the temporary and mobile directive, lately published in 1992.

The temporary or mobile work sites Directive 92/57/EEC defined in details a workplace as "any construction site at which building or civil engineering works are carried out". This new directive intended to implement the minimum health and safety requirements at temporary or mobile construction sites. These requirements should have been brought into force in the Member states by 31st December 1993. The temporary or mobile construction sites directive applied to any construction sites at which works were carried out, i.e. according to the Council Directive 92/57/EEC Annex 1: any "excavation, earthworks, construction, assembly of disassembly of prefabricated elements, conversion or fitting out, alterations, renovation, repairs, dismantling, demolition, upkeep, maintenance and drainage", for any construction sites on which "more than one contractor is present."

Specific provisions were made regarding fire safety under the Annex IV Part A, section 3 (emergency routes and exits) and 4 (fire detection and fire fighting). These sections required the employer to provide minimum clear emergency procedures in case of fire and an operational fire protection system on temporary or mobile construction sites. Requirements regarding emergency exits and routes tended to be very general except a clear provision for fire exit signage and emergency lighting. These requirements were completed within the Council Directives 77/576/EEC and 92/58/EEC for provisions of health and safety signs at work. However requirements regarding fire fighting and detection were much more specific to implement active fire protection measures, and in certain cases a temporary automatic fire detection system (alarms, portable detection equipment and fire extinguishers, etc.). Furthermore such requirements required an adequate maintenance plan and regular checking. There was no indication on the frequency of this maintenance and checking plan.

Independently to the measures detailed above, the Directive introduced a new concept and required the client to appoint a Planning Supervisor whose role was to develop and implement a Health & Safety Plan on behalf of the client. Under the Articles 4, 5 and 6 the Directive required the Planning Supervisor to act at different stages of the construction project:

- Article 4: Project preparation stage where the planning supervisor must take into account "the general principles of prevention concerning health and safety";
- Article 5: Project preparation stage, detailing the duties of coordinators: "(a) coordinate the implementation of the provisions [of the Directive], (b) draw up, or cause to be drawn up a safety and health plan, (c) prepare a file appropriate to the characteristics of the project."
- Article 6: Project execution stage during which the Planning Supervisor is responsible for "(a) the implementation of the general principles of prevention and safety, (b) coordinate the implementation of relevant provisions, (c) make, or cause to be made, any adjustments required to the health and safety plan… (d) organise cooperation between employers and if necessary for the protection of workers, self employed persons, (e) coordinate arrangements, (f) take the steps necessary to ensure that only authorise person are allowed onto the construction site."

A review of the provisions required under each directive was now complete. The role of each member state was to implement these directives within a limited timescale. Their objectives were to ensure that the prescriptive requirements were translated or interpreted through or within the Member State existing legislation and/or regulations. The objectives of the following chapters were to examine how the directives have been implemented in France and the UK.

2.8 The UK Legislative framework and general requirements regarding fire safety on construction sites:

A series of severe fires on UK construction sites gave rise to a lot of concerns regarding fire safety in facilities at which building works are carried out. The introduction of a set of documents between 1991 and 1999 was an answer to a need to improve the level of safety on site and implement appropriate prevention methods to reduce and as much as possible, minimise the risk of fire during the work execution. The HSE (1997) estimated that more than 15 fires occur on construction every working day. The cost of these accidents was more difficult to evaluate and as a consequence, information available on this subject was not very reliable. Nevertheless, it could be estimated the average annual cost of fires, according to the study of different sources (HSE, 1997; Home Office, 1998) to be around £40-70 million. This figure compared with the total fire losses in the UK gives an average cost between 5-10% of the total fire losses. The cause of these fires, when reported to the HSE was as difficult to access.

Three main sets of legislative documents were of interest in the case of fires on construction sites:

i. The Loss Prevention Council Code of Practice for Fire Prevention on Construction Sites and in Buildings undergoing renovation, published in 1992 under the pressure of insurers (last edition 2000).

ii. The Construction (Design and Management) Regulations 1994 which came into force on 31st March 1994 and as a result of the Council Directive 92/57/EEC.

iii. The Fire Precautions (Workplace) Regulations 1997 which came into force on 1st December 1997 (amended in 1999) and also as a result of the Council Directive 89/654/EEC.

The UK has adopted wide deregulation policies in order to reduce the large number of general health and safety related legislation. The last two documents reflected this political measure and contributed towards the improvement of the general health and safety requirements for workers on construction sites. The measures detailed in these documents had the objective to improve the level of health and safety on construction sites and provide specific requirements regarding fire safety in the workplace.

The Fire Code (LPC, 1992 and 2000), so called since its integration into the newly published main UK standard form of contracts JCT98 (Joint Contract Tribunal published in 1998), was an essential requirement for any contractor undertaking building works. This Fire Code highlighted a number of important principles the contractor was required to follow during the construction or any other type of building works. Its principles were simple, easy to implement and somehow logical for any mind concerned about the safety of the workforce and the general public. However, this document was a Code of Practice and not a legislative enforcement. Contractors were forced to respect the terms of this code by the pressure of insurers, following two majors construction related fires in 1991 and 1992, highlighted later in this chapter.

Following major concerns regarding health and safety in the workplace in EU Members State, the ECC decided to implement a specific number of Council Directives regarding health and safety solely. In 1989, the Framework and Workplace Directives were prepared. Both directives gave rise to a very large number of modifications of the UK_health and safety legislative framework. A review of existing documents (A review of health & safety legislation, 1989) highlighted a need to significantly reduce the number of existing documents and secondly to adopt an innovative approach to reduce and minimise health and safety risks on construction site. Following the Workplace Directive in 1992, the UK modified or updated twenty different sets of documents (regulations, code of practices, guidance).

i. The Construction (General Provision Regulations) 1961.

ii. The Construction (Lifting Operations) Regulations 1961.

iii. The Construction (Working Places) Regulations 1966.

iv. The Construction (Health and Welfare) regulations 1966.

v. Six amendments of Regulation 1961 between 1974 and 1992.

vi. Four amendments of Regulation 1996 between 1974 and 1992.

vii. The Construction (Design and Management) Regulations 1994.

viii. The Construction (Health, Safety and Welfare) Regulations England, Wales and Northern Ireland 1992.

In 1992, contractors were flouted with the recent "six pack" of safety rules, officially called the Workplace (Health, Safety & Welfare) Regulations 1992. Until that date, the contractors were solely responsible to control their own safety regime. However since 31st March 1995, new duties have been placed upon the clients, client's agents, designers and contractors to rethink their approach to health and safety. The CDM (Construction (Design & Management) Regulations 1994 were a major step ahead regarding safety on construction sites. It focussed on the redistribution of responsibilities among the construction participants by transferring part of the risk to the clients and designers. There were also emphasis to re-organise the health and safety prior to the execution phase from the conception phase to the hand over and beyond.

A Report commissioned by CIRIA (1997) concluded that following the implementation of the CDM Regulations "the profile of health and safety in the industry has increased dramatically and most practitioners readily admit that they are still learning. Health and safety is less and less seen as a site issue or as a specialist skill." Although the report highlighted difficulties to understand and interpret the regulation, often linked to a lack of knowledge and incompetence of their participants, it "generally appeared the industry made its best to make CDM work."

Following a study of small and medium construction companies in the UK, Tyler and Pope (1999) concluded that there is almost universal awareness of the existence of the regulations except in respect of firms with less than 5 employees.

The CDM regulations 1994 focussed on four main areas: The role of the client, The role of the designer, The role of the Planning Supervisor, The Health & Safety File.

The degree to which this regulation related to fire safety on construction is not clear. However the role of the Planning Supervisor is clear regarding the preparation of the health and safety plan and as a liaison between the parties, at pre-contract stage and throughout the execution of the works. Preece and al (1999) highlighted that the single most significant change the CDM brought was the introduction of a new role, namely the Planning Supervisor. The client appoints this later.

The Fire Precautions (Workplace) Regulations 1997 imposed duties on the employer to provide the employees with the adequate fire safety provisions in respect of every workplace, which was under the control of the employer. These requirements included the provisions of fire-fighting and fire detection measures in case of fire, emergency routes and exits in order to safeguard the safety of employees and the implementation of a "... suitable system of maintenance..." This regulation defined workplace as "any premises, not being domestic premises, used for the purposes of an employer's undertaking and which are made available to an employer as a place of work..." **Unfortunately this definition excluded a construction site as place of work**. However, where construction operations take place in an occupied facility, the directives applies.

2.9 The French Legislative framework and general requirements regarding fire safety on construction sites:

In contrary to the UK, France didn't have a track record of major fires on construction sites. At least, there were no statistics which demonstrate the impact of fire incidents. However, detail statistics were available for Paris and its region compiled by the Paris Fire Brigade on a regular basis. For a total of 18,500 reported fires in Paris and its region, in average more than 250 fires occur on site (Brigade des Sapeurs Pompiers de France, 1999). In France, fire safety legislative requirements are covered in a Decree and Order from 1992. These documents were published following the new Framework Directive 89/391/EEC on the introduction of measures to encourage improvements in the safety and health of workers at work. These texts introduced a specific number of preventive fire safety requirements for every facility used as a workplace. Prior to 1992, the French Code du Travail did not provide any requirements regarding fire safety at the workplace. Chapter 3.2 describes the main health and safety requirements on construction sites in France and the texts applying to site coordination.

Following the Workplace Directive in 1992, France modified or updated six different set of documents (either Decrees or Act) compared to twenty by the UK.

INRS ND 1993-159-95:

i. Act N. 93-1418 of 31st December 1993 modifying the Code du Travail applicable to the building and civil engineering operations at the workplace.
ii. Decree N. 94-1159 from the 26th December 1994 regarding the integration of security and coordination of health and safety matters at the workplace,
iii. Order of 7th March 1995 describing the duties of the Planning Supervisor to communicate a prior notice in the case a specific construction sites.
iv. Order of 7th March 1995 detailing the requirements regarding the training of Planning Supervisors and the accreditation of training centres.
v. Lettre Ministerielle of 3rd October 1995.
vi. Lettre Ministerielle of 10th October 1995.

The role of the Planning Supervisor in France is someone different from the UK concept. The first Act 1991 provides requirements which were not covered in the Code du Travail. The Act introduces specific measures on the health and safety at the workplace, and specifically general principles regarding the prevention of accidents. These principles should force the construction sector to adopt an innovative approach towards the prevention and coordination of health and safety matters in the workplace. An analysis of the risks and a systematic prevention approach is promoted, taking into account technical factors and human behaviour in the place of work. A control and monitoring system is implemented and the role of the inspectors is reinforced. By using a punitive approach, and employers are forced to respect the law. However prior to this Act, the definition of the workplace did not fully recognised a site as a workplace. The 93 Act introduces the Planning Supervisor, his role and responsibilities throughout the construction project. Articles 1 to Article 8 are an interpretation of the 91/383/EEC Directive. However Article 9 present a punitive procedure, whereby the employer would be required to pay at least £3,000 if he doesn't respect the law. In certain cases, penalties reach the sum of £6,000 when a Planning Supervisor has not been appointed by the client, when the competencies of the Planning Supervisor are argued or if no Health and Safety Plan is not implemented. This punitive procedure is not a requirement of the UK CDM Regulations 1994. The French 93 Act requires the client to employ a competent Planning Supervisor under the Article 2, Section 2: Art. L. 235-4. This person must be any natural or legal person entrusted by the client and/or project supervisor. However according to the same Article, the function of the Planning Supervisor is defined in the Decree 94-1159 of 26 December 1994, on safety integration and the organisation of the coordination in the interest of health and safety, stating, inter alia, the conditions inherent in the role of the Planning Supervisor. Two successive Orders of March 1995, fixed the content of the prior declaration to be made by coordinators working on certain building and civil engineering works (translation of the Annex III of the Directive 92/57/EEC), and on the training of coordinators and their training instructors, and the official accreditation of training organisations.

Under the 92/57/EEC Directive, Annex IV describes the minimum safety and health requirements for construction sites. Part A of this annex provides general requirements for on-site workplaces, and cover emergency routes and exits, fire detection and fire fighting and other health and safety issues. The French documents published following the publication of this Directive and others, did not cover these minimum requirements. The current French practice regarding fire safety separated the construction sites facilities from the building under construction. For the construction site facilities and as much as possible, the fire safety prevention measures apply. These requirements were detailed in three different Decrees (92-322 / 92-323 / 92-332) and one Order (04/11/93) following the Council Directive 89/391/EEC concerning safety and health requirements in the workplace. For the construction site under development and depending on its future use, the fire safety measures applying to this type of building were progressively applied throughout the completion. This procedure is currently used by the Planning Supervisors in France. Unfortunately there were no guidelines available to this profession.

2.10 Comparative study France / UK and discussion:

Interpretation and transposition of the Council Directives between 1989 and 1999: The comparative analysis revealed a number of discrepancies between the French and UK legislative procedure. An outline of the transposition of the directives in the UK and French legislative and regulatory framework was proposed in the table 2.2.. A discussion around the mechanism of transposition of the European directives in Members States on general perspective is presented. First of all, the initiative to develop a European Directive was built on a common approach on a specific issue and could emerged from the need and interest (political, economical...) of various entities: commission, one or more members states, lobbies, European Parliament, professional institutions... A complex stage of discussion was materialised through the proposal of a draft, then a review (internal or external). The comments were expressed through a new draft proposal and the acceptance and publication of the text is decided. In average (except perhaps for stringent matters) we estimated a minimum period of three years to materialised this first stage.

Field	France	UK
Coordination and Planning of H & S	Act 93	CDM regulations 1994
Mission of the Planning Supervisor	Decree 94	CDM Regulations 1994
Training of Planning Supervisor: Health & Safety Fire Safety	 Order of 7th March 1995 No text	 No Text No Text
General Health & Safety requirements at the Workplace	Act 91 Decree 92-323 Decree 65	Construction (Health, Safety & Welfare) Regulations 1992
Fire Safety on construction sites	No text	LPC Code of Practice for Fire Prevention on Construction Sites 1992
Fire Safety in the workplace (excluding a construction site, but including facilities where construction operations take place while in use)	Decree 92-158 of 20 February 1992 Arrêté of 19 March 1993	Fire Precautions (Workplace) Regulations 1997

Table 2.2: Comparative table of UK vs. France regulatory requirements

A stage of interpretation was necessary to appreciate the content and the scope of the European text and the legal strategy to transpose the requirements in each member state. Each government must identify which part of the text was already covered under the existing regulations and how to apply the remaining in their legal framework. The European Commission estimated that a deadline of three years is necessary to interpret the directives and implement them in the member states. The Framework and Workplace Directives were published in 1989 and a deadline of implementation was required for December 1992. However the analysis could identify some discrepancies between the deadline for implementation and the publication of regulation in member states. Major differences between the way France and the UK address the problem of fire during construction may be highlighted. Following the occurrence of fires in the UK in early 1990s, specific measures were developed under the pressure of insurers. France did not follow a similar pattern. **The UK approach seemed reactive unless the European one whereby a pro-active politic has been slowly developed regarding fire safety**. The track record of the publication of Council

Directives answered a need to improve preventative health and safety measures, and specifically in certain cases (92/57/EEC) fire safety. It was surprising that in a deregulation context, overall fire safety matters gave rise to no restrictions. France decided not to implement fire safety requirements on the Planning Supervisor following the last European Directives. The work inspector (nominated by the Government) was supposed to pursue his role in the field of fire safety and its requirements in the workplace. However the lack of training and support to complete his duties was a major barrier to control and monitor the application of the new health and safety objectives. Furthermore no major fires justified the implementation of new policies. The Decree of 65 provided all the necessary requirements regarding general safety, except fire safety.

On the other hand it was also important to highlight that the problem of fatalities caused by fires on construction sites must be distinguished from the number of fatalities where a fire was construction related. In the earlier case, the construction workforce was the victim and the later, both the workforce and the general public. Two relatively recent incidents in France and Germany illustrated this issue. In both cases, members of the construction workforce were not victims. However, members of the public were severely injured by the fire and in unfortunate cases were fatal victims. Dusseldorf counted 17 fatalities and 100 injured. The Barbotan fire in 1991 counted 21 fatal injuries. The interaction between construction site and facilities under normal use has not been addressed thoroughly. In France, the fire safety regulation for facilities receiving members of the public, provided a brief outline (Article GN13 of *Réglement de sécurité contre l'incendie*). Similar provisions also exist in the UK.

A cost benefit approach review should be an effective tool to measure the impact of current regulations and codes. As far as the author is aware there were no studies available on this issue. It seems that the low number of victims did not justify an in-depth analysis of a prescriptive fire safety approach for construction sites. In fact, such requirements would drive both contractors and clients to invest into appropriate fire detection and fire fighting equipment, as well as a number of specific procedures that would require dedicated and trained staff. A partial answer to these measures has been developed in the UK by using portable fire protection equipment. The type of measures would have an impact on the overall construction of the facilities.

The **UK approach regarding construction contract was very prescriptive**. The extensive use of standard forms of contracts for the last half of a century was a useful mechanism to specify requirements. The author highlighted earlier in this chapter the engagement under the terms of the contract, of the contractor to strictly follow and apply a set of rules regarding fire safety during construction works. In fact the contractor was required to follow the LPC Fire Code and the CDM Regulations 1994. **In France, the contractual link as far as the fire safety was concerned, couldn't be as strengthened as in the UK, due to the lack of specific ad hoc guidelines**.

The author demonstrated the assessment of the problem, the function of the Planning Supervisor and the applications of fire safety requirements tend to widely vary from a country to another one. **Cultural and cost benefit approaches may explain differences in the way the problem was tackled. Overall France tend to ask for external competencies through accredited bodies, whereas the UK emphasis on an internal approach**. As a consequence, the function of the Planning Supervisor varies but was a key role player throughout the whole process.

2.11 Conclusion Chapter 2:

The large number of disparities between the Fire Safety Legislative Framework in the EU countries studied made the approach to the problem quiet difficult. There were no universally applicable good practice examples throughout the EU that could be used as a guide for a future European Directive or a harmonised Fire Safety Legislation. Nevertheless, the Canadian approach and its Fire Safety Frameworks, i.e. pre-1975 approach and the post-1975 approach, indicated that Decentralisation was the most effective solution. Some EU Member

States already were adopting this approach, such as Germany and Spain. The UK was slowly moving towards a new regime and just adopted a new strategy to reduce fires in homes and in buildings in general.

It was still too early to entirely appreciate the impact and benefit of the implementation of the EU directives in France and the UK. Furthermore, the Member States were still improving their current legislation and/or regulation. There was a need to review the long term impact of the new directives and how did they contribute to improve the level of fire safety on construction sites. It was assessed that the best way to analyse the strengths and pitfalls a new set of regulation, was to examine a significant reduction of fires on construction sites, their economic losses and closely look at the causes of these incidents. The lack of clear structure to collect the relevant and significant range of statistical data at a European level was to date out of scope. The assessment and impact of the dimension of the problem of fire on sites was currently not on the agenda. A second stage would comprise a modification of the existing framework to reduce and/or eliminate the fire occurrence to zero or as close to zero.

This chapter compared the Fire Safety Legislative situation in several European countries with the Canadian model and identified strengths and weaknesses within the Legislative Frameworks. A Fire Safety Framework has been proposed and three main issues have been identified: Control, Feedback and Consultation.

More research and investigations will need to be carried out in order to identify best practice and create a Fire Safety Model that could be adopted throughout the EU. The objective of this research was to develop such a model.

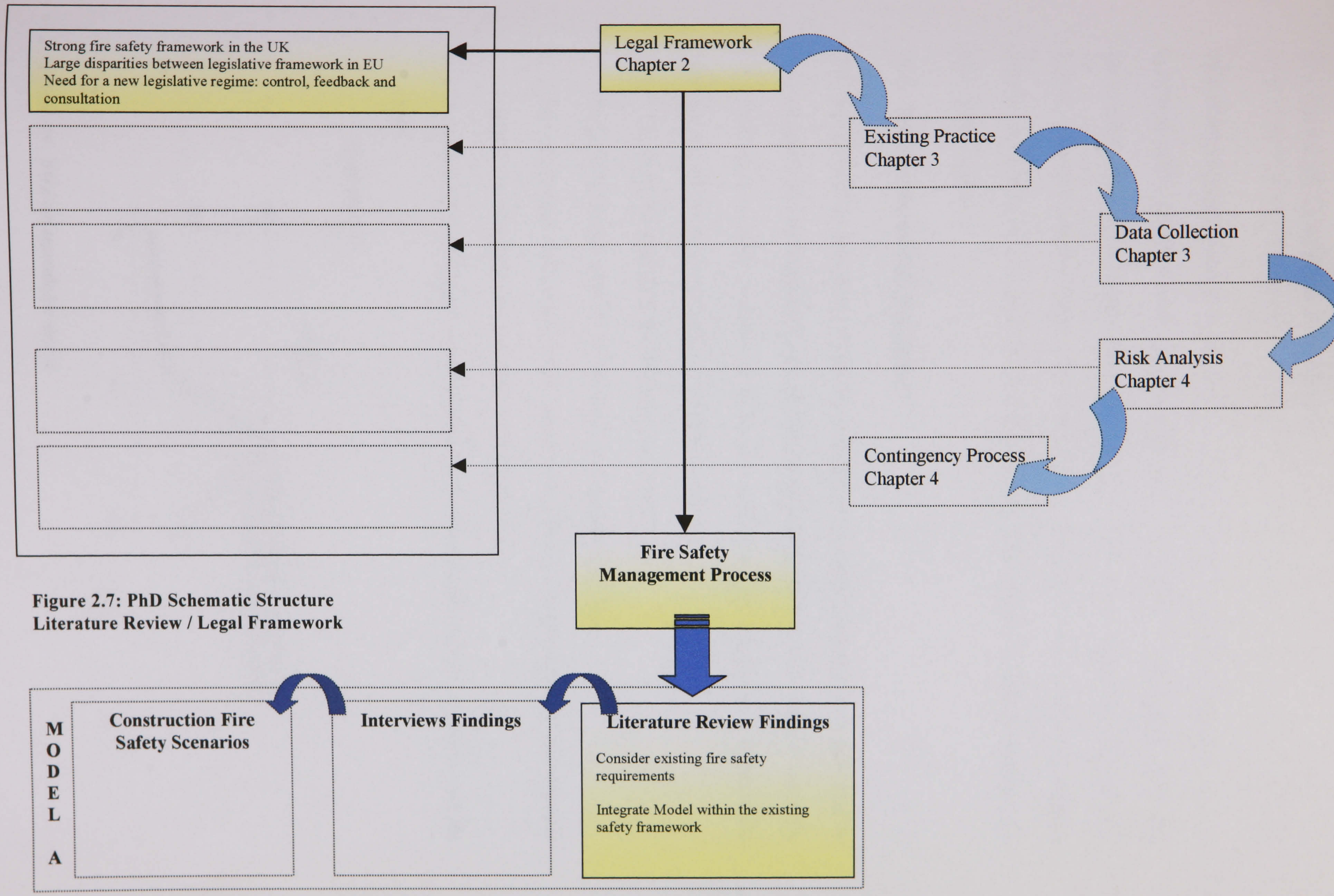


Figure 2.7: PhD Schematic Structure
Literature Review / Legal Framework

3 FIRES ON CONSTRUCTION SITES

This chapter aimed to provide an overview of the characteristics of a construction site, its definition and a detail survey using an engineering approach. In the second part of this introductory chapter, an attempt is made to quantify the fires on construction sites and their losses. A review and discussion of major literature published on the subject in presented. Finally the author looked at current practices and the construction companies response to a fire safety situation.

3.1 Background and principles

The growth and development of fire has been shown to be dependent to a large extent on the geometry and ventilation of the enclosure containing the fire. The condition necessary for combustion to occur was known to be one where the fuel, oxygen are present in the correct propositions in the presence of an ignition source.

A fire would get through three different phases (Figure 3.1):

- The *growth period*: ignition of material and propagation of flame
- The *steady state combustion*: a fire cannot keep growing indefinitely and its development continues until severity is controlled or flashover occurs.
- The *decay*: as fuel supply is depleted the fire will eventually reduce in severity and die down.

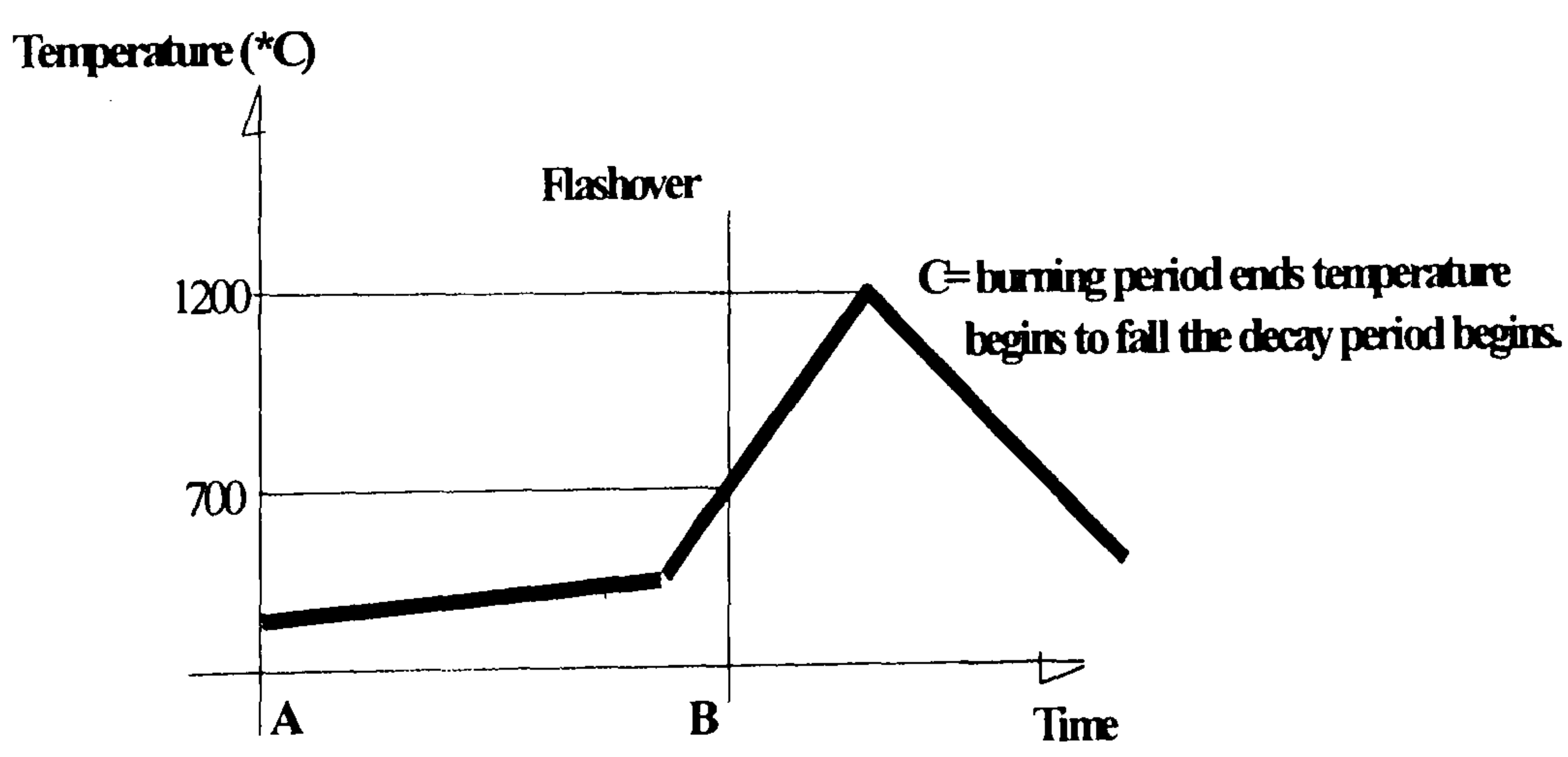


Figure 3.1: Fire temperature curve

There are many factors affecting the fire development. A fire usually started because a material was ignited by a heat source. The fire development depended on:

- The item first ignited was sufficiently flammable to allow flame spread over its surfaces.
- The heat flux from the first fuel packages which in turn would begin to burn.
- Sufficient fuel existed within the compartment otherwise the fire may simply burn itself out.
- The fire may burn very slowly because of a restricted oxygen supply, e.g. in a well-sealed compartment the fire eventually smother itself.
- Providing that there was sufficient fuel and oxygen available the fire may totally involve the compartment.

Ignition, fuel and oxygen are three elements always available on a construction site. It would be feasible to control to the ignition source through the strict implementation of a non-smoking policy, the use of hot work permits and the proper inspection strategy to support its efficiency. The fuel composed of materials and of components of the building would be slightly more difficult to control as without materials or components the facility couldn't be built. However the choice of materials and its selection to restrict their combustibility was a positive initiative. The control of waste on site contributed to control the fire load and potential fuel sources. The last elements of the combustion process was the oxygen, which is freely available on site and throughout most of the construction process as no air flow control was operational nearly until completion.

The term fire load is used to describe the heat energy which could be released by meter square of floor area of a compartment or storey by the combustion of the contents of the building and any combustible parts of the superstructure itself. The concept of fire loading attempts to relate the combustible contents of a building to the potential severity of a fire in that building and consequently to the fire-resisting capabilities of the elements of the structure. It is therefore assumed that the building will remain structurally intact during a complete burnout of all combustible materials. However **when we consider a construction site, there are no guarantee that the uncompleted facility will sustain a major fire and retain its integrity**. The specific characteristics of a construction site lies into the constantly changing design and evolutionary spatial framework. The building content and the materials used in the construction of a facility will help engineers to determine the fire load. In the construction process, this fire load will increase throughout the execution phase to reach its maximum value when the building is complete.

However, the ability of construction or component of a building to satisfy a determine level of fire resistance during the construction process is not always the same when a component is being installed, completely installed or even stored on site. These engineering characteristics will contribute to the development of a fire in a given space.

The easier a material is to ignite and the greater the rate of heat production, the faster the growth of the fire. Large expanses of combustible materials such as wall and ceiling linings, especially unfinished and often unprotected, can contribute significantly to the rapid growth of a fire.

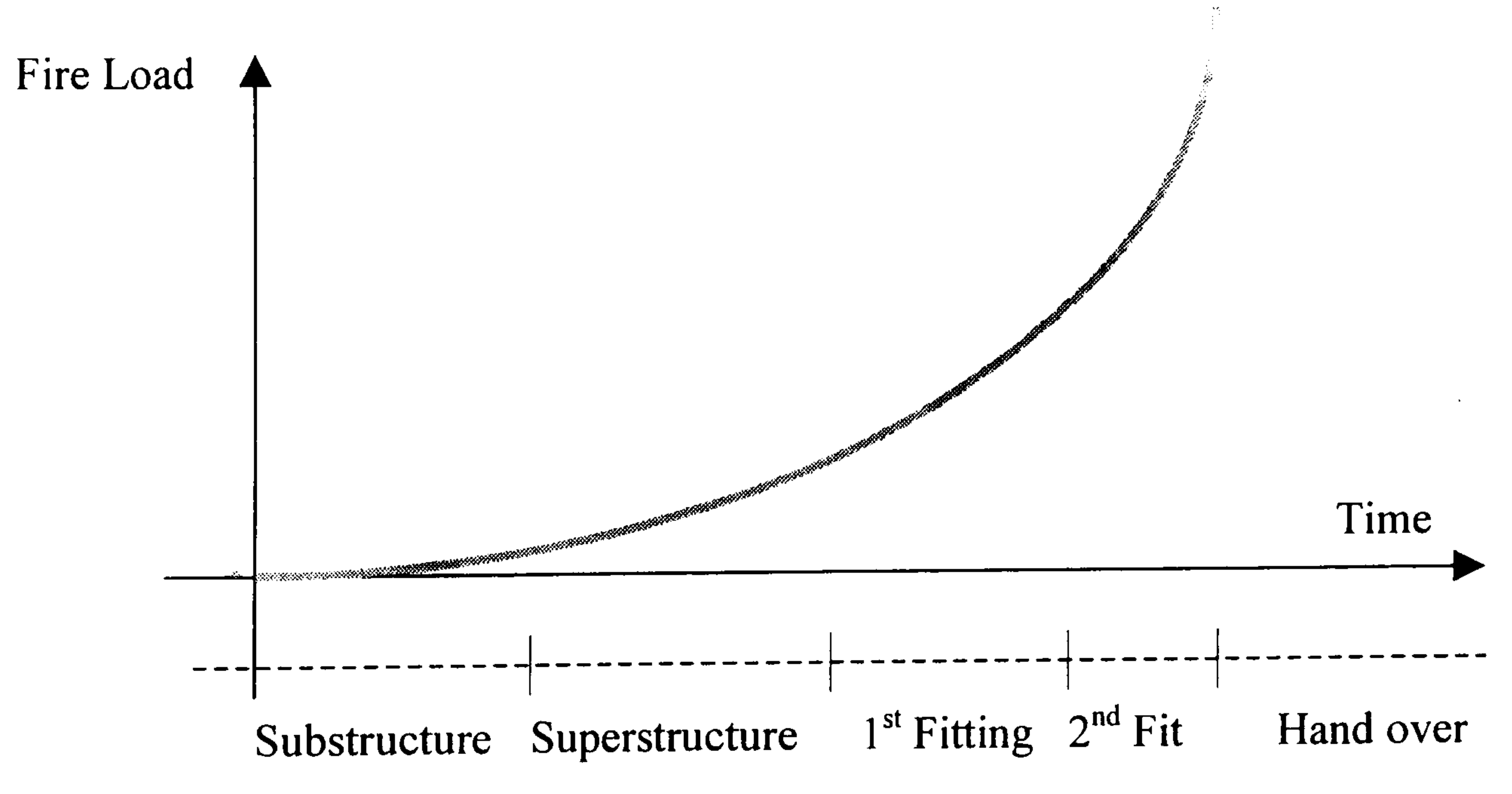


Figure 3.2: Illustration of the distribution of fire load throughout the construction process.

It is therefore important to carefully consider what is the definition of a construction site. There is common belief that each construction site is unique, with its own characteristics.

However the spatial characteristics of a site would greatly affect how we perceive the limit of a site and its boundaries. A site could be presented in many forms and specifications.

A construction site could be a complete facility.
Its limits would be the limits of the facility (external walls and area of landscape around it.

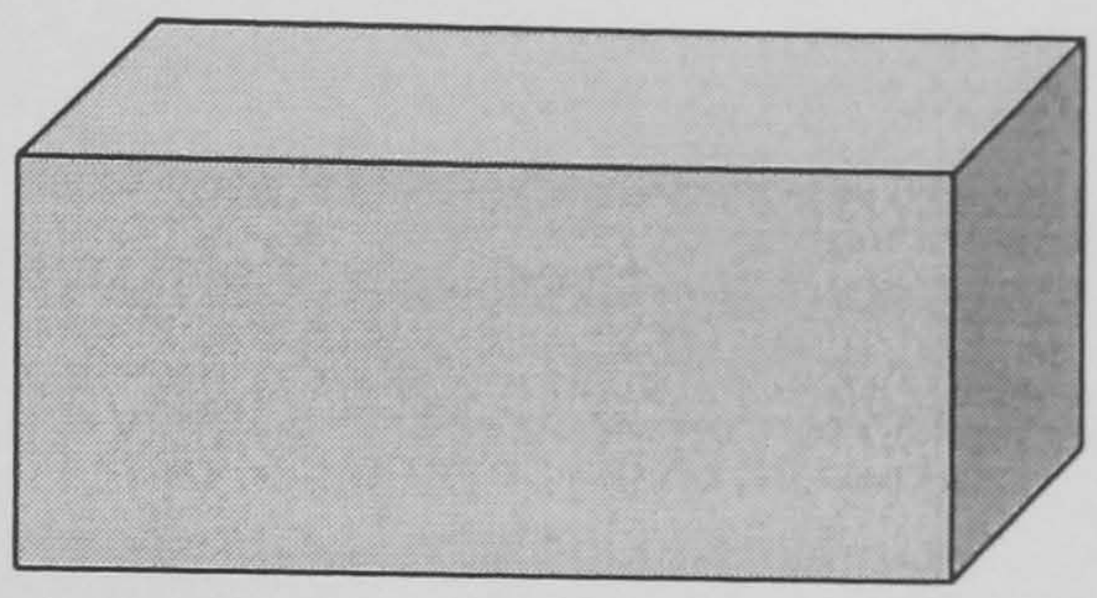


Figure 3.3: Construction Site: Complete Facility

A site could a limited space within a larger space
This limits could be a room or an open space in the facility (atrium, car park area…)
The facility could be occupied at the time of the construction activities (maintenance, refurbishment…)

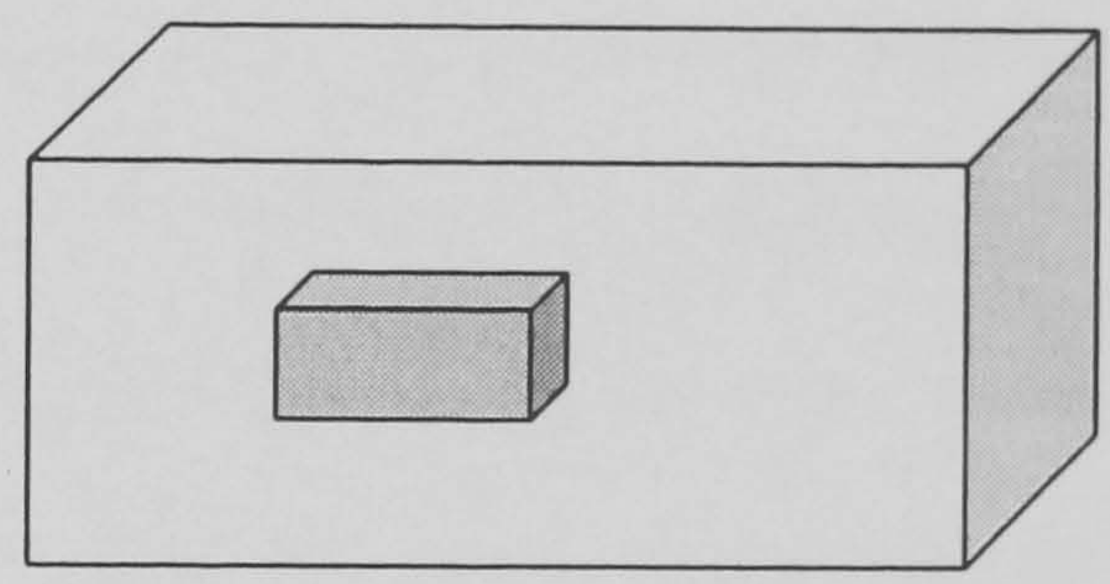


Figure 3.4: Construction Site: a room / a limited space in the Facility

A site could involve the refurbishment or renovation of a floor in a facility.
The rest of facility could be occupied and in use at the time of the construction works.

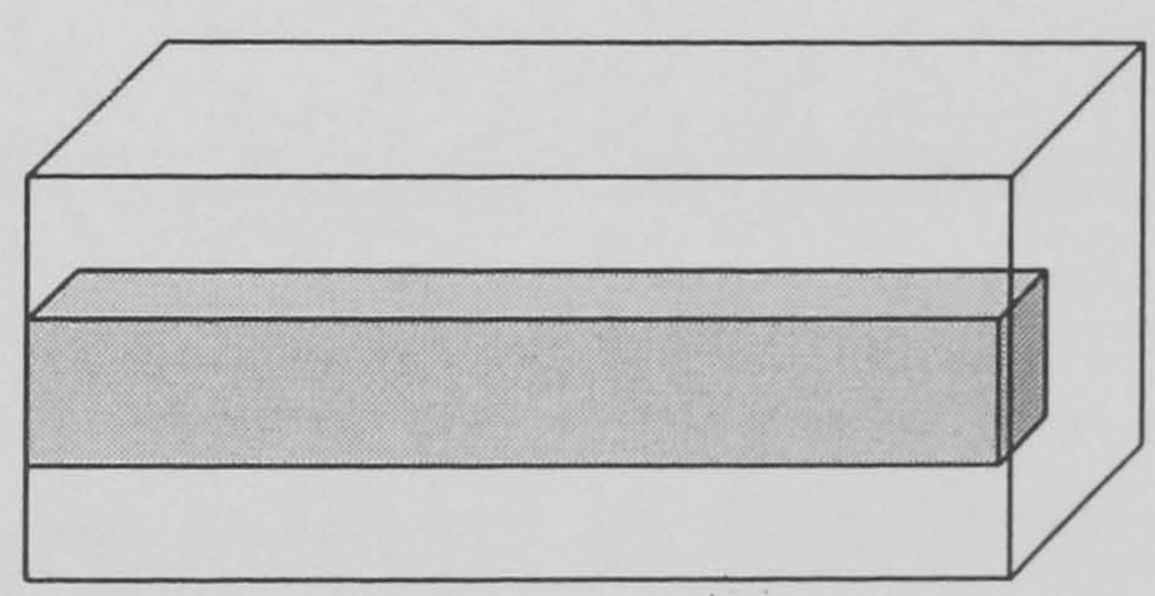


Figure 3.5: Construction Site: A floor in a Facility

A site could be located in an occupied facility and limit of one part of the facility (one wing, half of the facility…).

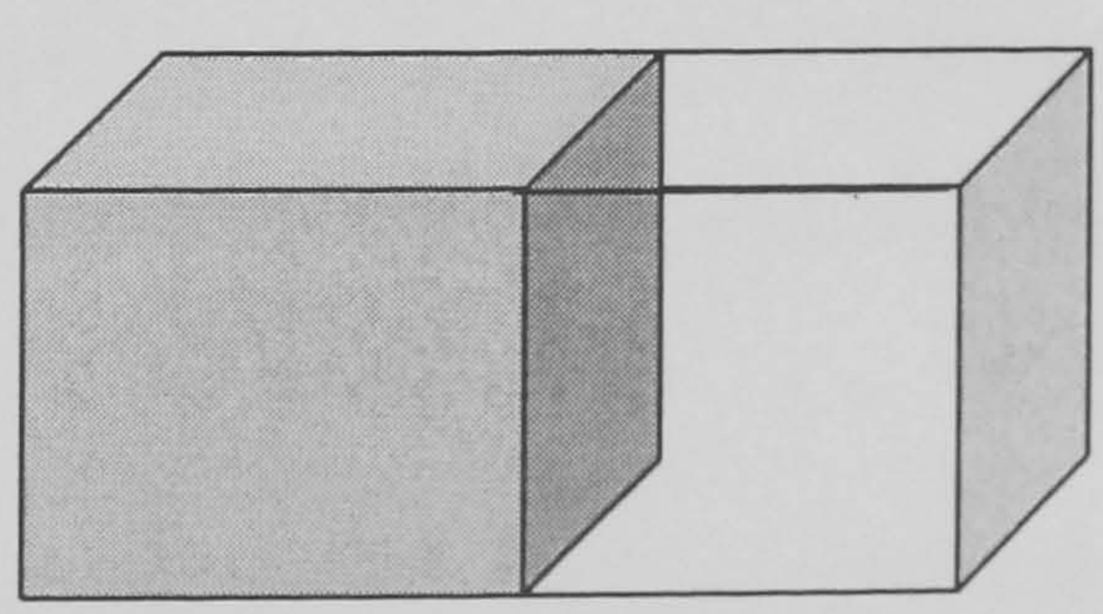


Figure 3.6: Construction Site: Part of the Facility

The complexity of a construction site and its characteristics required a broader approach towards defining a construction site, considering its characteristics and specification.

The author defines construction site as *any facilities where there is new construction taking place, where modifications are being made to the existing facilities, and/or there are maintenance works being undertaken in part or all of the premises.*

It is also important to define what do we mean by a construction activity: *A construction activity is a work operation outside the normal use of the facility: new constructions, alterations, refurbishment, change-in-use, maintenance, demolition.*

There are a number of factors that affect the duration of the growth period of a fire and they are:

- Spacing of combustible fuel packages within the compartment: storage of material on site can contribute to the growth of fire and its spread outside the limits of the compartment.
- Mass and surface area of the combustible materials dispersed within the room or the compartment: many materials and components are highly flammable before they are installed in the facility, e.g. insulation materials, unprotected timber, packaging material, etc.
- Size and location of ignition sources: space could be restricted on site and forced contractors to store material in unprotected areas which increase the fire load.
- Size and location of the openings in the compartment boundaries: an unfinished or modified building could offer an unrestricted open space and no adequate or temporary not adequate compartmentation throughout the facility. Fire doors could be missing, windows not installed, roof uncomplete, liftshaft / staircases unfinished, openings without fire stopping, etc.
- Geometry of the compartment: unfinished building present an uncompleted geometry of its compartments. It is not rare to find large open spaces where the spread of a fire could be accelerate by the lack of passive design.

The elements discussed above are essential to understand the complexity of a site and its geometry and how in a fire situation, the damages sustain by the building could be much more important than in a finished facility. In situations where part of the facility is occupied and used during construction activities, the damages would be much more devastating to life, property and ultimately the business.

3.2 Towards a fire safety engineering approach:

The interaction of fire, facilities and their occupants provided a very complex framework and a large number of different scenarios. In the UK, the minimum standard were described in the legislative and regulatory documents and building owners and designers were required to provide the minimum standard. This simplistic and minimalist approach to fire safety in building was not always the key to success, especially when dealing with complex structures. Fire safety had a long history which helped to change the UK fire safety framework, often modified after major disasters.

In order to enhance the level of safety of occupants in building and especially complex facilities, engineers designed a method, based on a fire risk assessment approach developed in the United States and generally known as the Building Fire safety Engineering Method – BFSEM (Wade and Whiting, 1997). A fire safety engineering approach may have many benefits over the prescriptive approaches developed in the fire safety regulations. The BSI ISO/TR 13387-1 (1999) argued that the FSE approach takes into account the totality of the fire safety package and provides a more fundamental and economic solution than traditional approaches to fire safety.

The first research into fire engineering could be traced to the 1930s. We tried to understand the phenomenon of fire, its chemistry, its development, and to best fit the building systems to minimise the impact of a fire on the occupants, the property and its surrounding environment. FSE is the use of engineering methodology to determine the precise fire safety requirements and the design of the system to provide the required level of safety. FSE focus on the safety of the occupants, the mitigation of losses, the prevention of fire spread, the minimisation of environmental damages.

The legislative documents focused on providing adequate fire safety precautions to protect the life of the occupants and the property as a whole. According to BS4422, Fire precautions could be divided into fire prevention and fire protection. Fire prevention was concerned with the implementation of measures to prevent the outbreak of a fire and/or to limit its effects. Fire protection comprised the design features, systems, equipment, buildings, or other structures to reduce danger to persons and property by detecting, extinguishing or containing fires. It comprises any active or passive measures.

In the UK two British Standard were of importance:

- Draft BSI DD240: Part 1 and 2 (1997) Fire Safety Engineering in Buildings. This Draft Standard provides guidance on the application of scientific and engineering principles to the protection of people and property from fire. It includes guidance on the design and assessment of fire safety measures in building and an alternative approach to existing codes and guides. It is not to be regarded as a British Standard.
- BSI ISO/TR 13387-1 (1999) Fire Safety Engineering. This Technical Report is in 8 parts and still under technical development. The principles of this Standard are based on the BSI DD 240. However the approach will not necessarily means compliance with national regulations.

Recently, the draft ISO Standard (BSI, 1997) on FSE Life Safety extended its definition and objectives to not only life safety and property loss, but also business interruption, contamination of the environment and destruction of heritage.

3.2.1 Fire Safety Engineering (FSE) Approach:

BSI ISO/TR 13387-1 defined FSE as "the application of engineering principles, rules and expert judgement based on a scientific appreciation of the fire phenomena, of the effects of fire, and of 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."

The process described in the BSI DD240 (1997) had four main stages:

a) Qualitative design review

b) Quantitative analysis

c) Assessment against criteria

d) Reporting and presentation.

Due to the complexity of the ever evolutionary design of a construction site throughout the construction activities, the author would like to test and challenge the FSE approach to enhance fire safety on sites.

The FSE approach supposed the facility is complete and relied on a set of parameters which are most likely stable in time. A construction site is not and the increase of its fire load, i.e. the quantity of heat which could be released by the complete combustion of all the combustible materials in a volume, including the facing of all boundaries (BSI, 1997), will effect the engineering approach. However, let's consider three scenarios:

- The construction of a new facility: the lack of precautionary measures until completion and the evolutionary design of the facility would make the Qualitative Design Review very subjective.

- A refurbished facility:
    - Partially Occupied: the interaction between the site (under modification and change) and the facility in-use (normal occupancy and under a different set of regulations – workplace regulation, public assembly, warehouse…).
    - Not occupied: the site boundaries are clear defined and the limit in the space and time. Fire precautions measures might not be operative throughout the construction process and design arrangements would change in the time.
- A facility being maintained: the action of an external organisation or in-house team to carry out some work operations (maintenance of technical equipment, day-to-day maintenance works…) in a facility occupied by normal users (staff, customers and the public, patients…). In this situation it is sometimes difficult to assess the boundaries of the site (room, an open area, a corner, a contained space…). However we assume that the normal fire precautions measures are operational and that safety of the occupant is maintained to an acceptable and minimum level.

3.2.2 The Qualitative Design Review: QDR

The first phase of the FSE approach required a Qualitative Design Review (QDR), where "the scope and objectives of the fire safety design are defined, performance criteria established and one or more potential design solutions proposed" (BSI, 1997). Tables 3.1, 3.2 and 3.3 detailed the QDR for a new construction, a refurbishment/renovation project and a facility affected by maintenance activities.

Table 3.1: Qualitative Design Review: New construction

QDR	New Construction
Review the architectural design	*Building Design*: Geometry and interconnection of space is complex due to the changing and evolutionary design in time and space. The fire load will increase from stage one of the construction process to completion of the facility. The fire load density will vary from 0 to the maximum fire load density of the finished facility (office construction: 0 to 420MJ/m2; Manufacturing construction: 0 to 300 MJ/m2…). The quantity of combustible materials will vary and reach some picks at certain stages of the project (1st and 2nd fit out and finishes). Internal layout of the site will be modified and large open spaces will be created throughout the first construction of the superstructure. The passive and active measures are most likely not to be operational until completion. The passive measures might be in place at an earlier stage. Compartmentation will not be achieved until an advanced stage of construction. Normal circulation routes will not be definitive until a late stage of completion of the construction. Escape routes will be reviewed and change periodically. Access to the fire brigade and connection to water supply will be ensured. Adequate level of fire safety management will be implemented (JCOP requirements) *Occupants*: The number and distribution of occupants throughout the building would vary on a daily basis, but can be planned and control for. The high degree of mobility is required and it is expected that their responsiveness to a fire is good. A very good familiarity of the building and its internal layout proved to contribute to life safety and enhance evacuation success. Interaction and group activities are high and in an emergency situation would be a positive. *Enclosure*: A site could provide a high degree of potential ignition sources (hot work, welding and cutting) at different stages of the construction process Storage areas and temporary storage of material would modify the spread of combustible content and increase the fire load density in certain area of the site. Structural fire resistance of the wall, floor and ceiling will not reach its full capacity until completion. This will affect the structural stability of the facility. The lack of fire resisting boundary elements and separating elements will affect an effective compartmentation and allow the fire and smoke to spread within the uncompleted facility and its boundaries. The lack of active fire protection measures (automatic extinguishment, ventilation, detection and warning system…) contributing to control the growth and development of the fire.
Perform a characterisation study of the building, environment and occupants	Building Characterisation: The layout and the geometry of the site are complex to establish and would require to develop several scenarios. Environmental influences:

	A fire during unfinished works and under completion operations will be influenced by external environmental factors, such as wind (fire development and spread), rain (fire extinguishment) and dry weather conditions (dry material and storage). Occupant characteristics: The workforce would be very familiar with the geometry and layout of the facility. Its distribution in different part of the site is unavoidable, but they would be trained to respond to a fire (manual firefighting and alarm raising).
Establish fire safety objectives	*Fire outbreak*: Proper assessment of the risks should be developed prior to construction operations. This risk assessment should be periodically reviewed and a strategy developed to control and prevent the risks. (JCOP 2000) *Life safety*: An evacuation plan should be developed to enable the workforce the safely evacuate the site and reach a safe area. (CDM Regs 1994) Link with the fire brigade would be established prior to the commencement of the works on site. Risk of collapse could be high due to the unfinished nature of the building under completion. *Loss prevention*: Consideration for the continuity of the business activities should be raised with the concerned parties and a loss prevention programme developed to manage a crisis such as a fire. The development of a contingency plan or business continuity plan needs to be implemented in the fire safety strategy. *Environmental protection*: Measures to protect the environment against the impact of a fire need to be taken prior to the commencement of the work: collection of used waters and their evacuation, management of waste on site and their safe storage…
Establish an evacuation strategy	Occupants should be trained to evacuate the site to a safe location. It is recommended to process to a total evacuation of the unfinished facility due to the unpredictable nature of a site under construction. Evacuation strategy will be detailed in the evacuation plan (CDM Regs 1994)
Identify acceptance criteria	A deterministic approach would not be adequate as a site under construction will offer a different set of input data at each stage of the construction process. Certainly considering the worst case scenario would be the most realistic approach but would not represent the majority of the cases of fires on site. A probabilistic approach is based on a detailed analysis of fire statistics. Unfortunately, statistics of fire on construction sites are not available. A comparative approach could be developed. The level of health and safety should comply with the CDM Regs 1994 and the level of fire safety with the JCOP 2000. The general minimal level of fire safety of the structure should comply with the Approved Document B or equivalent guidance or code. A financial approach is not excluded as an Estimated Maximum Loss calculation can be carried out and is usually provided by the Insurer.

Identify fire hazards and possible consequences	A risk management approach would require a clear fire hazards assessment for the site. This exercise should be systematic and updated periodically to address the changing environment of a site. Possible failures scenarios should be designed and an assessment of the consequences and maximum site disruption addressed.
Establish trial fire safety design	The limit of trial solutions for a site and the financial constraints of the contractors do not allow the implementation of a sophisticated fire protection strategy. Minimum requirements would be addressed and compliance would the JCOP ensured. However a better project management approach and method statement would allow more flexibility in the earlier delivery of fire safety protection measures prior to completion (completion of passive design, compartmentation, active fire protection systems...).
Specify fire scenarios for analysis	Three possible scenarios can be designed: Minor destruction of the site (<25%): no interruption of the construction activities and minor repairs and cleaning. Partial destruction of the site (26-50%): major repairs and cleaning but minor disruption of the construction activities. Major destruction of the site (51-100%): major repairs and cleaning and major interruption of the construction activities. The site might need to be rebuilt.
Indicate appropriate methods of analysis	A quantitative analysis would require relying on a large number of statistical data which is not available to date. A qualitative analysis of the fire scenarios sounds to be the most appropriate method for this type of construction.
Prepare fire safety manual	The reliance on a strong and operational fire safety strategy complement with the use of engineering methods to enhance the level of safety is demonstrated when dealing with a site under construction. The fire safety strategy would be detailed in a fire safety manual which reflects the general management and operational procedures of the organisation concerned.
Output results of QDR	The set of outputs collected through the QDR does not constitute an adequate set of data to develop a quantitative analysis. The optimum fire safety design could only be achieved in a non-changing environment, which is not the case with a site. The set of outputs collected through the QDR will enable the team to develop a strong qualitative approach and formulate a proper fire safety strategy.

Table 3.2: Qualitative Design Review: Refurbishment / Renovation QDR (Modification from New Construction QDR Underlined)

QDR	Refurbishment / Renovation
Review the architectural design	*Building Design*: Geometry and interconnection of space is complex due to the changing and evolutionary design in time and space. The fire load will increase from stage one of the construction process to completion of the facility. The quantity of combustible materials will vary and reach some picks at certain stages of the project (1st and 2nd fit out and finishes). Internal layout of the site will be modified and large open spaces will be created throughout the first construction of the superstructure. The passive and active measures are most likely not to be operational until completion. The passive measures might be in place at an earlier stage. Compartmentation will not be achieved until an advanced stage of construction. Normal circulation routes will not be definitive until a late stage of completion of the construction. Escape routes will be reviewed and change periodically. Access to the fire brigade and connection to water supply will be ensured. Adequate level of fire safety management will be implemented (JCOP requirements) *Occupants*: The number and distribution of occupants throughout the building would vary on a daily basis, but can be planned and control for. The high degree of mobility is required and it is expected that their responsiveness to a fire is good. A very good familiarity of the building and its internal layout proved to contribute to life safety and enhance evacuation success. Interaction and group activities are high and in an emergency situation would be a positive. *Enclosure*: A site could provide a high degree of potential ignition sources (hot work, welding and cutting) at different stages of the construction process Storage areas and temporary storage of material would modify the spread of combustible content and increase the fire load density in certain area of the site. Structural fire resistance of the wall, floor and ceiling will not reach its full capacity until completion. This will affect the structural stability of the facility. Possibility to retain fire resisting boundary elements and separating elements to enhance an effective compartmentation and control the fire and smoke spread within the refurbished facility and its boundaries. Possibility to retain the existing active fire protection measures (automatic Extinguishment, ventilation, detection and warning system and control the growth and development of the fire.
Perform a characterisation study of the building, environment and occupants	*Building Characterisation*: The layout and the geometry of the site are complex to establish and would require developing several scenarios. *Environmental influences*: A fire during unfinished works and under completion operations will be influenced by external environmental factors, such as wind (fire

	development and spread), rain (fire extinguishment) and dry weather conditions (dry material and storage). *Occupant characteristics*: The workforce would be very familiar with the geometry and layout of the facility. Its distribution in different part of the site is unavoidable, but they would be trained to respond to a fire (manual firefighting and alarm raising). The existing users could occupy part of the facility under refurbishment and a different category of work carried out (workplace, industrial activity, entertainment, and public service…). This part of the building will be under a different set of regulations and under the responsibility of a different entity. The duties and responsibilities of the contractor to communicate with the facility owner or Facilities Manager are essential to develop an effective fire safety strategy.
Establish fire safety objectives	*Fire outbreak*: Proper assessment of the risks should be developed prior to construction operations. This risk assessment should be periodically reviewed and a strategy developed to control and prevent the risks (JCOP 2000). *Life safety*: An evacuation plan should be developed to enable the workforce, and any other occupant of the facility, the safely evacuate the site and reach a safe area. (CDM Regs 1994 and any other regulation applying to the facility in use – Fire Precautions (Workplace) Regulation 1997, the Fire Precautions Act 1971). Consider modifying the existing evacuation plan of the facility in use if the site affects the safe evacuation of the occupants. Link with the fire brigade would be established prior to the commencement of the works on site. Risk of collapse could be high due to the unfinished nature of the building under completion. *Loss prevention*: Consideration for the continuity of the business activities (of the contractor and the facility owner) should be raised with the concerned parties (contractor/subcontractors, facilities manager, client/owner, and insurer) and a loss prevention programme developed to manage a crisis such as a fire. The development of a contingency plan or business continuity plan (Project BCP for the contractor) needs to be implemented in the fire safety strategy. If the owner/client is using the facility, he should modify his BCP to address the new situation and update it in accordance. *Environmental protection*: Measures to protect the environment against the impact of a fire need to be taken prior to the commencement of the work: collection of used waters and their evacuation, management of waste on site and their safe storage…
Establish an evacuation strategy	Occupants should be trained to evacuate the site to a safe location. It is recommended to process to a total evacuation of the unfinished facility due to the unpredictable nature of a site under construction. In case of fire, the occupied facility will also need to be evacuated. A joint alarm or procedure of warning and evacuation would be required between the site and the occupied facility. The site evacuation strategy will be detailed in the evacuation plan (CDM Regs 1994) and a separate evacuation plan for the occupied facility.

Identify acceptance criteria	A deterministic approach would not be adequate as a site under construction will offer a different set of input data at each stage of the construction process. Certainly considering the worst case scenario would be the most realistic approach but would not represent the majority of the cases of fires on site. A probabilistic approach is based on a detailed analysis of fire statistics. Unfortunately, statistics of fire on construction sites are not available. A comparative approach could be developed. The level of health and safety should comply with the CDM Regs 1994 and the level of fire safety with the JCOP 2000. The general minimal level of fire safety of the structure should comply with the Approved Document B or equivalent guidance or codes. A financial approach is not excluded as the Estimated Maximum Loss calculations can be carried out and is usually provided by the Insurer.
Identify fire hazards and possible consequences	A risk management approach would require a clear fire hazards assessment for the site. This exercise should be systematic and updated periodically to address the changing environment of a site. Possible failures scenarios should be designed and an assessment of the consequences and maximum site disruption addressed as well as the normal running business of the occupied facility if concerned.
Establish trial fire safety design	The limit of trial solutions for a site and the financial constraints of the contractors do not allow the implementation of a sophisticated fire protection strategy. Minimum requirements would be addressed and compliance would the JCOP ensured. However a better project management approach and method statement would allow more flexibility in the earlier delivery of fire safety protection measures prior to completion (completion of passive design, compartmentation, active fire protection systems...).
Specify fire scenarios for analysis	Three possible scenarios can be designed: Minor destruction of the site (<25%): no interruption of the construction activities and minor repairs and cleaning. And no impact on normal business activities of the occupied facility. Partial destruction of the site (26-50%): major repairs and cleaning but minor disruption of the construction activities. Minor or No impact on normal business activities of the occupied facility. Major destruction of the site (51-100%): major repairs and cleaning and major interruption of the construction activities. The site might need to be rebuilt. Major business interruption for the facility occupied.
Indicate appropriate methods of analysis	A quantitative analysis would require relying on a large number of statistical data which is not available to date. A qualitative analysis of the fire scenarios sounds to be the most appropriate method for this type of construction.
Prepare fire safety manual	The reliance on a strong and operational fire safety strategy complement with the use of engineering methods to enhance the level of safety is demonstrated when dealing with a site under construction. The fire safety strategy would be detailed in a fire safety manual which reflects the general management and operational procedures of the organisation concerned.

Output results of QDR	The set of outputs collected through the QDR does not constitute an adequate set of data to develop a quantitative analysis. The optimum fire safety design could only be achieved in a non-changing environment, which is not the case with a site. The set of outputs collected through the QDR will enable the team to develop a strong qualitative approach and formulate a proper fire safety strategy.

Table 3.3: Qualitative Design Review: Maintenance QDR (<u>Modification</u> from Refurbishment/Renovation QDR <u>Underlined</u>)

With construction operations involving maintenance activities, the scenarios to develop a QDR will be very different. The facility concerned with the maintenance operations would already have an existing fire safety design, which also could be satisfactory and operational at the time of the works. We are therefore looking at the modification of the existing fire safety design to permit safe maintenance activities and a fire free environment for the workforce and the occupants.

QDR	Maintenance
Review the architectural design	*Building Design*: <u>The nature of the construction could be temporarily modified during the maintenance activities.</u> <u>Change of the normal circulation routes could imply a temporary modification of means of escape and the evacuation procedure of the occupants.</u> <u>Access of the fire brigade and fire appliances might be temporarily modified to allow some maintenance activities to be complete. The fixed firefighting appliances might be affected by these activities and temporary out of order. Alternative solutions need to be implemented to ensure an adequate level of safety throughout the work activities to safeguard the occupants and the property.</u> <u>Compartmentation could be modified during the maintenance activities and affect containment within a compartment. The implementation of further fire protection measures might be required to sustain the level of fire safety within the facility.</u> <u>The existing geometry and interconnection of spaces might be temporarily modified. Precautions should be taken to identify if this change would affect the occupants of the facility and their fire safety protection.</u> <u>The fire load density is expected to be at least the fire load of the finished facility plus any extra fire load brought in due to maintenance activities (extra construction materials and flammable liquids).</u> <u>The active and passive measures in facilities could not be affected or temporarily. Alternative solution to sustain the same level of fire safety prior to the commencement of the maintenance activities must be implemented.</u> <u>The continuity of fire safety management during the maintenance activities must be ensured and any plans or document related to this fire safety strategy, modified to allow the safe completion of the works and maximum safety of the occupants.</u> Access to the fire brigade and connection to water supply will be ensured. Adequate level of fire safety management will be implemented (JCOP requirements) *Occupants*: <u>The number and distribution of occupants would not change compared to the normal use of the facility. The maintenance team would be add to this distribution.</u> <u>The maintenance team or contractor might be required to move throughout the facility and display a high mobility. A permit of work would be completed and if required a hot work permit issued to control the high risk of fire in work activities involving the use of a naked flame, cutting and/or welding.</u>

	The facilities manager should ensure the safe completion of these activities in his premises. The usual circumstance of these activities might bring a higher risk of fire outbreak in the premises. The existing fire safety design might not have been planned to sustain this type of fire (maybe involving flammable materials and liquids or a higher quantity of materials). Action in case of fire and the use of portable and fixed fire protection systems might not be adequate at the time of the fire outbreak. Alternative and temporary solutions should be provided. The lack of familiarity with the facility and its environment reduces the familiarity of the maintenance team or workforce to evacuate the facility. *Enclosure*: The combination of a higher potential of ignition sources with the normal fire load and combustible content of the facility would be allow a fire to spread rapidly within a compartment and maybe outside. Additional preventative measures would be required to prevent fire outbreaks. The structural fire resistance of the existing facility shouldn't be affected by the maintenance activities and contribute to provide a good level of fire resistance of the facility. Any modifications (permanent or temporary) could affect the future fire resistance of the structure and be carefully thought through before any work starts (reservations in walls, ceiling, floors; cutting in partitions like a sandwich panel; removal of fire doors, windows, partitions…). It could contribute to the spread of smoke and fire to other compartments. Priority to retain the existing active fire protection measures (automatic extinguishment, ventilation, detection and warning system and control the growth and development of the fire.
Perform a characterisation study of the building, environment and occupants	*Building Characterisation*: The layout and the geometry of the facility might be affected by the maintenance activities. The fire load density would vary from the normal load of the facility (offices, 420MJ/m2; shops, 600 MJ/m2…) to the additional fire load brought by the work activities (extra 200MJ/m2 in one room or the storage area) and either temporary or permanently. *Environmental influences*: Some maintenance activities linked to the environmental conditions (roof works by dry weather conditions, drainage repairs…) or on a category of technical equipment in balance with the environment (air conditioning system, ventilation and HVAC, heating system, water shortage…) could have an impact on the response of the fire safety design during a fire outbreak: failure of the technical equipment to operate, extreme dry conditions which contribute to the development and spread of fire, shortage of water, low pressure of rising system… *Occupant characteristics*: The workforce might not be very familiar with the geometry and layout of the facility. Its distribution in different part of the site could be unavoidable, but they would be trained by the facility manager to respond to a fire (manual firefighting and alarm raising). The occupants would be working in the same environment and should be informed of any modification of the current fire safety procedure: raising the alarm, modified evacuation and means of escape. The duties and responsibilities of the contractor to communicate with the facility owner or Facilities Manager are essential to develop an effective fire safety strategy.

Establish fire safety objectives	*Fire outbreak*: Proper assessment of the risks should be developed by the facilities manager and maintenance contractor prior to construction or maintenance operations. This risk assessment should be periodically reviewed and a strategy developed to control and prevent the risks in the occupied facility (JCOP 2000 / CDM Regs 1994 and any fire safety regulation for building in use). *Life safety*: An evacuation plan should be developed to enable the occupants and the workforce, and any other occupant of the facility, to safely evacuate the facility and reach a safe area. (CDM Regs 1994 and any other regulation applying to the facility in use – Fire Precautions (Workplace) Regulation 1997, the Fire Precautions Act 1971). Consider modifying the existing evacuation plan of the facility in use if the maintenance activities affect the safe evacuation of the occupants. Link with the fire brigade would be established prior to the commencement of the maintenance activities if they were major. *Loss prevention*: Consideration for the continuity of the business activities (of the facility owner) should be addressed with the concerned parties (contractor/subcontractors, insurer) and a loss prevention programme developed to manage a fire outbreak. The modification of the existing contingency plan or business continuity plan needs to be integrated in the fire safety strategy. *Environmental protection*: Measures to protect the environment against the impact of a fire need to be taken: collection of used waters and their evacuation, management of waste on site and their safe storage…
Establish an evacuation strategy	Occupants and the workforce should be trained to evacuate the facility to a safe location. It is not recommended to process to a total evacuation of the facility but instead a zoned evacuation. The facility's evacuation plan will be detailed in the evacuation strategy.
Identify acceptance criteria	A deterministic approach would be adequate as the facility will offer a set of input data. Certainly considering the worst case scenario would be the most realistic approach but would not represent the majority of the cases of fires in maintained and occupied facilities. A probabilistic approach is based on a detailed analysis of fire statistics. Statistics of fire in different facilities are available. A comparative approach could be developed. The level of health and safety and the level of fire safety should comply with the current legislation and regulations. The general minimal level of fire safety of the structure should comply with the Approved Document B or equivalent guidance or codes. A financial approach is recommended as the Estimated Maximum Loss calculations can be carried out and is usually provided by the Insurer.
Identify fire hazards and possible consequences	A risk management approach would require a clear fire hazards assessment for the facility under maintenance activities. This exercise should be systematic and updated periodically to address the changing environment of a site. Possible failures scenarios should be designed and an assessment of the consequences and maximum site disruption addressed as well as the normal running business of the occupied facility.

Establish trial fire safety design	The trial solutions for a facility affected by maintenance activities is wide and alternatives and improved solutions could be recommended to enhance the existing fire protection strategy. The specification of alternative fire protection strategies would be a simple task. A financial criteria would easily identify the validity of alternative fire protection strategies. Minimum investment to protect the maximum value of the premises and the business activities. However better project management approach and method statement should be promoted to allow more flexibility in the earlier delivery of finished works.
Specify fire scenarios for analysis	Three possible scenarios can be designed: Minor destruction of the facility (<25%): no interruption of the business activities and minor repairs and cleaning. Partial destruction of the facility (26-50%): major repairs and cleaning but minor disruption of the business activities. Major destruction of the facility (51-100%): major repairs and cleaning and major interruption of the business activities.
Indicate appropriate methods of analysis	A quantitative analysis would be appropriate and detailed quantitative calculations could be carried out. A qualitative analysis of the fire scenarios would enforce the implementation of a better fire safety strategy.
Prepare fire safety manual	The reliance on a strong and operational fire safety strategy complement the use of engineering methods to enhance the level of safety is demonstrated. The fire safety strategy would modify the existing fire safety manual which reflects the general management and operational procedures of the organisation concerned.
Output results of QDR	The set of outputs collected through the QDR does constitute an adequate set of data to develop a quantitative analysis. The optimum fire safety design could be achieved in this environment. The set of outputs collected through the QDR will enable the team to develop a strong quantitative and qualitative approach and formulate a modified fire safety strategy.

3.2.3 The Quantitative Analysis

The second phase of the FSE process required a quantitative analysis of the QDR inputs. BS DD240 recommended splitting the analysis in to a number of parts, referred to as sub-systems. "The sub-systems are intended to provide guidance on the type of calculations that may be carried out in support of a fire engineering study and to present the appropriate general principles and procedures. The sub-systems are as follow:

(a) Sub-system 1: initiation and development of fire within the enclosure of origin
(b) Sub-system 2: spread of smoke and toxic gases within and beyond the enclosure of origin,
(c) Sub-system 3: fire spread beyond the enclosure of origin
(d) Sub-system 4: detection and activation of fire protection systems
(e) Sub-system 5: fire service intervention
(f) Sub-system 6: evacuation."

Sub-system 1: Fires at construction sites are very specific, as the enclosure of origin might either be a very enclosed space (roof space, basement, voids...) or a large open area (unfinished and uncompartmented floor, unfinished compartment...) which would allow a fire to spread beyond its enclosure of origin faster than in a completed building.

The unfinished nature of a construction site also demonstrated that material uninstalled (stored or/and packed) and unfinished could be more flammable than expected. The finished manufactured product installed in the finished product is guaranteed for a minimum fire resistance of 30mm, 1 hour, 2, 3, 4 hours... In the Minster Court fire (1991) the LFCDA reports that the fire " a cardboard type covering linked to the outside face of the fire resistant polystyrene blocks was likely to assist with ignition when subjected to a fire situation. The cardboard outer sleeve is apparently to prevent damage to the polystyrene." Until the facility is completed, it is often difficult to have a structure which is fire resistant and which would contain a fire and restrict the spread of smoke and fire within the facility and outside. The unusual high quantity of flammable material and products would increase the fire load and produce enough fuel for a fire to develop.

Sub-system 2 and 3: The lack of compartmentation and uncompleted passive fire safety measures allow the smoke and toxic gases to spread within and beyond the enclosure of origin. In the Minster Court fire (LFCDA, 1991) between the time of the discovery of the fire (07.20) and the arrival of the fire brigade (07.34), one foreman was trapped in the upper floor because "the smoke was too thick and he could not get out of the building." At 07.20 another foreman at the upper ground floor "went towards the atrium to collect some tools and saw a 'wall of flame' on the opposite side." In circumstances where fire cannot be contained there is often no distinction between the spread of smoke and fire within and beyond the enclosure. A proper completed design would have contributed to contain the fire for a given period of time to allow the fire brigade fight the fire and restrict its spread. In the Broadgate fire (The Steel Construction Institute, 1991) "none of the fire doors to the staircases or lifts were in position when the fire occurred."

Sub-system 4: The Joint Code of Practice for fire prevention on construction sites (1992-2000) requires the implementation of a Fire Safety Plan. This FSP should detail the fire safety measures in place on site. There are no statutory requirements for the implementation of any detection and warning systems, but every reasonable and minimum measure should be implemented to protect the workforce against fire. The use of a fixed detection system is rare but recent disasters recommended the use of the existing and operational detection system as early as possible before completion. Portable detection systems are now available but they are not commonly used by contractors, and only when special risks are involved (hot works in historic buildings, confined spaces, industry with high risks such as chemical, nuclear power stations, off shore industry…). We would expect on site, no automatic detection and manual warning. Instructions on how to call the fire brigade is usually located in the security hut or main office. The provisions for an active fire protection system and its activation after raising the alarm could also contribute to restrict the damages. In Broadgate fire the Steel Construction Institute (1991) recommends that "in a completed building any fire should be controlled in its early stages by the sprinkler system." They highlighted "the necessity to consider appropriate fire precautions during the construction phase."

Some refurbishment sites might benefit from the use of the existing and operational fire protection system and maintain its operation throughout the construction works. However it doesn't seems to be a systematic approach. Maintenance operations are most of the time carried out in an occupied facility, in use and under the responsibility of the owner. In this situation, it is most likely that the existing fire protection system will be maintained throughout the maintenance operations and no interruption of the fire safety protection system would be allowed. We however experienced some fire where the fire protection system had been temporarily disconnected to complete the works and a fire broke out at the time. The activation of the fire protection systems (manual or automatic) might therefore be delayed by a crucial time which allow the fire to develop within the enclosed space. It is most likely that the fire would be detected by one of the occupant (workforce, user, fire watch, site manager, member of the public...). In Broadgate (The Steel Construction Institute, 1991) "the building has a sprinkler system but this was not installed at the time of the fire. The automatic fire detection and alarm system was not installed when the fire occurred."

Sub-system 5: the intervention of the fire brigade on a construction site is crucial to control the development of the fire. Like in Broadgate (The Steel Construction Institute, 1991) the unfamiliarity of the building site was an major issue to tackle the fire: "Problems were encountered in locating fully operational dry risers as a consequence of unfamiliarity with the building layout and the access route, hoarding and inadequate signs." There is no requirement under the law to force the fire brigade to visit the site on a regular basis. The contractor is under the obligation to inform the fire brigade of the location, size and layout of the site, as well as to the Local Authorities. A Fire Safety Plan and Health and Safety Plan (respectively developed under the JCOP 2000 and CDM Regs 1994) requires that a set of plans of the facility must be available at the entrance of the site in the security hut for inspection and use by the fire brigade.

Sub-system 6: the evacuation of the site would be given by a person of authority (site manager, health and safety manager, fire watch, security officer) and in large and complex site a voice system should be installed. Otherwise, the alarm is raised by the occupant. Delay and receiving instructions to evacuate the site can be a major factor in a fire situation. Both in Minster Court (LFCDA, 1990) and Broadgate (The Steel Construction Institute, 1991) some members of the workforce were trapped in upper floors and had to be rescued by the fire brigade. The changing environment of a site on daily basis could affect the evacuation process. Lack of signage or blocked fire escape routes are a common practice on site.

3.2.4 Assessment against criteria: Probabilistic, Deterministic and Comparative.

A probabilistic approach to assess each of the above system would be possible if our site characteristics were static. Moreover, the statistical data and annual probability of the unwanted event occurring to express a risk criteria and probabilistic approach was not available yet. The dearth of research, scientific theories and lack of statistical data to assess the problem of fires on construction sites was a major barrier to address the problem from a fire safety engineering approach. A deterministic approach would be possible for each of the system, but it would require the compilation of thousands of scenarios to address each fire situation at each stage of the construction. BS DD240 (BSI, 1997) actually comments on the limits of application of the deterministic criteria and precise that "justification should be given for any extrapolation of test data." We can assess three fire scenarios (Figure 3.7):

Figure 3.7: Possible Failure scenarios

Figure 3.8: Assessment against criteria

BS DD240 (1997) states that "it can be often difficult to establish the level of safety achieved in absolute terms and that it may be relatively straightforward to demonstrate that the design provides a level of safety equivalent to that in a building that conforms to more prescriptive codes." The Joint Code of Practice (2000) does not prescribe a detail set of requirements to use it as an outstanding document to complete the FSE method. A deterministic approach seems to be the most valuable and reliable solution to demonstrate a satisfactory fire safety strategy for construction sites (new, refurbishment/renovation, maintenance). It is essential to consider several fires scenarios, maybe at the most critical stages of the construction works: completion of the superstructure, fit out, finitions and hand over.

3.2.5 Reporting on the validity of a FSE approach (for buildings under construction, refurbishment/renovation or maintenance)

The complexity of a construction site in its changing design and fire load, the non static spread and mobility of occupants and the availability of combustibles and the fractile fire load on the imposed structure made it difficult to assess and quantify the building data to develop a probabilistic design. A deterministic approach was not excluded if several scenarios were developed at critical and high risk phases of the construction process. A comparative approach was to date excluded, as the JCOP was not prescriptive enough.

However early stages of the FSE method and the QDR are very informative and would form an excellent basis to develop further the qualitative method. The JCOP requirements focus on the development and implementation of a "made to measure" fire safety strategy for the management and prevention of fires during construction works. The implementation of fire safety measures and protection systems on construction sites as soon as feasible and possible should be taken into account in the design and the FSE approach for the finished facility. BS DD240 (1997) focus on the safety of the occupant in the finished facility but not during construction. The QDR exercise could to be extended to consider the early implementation of protection system to protect construction workers in new construction and refurbishment/renovation works. Maintenance sites were to be considered in a different category and the design and FSE approach should provide a flexible design, easy access to technical equipment to prevent fires during maintenance operations.

There was room for improvement within the FSE approach to consider the stage of construction as well as the finished facility. However the use of the FSE approach for construction site safety was to date not feasible. The lack of statistical information of fires on construction sites was a major barrier and no probabilistic data could then be developed. However, as demonstrated, the QDR was very informative. The author suggested that this exercise should be extended to develop a detailed qualitative analysis to determine a fire safety strategy for the prevention and management of fires on construction sites.

3.3 Fire Statistics

The statistics presented in this chapter have been built with a series of published and non-published documents by different governmental organisations and other bodies. The accessibility and reliability of these figures was unfortunately uncertain and could lead to a misinterpretation of the true figures. The governmental organisations and bodies relied on the fire reports completed and forwarded by the Fire Brigades and the Insurance companies which most of the time protect information from the general public. Accessing those primary sources of information is restricted in order to protect the interest of both contract parties and Insurance Companies involved in the incident. It was therefore impossible to dress a real *portrait* of the situation and the problem of fire on construction site and the economic impact of a fire. Figure 2.6 illustrated the complexity of the framework of collection of data.

Figure 3.9: Collection of fire statistics: a complex framework

The second problem related to statistics was the fact that a large number of fires are unreported because they are without any financial and human consequences. Fortunately a very low number of fatal injuries has been reported this last ten years. **It was therefore impossible to evaluate the number of unreported fires on site.** Construction Safety has been a serious concern to most construction companies since accidents not only reduced productivity and damaged equipment but frequently also injured human beings. Accidents affected both construction costs and profitability through delays, damage to equipment and materials, damage to the facility under construction or through compensation payable as damages for accidental injury or loss of life. Every year many fires occurred in buildings under construction, and the occurrence of these fires contradicted the popular belief that modern buildings couldn't burn. Very few fires on building sites made headline news because loss of life was relatively small. The total damage, however, could be very costly - not only in terms of direct damage but also through the imposition of contract time penalties and because of the inflationary costs of replacement materials and labour. Tables 3.4 and 3.5 summarised a number of major fires in the UK and around the world.

Table 3.4: A Selection of major UK fires on construction sites: Construction, Refurbishment, Renovation and Demolition.

DATE	LOCATION	Total loss in the year and number of fires	OCCUPANCY	TOTAL LOSS: £	Type of PROCUREMENT	Advancement of the work	CAUSES	Fire Damages	InjuriesMajor /Minor :
23/06/90	London, UK Broadgate Phase 8	£39,820,000 8 fires	Commercial Building	£33,500,000	Construction Modern "fast-track" steel frame	Fire occurred during the final stages of the construction programme	Fire began in a large contractor's hut	Limited damage to the structural framework Small deformations to the heads of the columns large deflection to floor and truss assemblies Small deflection to many secondary beams Significant smoke damage throughout the entire building	No injuries
07/08/91	London, UK 8 Minster Court	£109,575,000 7 fires	Multi-storey office block under refurbishment	£105,000,000	Refurbishment	Advance stage of major works programme fitting out	Unknown Supposed naked flame.	50% floor and 50% ceiling severely damage by fire 25% floor and 25% ceiling damage by heat and smoke	2 minor injuries
04/11/91	Linconshire, UK	£109,575,000 7 fires	Hall	£2,000,000	Renovation	Later stages: redecoration of windows	Electric: house alight	Extensive fire damage to the southern wing Nearly complete destruction	No injuries
17/11/91	Kent, UK	£109,575,000 7 fires	School, Refurbishment	£2,000,000	Conversion and Renovation	Unknown	Arson	50% of the GF, 1st & 2nd severely damage by fire 100% of GF, 1st & 2nd by smoke	No injuries
15/06/85	Camberley, Surrey, UK	£3,300,000 4 fires	Council Offices, Construction	£2,500,000	Construction, Package Deal JCT Form of Contract	80% completed 18 months contract	Malicious: plumbing work in the roof space above acoustic material	Extensive fire damages on the totality of the building (100 yards). Fire burnt 8 hours. Very fast fire spread.	No injuries.

Table 3.5: A selection of worldwide fires on construction sites: Construction, Refurbishment, Renovation and Demolition.

DATE	LOCATION	CAUSE OF FIRE:	OCCUPANCY	TOTAL LOSS: £	Type of Procurement	Advancement of the work	CAUSES	Fire Damages	Injuries Major /Minor:
03/05/84	Philadelphia, USA Harrisson Court Building[4]	Cutting Operations	Former Commercial Property Office space and shops	£36,000,000 equivalent to $20million	Extensive Renovation	Removal Phase to prepare the building for extensive renovation	Spark from cutting operation which ignited combustible debris	Totally destroyed by the fire 17 other buildings received varying degrees of fire damage 27 other buildings damaged by smoke and water.	6 minor injuries
15/01/85	Hoboken, New Jersey, USA Minneapolis Bank[5]	Burning materials	Warehouse	£18,000,000 equivalent to $10 million	Demolition	Undergoing demolition	Small fires in metal containers Burning materials from those fires ignited accumulated combustible rubble	Building, along with several small miscellaneous buildings contained in the block, was eventually destroyed by fire.	Unknown
1990	Meridien President Tower, Bangkok[6]	Explosion / Welding operations	Hotel complex	£75,000,000 equivalent to 25million DM	Construction	Later stage of completion.	Services equipment was installed and some welding operations provoked an explosion.	The fire destroyed 3,000m2 of the high rise construction (total: 130,000m2).	150 workers evacuated. 3 fatal injuries.
23/06/90	London, UK Broadgate Phase 8[7]	Unknown	Commercial Building	£33,500,000	Construction Modern "fast-track" steel frame	Fire occurred during the final stages of the construction programme	Fire began in a large contractor's hut	Limited damage to the structural framework Small deformations to the heads of the columns large deflection to floor and truss assemblies Small deflection to many secondary beams Significant smoke damage throughout the entire building	No injuries

[4] Rule, C. (1985) Fire destroys Philadelphia building under construction, Fire Journal – Investigation Report, May 1985.
[5] Kyte, G. (1985) Warehouse demolition fire takes out city block, Fire Command – Investigation Report, October 1985.
[6] Munich Re. (2000) Les immeubles de grande hauteur. Munich Re., pp89.
[7] The Steel Construction Institute (1991) Structural Fire Engineering: Investigations of Broadgate Phase 8 Fire.

07/08/91	London, UK 8 Minster Court[8]	Unknown / Supposed naked flame	Multi-storey office block under refurbishment	£105,000,000	Refurbishment	Advance stage of major works programme fitting out	Unknown Supposed naked flame.	50% floor and 50% ceiling severely damage by fire 25% floor and 25% ceiling damage by heat and smoke	2 minor injuries
30/01/96	Venice, Italy La Fenice Opera House[9]	Unknown	Opera House	£180,000,000 equivalent to $100 million	Renovation	Undergoing restoration Improving fire systems and alarms (had been switched off)		One of the 3 blocks making up the building was severely damaged. Roof comes down Outer wall standing	Unknown
02/96	Seville, Spain Expo '92, Pavilion Descubrimientos[10]	Unknown	Pavilion	£86,400,000 equivalent to 36 millions DM	Construction site.	Later stage of completion (2 months before completion) Steel Frame Structure	Soldered joint in paint. Spontaneous ignition	Complete destruction of the steel frame structure Extensive fire damage of several pieces of Art	Unknown
11/04/96	Dusseldorf Airport, Germany[11]	Unknown	Airport	At least £360m equivalent to $200-600 millions	Refurbishment Maintenance Work	Undergoing maintenance work above public circulation area	Welding work and bitumen above Departure Area caused spark	A surface of 200mx50m completely destroyed by flames. The conference centre, underground railway station and some storage premises have been extensively damaged by smoke. Dioxin contamination at the Arrival Level (10ngr/m2).	16 fatal injuries >100 injuries (2 major injuries)

[8] LFCDA (1991) North Area Fire Investigation Team Report: The London Underwriting Centre, 3 Minster Court, London EC3.
[9] Hooper, J. (1996) Blaze reveals huge risk to 'City of wood', The Guardian, 31/01/96.
Anon. (1996) Opera house will be rebuilt, ENR, v. 236 (6), pp11.
[10] Lardschneider, W. (1993) Gros incendie dans un pavillon d'exposition, Schadenspiegel, 36e année (2). Munich Re.
[11] NFPA (1996) Fire Investigation Report: Airport Terminal Fire, Dusseldorf, Germany, 11 April 1996. Prepared by Ed Comeau.

21/11/96	Garley Building, Hong-Kong[12]	Welding operations	Offices complex	Unknown	Renovation and Maintenance	Undergoing maintenance works. The high rise construction was occupied by 130 workers and staff.	Welding works ignited highly flammable materials in the basement of the facility in the lift shaft.	The fire spread through the lift shaft to the three above floors. Extensive fire and smoke damages.	39 fatal injuries and 80 minor injuries.
28/01/97	Sight & Sound Theatre, Pennsylvania, USA[13]	Welding operations	Theatre	£33,000,000 equivalent to $15 millions	Refurbishment	Undergoing renovation and the Theatre was closed to public	Construction worker welding steel plates on the stage floor directly above the point of fire origin in the stage storage area	The fire caused the collapsed of the Theatre and resulted in structural damage to most of the connecting building. The Theatre was a total loss.	200 people evacuated. 6 minor injuries
20/06/98	Ballymoney, Northern Ireland[14]	Accidental	Processing factory	£24,000,000	Refurbishment and construction works	Electrical works on a transformer	Metal bolt accidentally dropped onto a live electrical busbar.	Extensive fire and smoke damages. 90% of the premises destroyed.	2 minor injuries

[12] Munich Re. (2000) Les immeubles de grande hauteur. Munich Re., pp99.
[13] US Fire Administration (1997) Technical Report Series: $15 million Sight & Sound Theatre Fire and Building Collapse
[14] Fire Prevention (1999) Food processing factory, Fire Reports: Food Industry.

3.4 Fire Losses

Fire losses in the UK between 1984 and 1995 were estimated to be £152.4 million. During this period, two specific fire incidents should be noted. Both large fires which occurred during construction (at Minster Court and at Broadgate, London, in 1990 and 1991, respectively), they, alone, accounted for £138.5 million of losses. This sum represented 90.87% of the total cost of fires in the UK over the whole period.

Date	Site and Location	Individual Loss (£)	Cause
15/06/85	Building under construction Camberley, Surrey	2,500,000	Naked flame ignited fire proof material
11/07/87	Building under refurbishment Blackheath, London	1,000,000	?
30/05/89	Building under refurbishment Marlow, Buckinghamshire	3,650,000	?
23/06/90	Commercial building under construction, London (Broadgate)	33,500,000	Unknown
08/12/90	Offices under construction Glasgow.	5,000,000	Unknown, possibly electrical
19/08/90	Department store under construction West Hurrock, Essex	5,000,000	Suspected malicious ignition
31/01/91	Historic Building undergoing refurbishment, Aberdeenshire	6,000,000	Suspected Arson
15/04/91	School under refurbishment, St Helier, Jersey	2,800,000	Accidentally caused by contract workers on roof.
07/08/91	Offices under refurbishment London (Minster Court)	105,000,000	Unknown, supposed naked flame
17/11/91	School under refurbishment Ashford, Kent	2,000,000	Arson
21/02/92	Building under construction Newcastle-upon-Tyne, Tyne & Wear	2,500,000	Arson
16/05/93	Building under construction Strood, Rochester, Kent	1,320,000	?
09/02/95	Police training College under renovation	1,250,000	Electrical or blow lamp
09/02/95	Building under conversion (refurbishment) Slaugham, West Sussex	1,250,000	?
16/03/95	Building under construction Rochdale, Lancashire	1,000,000	Accidental ignition of roof by generator flue
03/08/95	High School under refurbishment, Wakefield, West Yorkshire	4,400,000	Electrical Fault
19/02/98	Hotel under refurbishment Washington, Tyne &Wear	3,000,000	Hot work
03/11/98	Hotel under renovation	4,250,000	Accidental / Deliberate

Table 3.6: A sample of U.K. Construction Fire Losses exceeding £1milion, 1984-1998

One might be forgiven for arguing that these two incidents should be considered as exceptional or due to some special circumstances of the period. However, when the causes were analysed, they were clearly management and/or worker attitudinal negligence. These studies revealed a lack of attention to prevention of fire on building sites. Preliminary research pointed out this problem being endemic to the industry, worldwide. Such major fire incidents have occurred in many countries, as listed in Table 3.5. Table 3.6 above, lists a sample of major construction site fires which have occurred in the U.K. during the period 1984 to 2000.

The **limited access to the record of fires on construction sites did not allow the author to develop a detailed quantitative analysis and probabilistic approach**. However an attempt to demonstrate the distribution of 50 fires between 1985 and 1998 based on their recorded direct losses was not completely conclusive. The restricted sample of data (50) over a 13 years period was not representative of the real extend of the problem. Moreover the data used for this short statistical analysis did not take into account fires with losses below £50,000 as they were not recorded by the statistical bureaux (FPA, Home Office, LPC, Fire Brigade, HSE). The evidence collected through this research however determined that the majority of fires had losses below £50k (more than 80%).

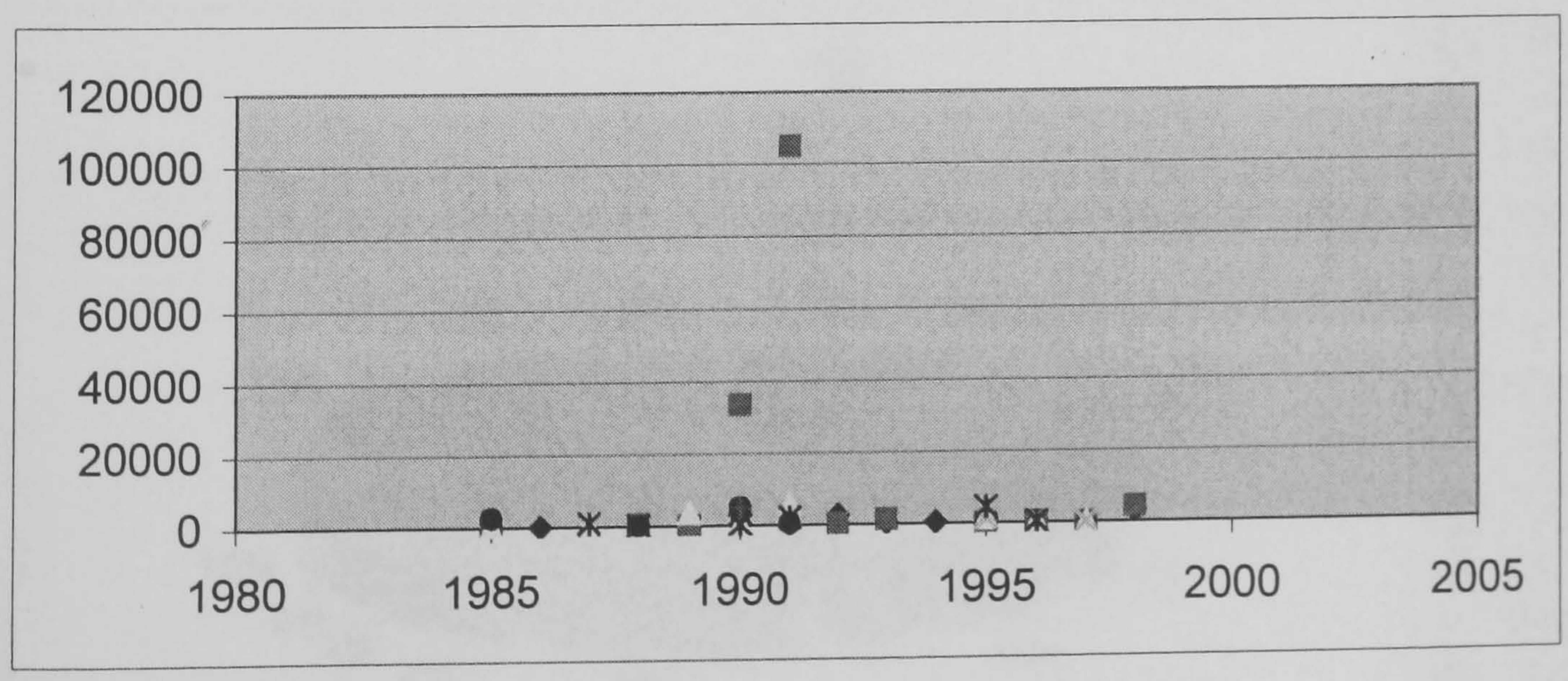


Figure 3.10: Distribution of fire losses (1985 - 1998), all fires in £000

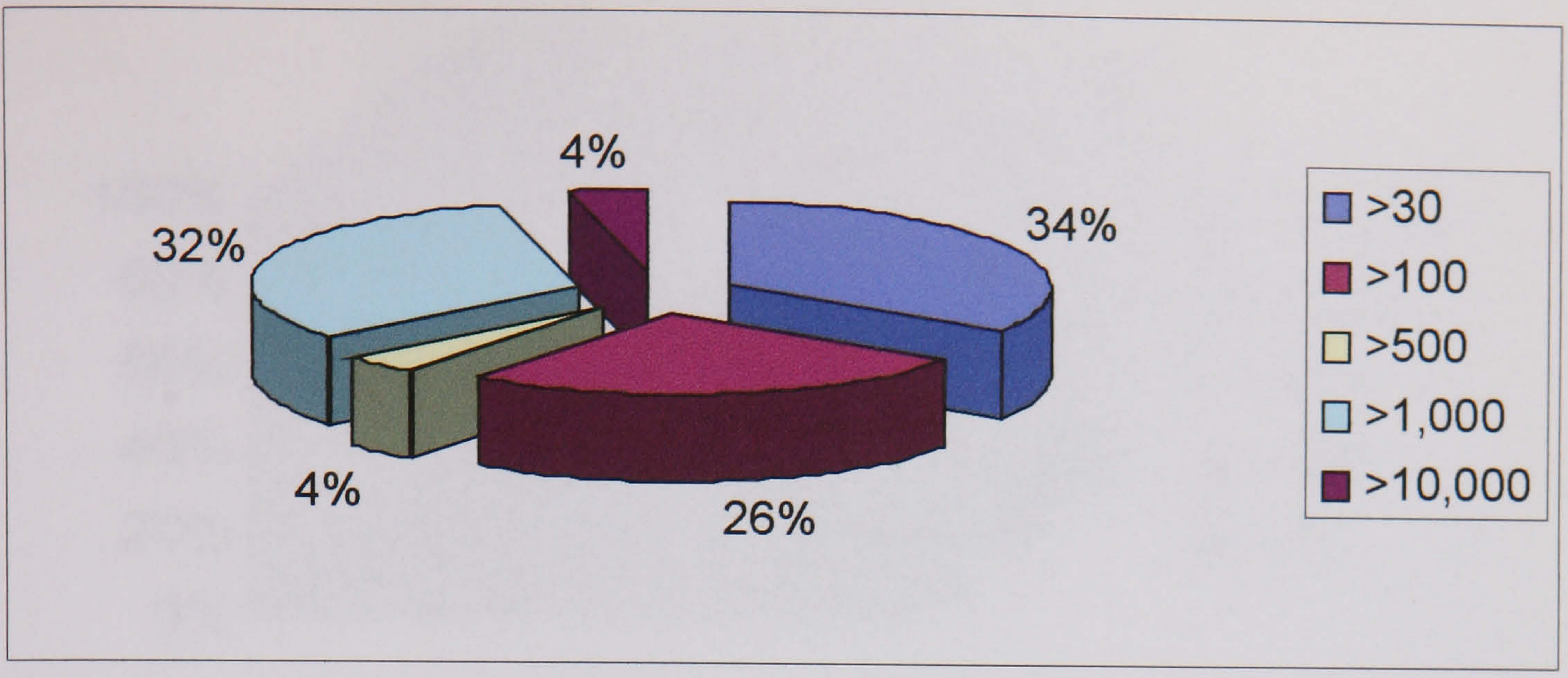
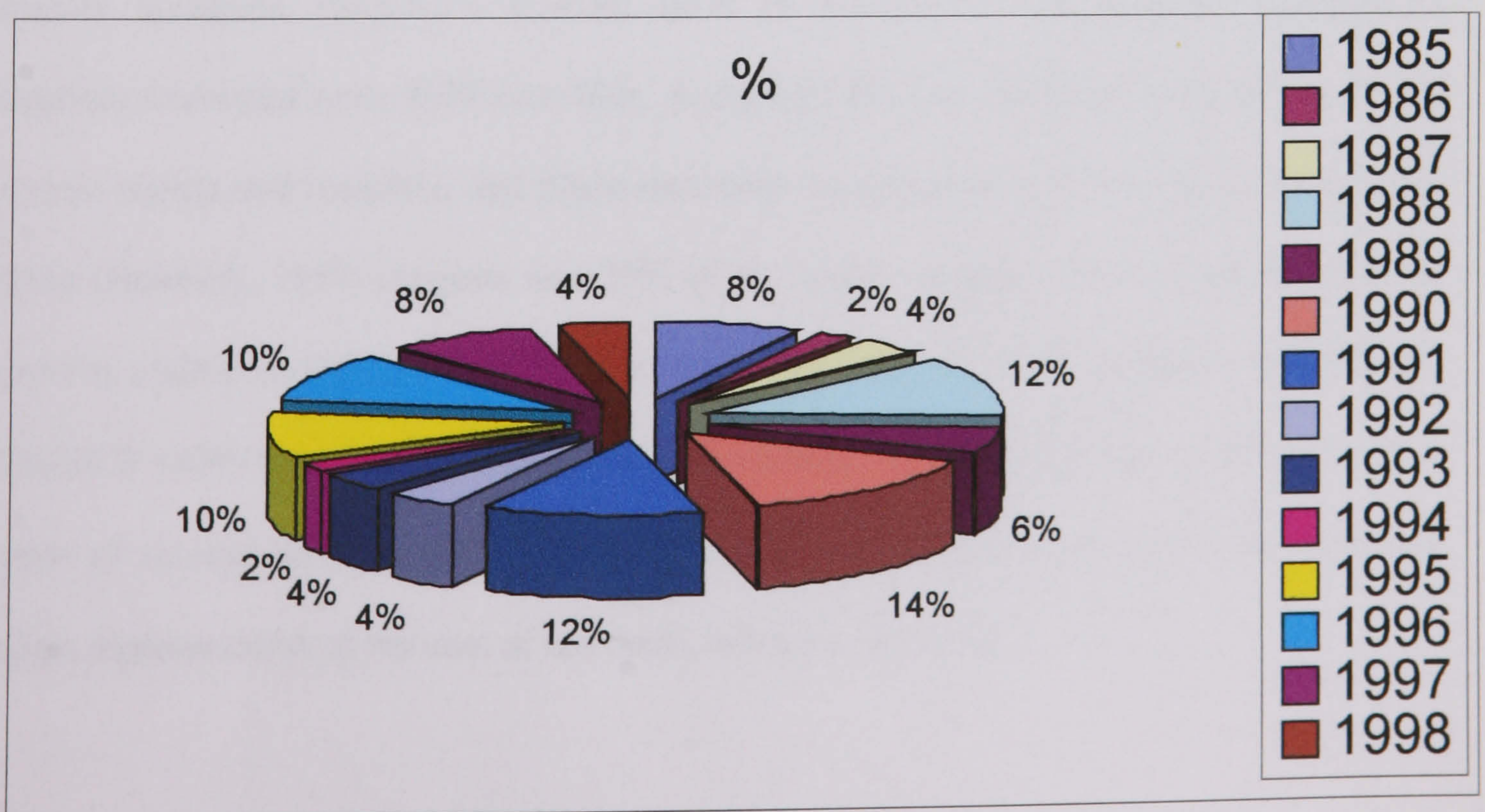


Figure 3.11: Pie's distribution of Fires in % for the years between 1985 and 1998 (in £,000)

The statistical analysis revealed that less than 50% of the fires had losses below £500K. More than a quarter of the fires generates losses between £100K and £499K and the remaining 34% for minor losses below £99K (Figure 3.11).



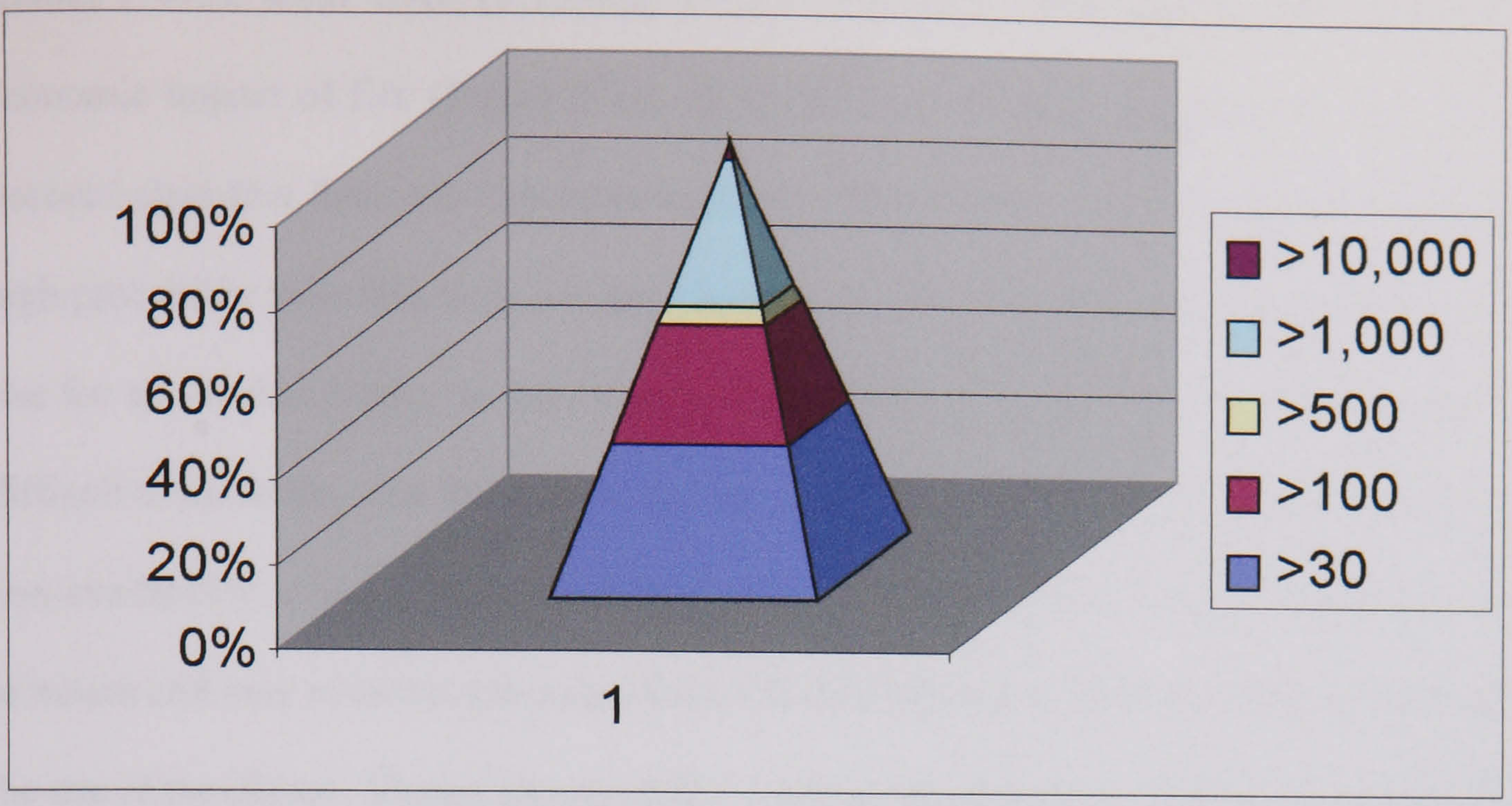


Figure 3.12: Pyramidal distribution of fires in % for the years between 1985 and 1998 (in £,000)

The top of the pyramid (4% in Figure 2.13) represented the two major London's fires in 1990 and 1991 (Minster Court and Broadgate). The exceptional nature of these fires and consecutive losses had a major impact on the industry (an increase of 400% of premiums).

A fire during the construction phase impacts dramatically on both contractor and client. The cost of fire could be illustrated by analogy with Heinrich's "Iceberg" (1959) explanation of industrial accidents. Heinrich's detailed study of the cost of occupational accidents to enterprises examined some 5000 case files. It distinguished two different kinds of cost for an accident: visible and invisible; and illustrated them metaphorically as an iceberg. Heinrich's Iceberg (Heinrich, 1959) suggests that 20% of the costs associated with accidents could be classed as visible or DIRECT COSTS, i.e. those usually covered by insurance, and 80% as INDIRECT COSTS which were invisible. This concept has been followed and re-used by a number of economists around the world and, moreover, this analysis was still recognised as the best representation of the cost of accidents, whatever the cause.

Rullier (1992), from UAP (a leading French insurance company), in 1992 analysed the economic impact of fire (Figure 3.13). In addition to the costs suggested by Rullier, it has become clear that there are two other aspects to this matter. The first was that there was a high probability that, following a major fire loss, the future cost of insurance premiums would rise for all insured parties as insurance companies try to recoup losses. Secondly, but more difficult to ascertain, was the costs to society resulting from the inconvenience caused by the non-availability or late completion of the building. Both were, of course, extremely difficult to assess and may even be non-quantifiable. Rullier alluded to these problems in his paper by the use of the phrase *"Pertes immaterielles"* (non-material losses). Rullier also argued that **in today's economy, where management was required to be more cost-effective, control of fire loss and business interruption was of prime importance**. Because of the human factor, it was impossible to entirely eliminate the possibility of fire where construction was in progress. Large losses, however, could be reduced significantly by taking proven loss control measures.

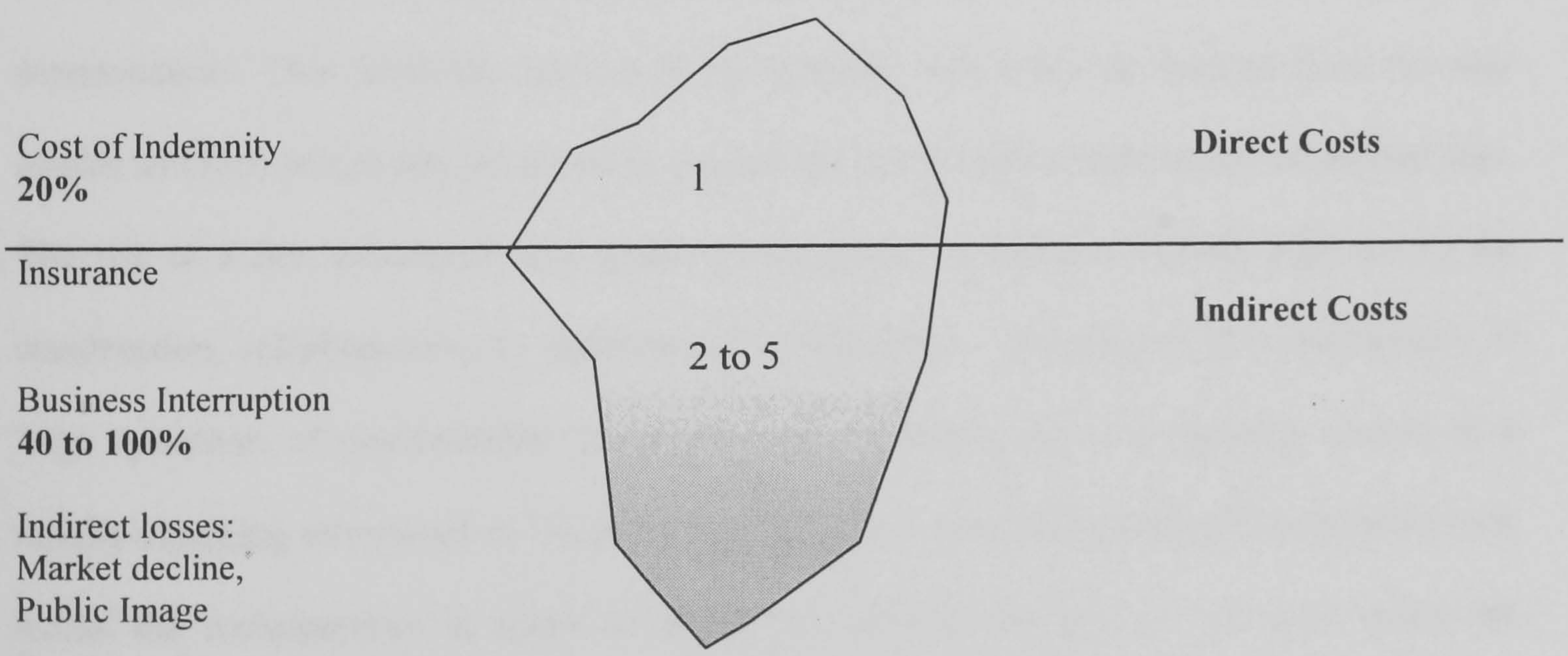


Figure 3.13: Impact Economique reel d'un incendie (Real economic impact of a fire), Rullier, P, UAP, France.

Even after assessing risks, it was not always easy for a client to understand, and accept, their importance at the outline brief stage of a project. However, **the problem of fire during the construction stage of a project became the problem of every participant in the process** should a fire occur. **Transfer of responsibility** was not the only solution and the site manager should not be the only person to blame.

Accidents affect both construction costs and profitability through delays; damage to equipment and materials (Puybaraud & Barham (1997) and Ebner (1994)); damage to the facilities under construction, refurbishment, or maintenance; and/ or through compensation payable as damages for accidental injury or loss of life.

The accessibility, comparability, and background of the figures were unfortunately also indeterminable. There is consequently some residual uncertainty about the realism and scope of the generalised statistical portrait, particularly when it is pushed to make assessments of process issues - a situation recognised for instance by Kidd (1992), Hinks (1992) and much later Carey (1997) and Puybaraud & Barham (1997). More valuable evidence tends to come from detailed reports for pivotal fire events. In the fire safety research field this problem is well recognised.

The second problem related to the statistics arises because a large number of fires appear to be unreported, usually because they are without any major or immediate financial and human consequences. This invisible element of the problem will leave the lessons from the near misses and fires where any processes or procedures lead to successful control unreported also.

The risk of a fire occurrence was generally recognised as being extremely high during the construction, refurbishment, or maintenance of buildings - because of the combination of large quantities of combustibles combined with numerous potential ignition sources in a rapidly-changing environment. In partially occupied or occupied buildings undergoing such works the consequences in terms of direct loss of property and/ or occupant safety are potentially profound, even where the fire which causes these problems may be relatively minor.

The significance of this issue for business appears to still require drawing-out, perhaps via the Facilities Management field. The direct consequences for the core and non-core business from fire events in critical core or support business premises (and/ or to people) are potentially very damaging to business continuity. However the issues appear to remain under-stated.

Turning to the attempts to quantify the visible, reported, element of this problem, the UK Home Office (1998) reported a total loss from fires of £706m for 1996. Every year in the UK, the total number of incidents attended by the fire brigade averages more than a million (UK Home Office, (1998)). The UK Health and Safety Executive (1997) reported more than 4,000 construction fires annually, the equivalent of more than 10 fires on construction site per day. Furthermore, there was evidence to suggest that of a total of 700 construction site fires during 1993 in the UK, 70% were adjudged to have be *deliberate* or *possibly deliberate* fires (UK Home Office, 1997).

The survey carried out by one of the major Insurance (Anon, 1998) provider in Europe and worldwide concluded that for all Contractor All Risks (CAR) policies –1,210 major losses between 1982 and 1996- constructions/buildings losses due to fire were the most important across all CAR activities (silos, roads, wet risks, tunnels, bridges, sewers and buildings). Losses due to fires account for 60% of total buildings losses between 1982 and 1996; 20% accounts for event of nature, 8% for construction methods, 3% for design, and 4% to other causes. The distribution of losses for buildings only across the same period (1982-1996) demonstrated that fires accounts for 63% in average for the period, with a significant increase in 1990 and 1991 due to the two major London fires (Minster Court and Broadgate). Figures from 1994 to 1996 showed a reduction in the percentage of loss amount due to fire but it does not demonstrate a significant profile of reduction. We would need to look at a longer period. However, following the introduction of measures of fire safety on site and during the construction process, 1993 showed a major reduction of losses due to fire (23%), but a major increase of losses due to construction methods. The survey and analysis of 485 major losses is the most accurate quantitative information available about construction fires and from a reliable source.

According to a number of survey sources (for example, the Fire Protection Association (1997); UK Home Office (1996); and the UK Health and Safety Executive (1997)) the average cost of construction sites fires per year exceeds £2m per year, and in 1990 and 1991 surpassed £34m and £109m (respectively). Meanwhile, insurance companies across Europe report an intriguing breakdown of figures – indicating that 36% of fires on site are caused by a fire ignition source, such as hot works, welding, and cutting. However, a further 11% arise from management mistake, which may originate from a lack of supervision or training. 7% were considered to occur as a consequence of a design mistake; 26% were considered to arise from natural disasters, and 20% were categorised as indeterminable or other causes.

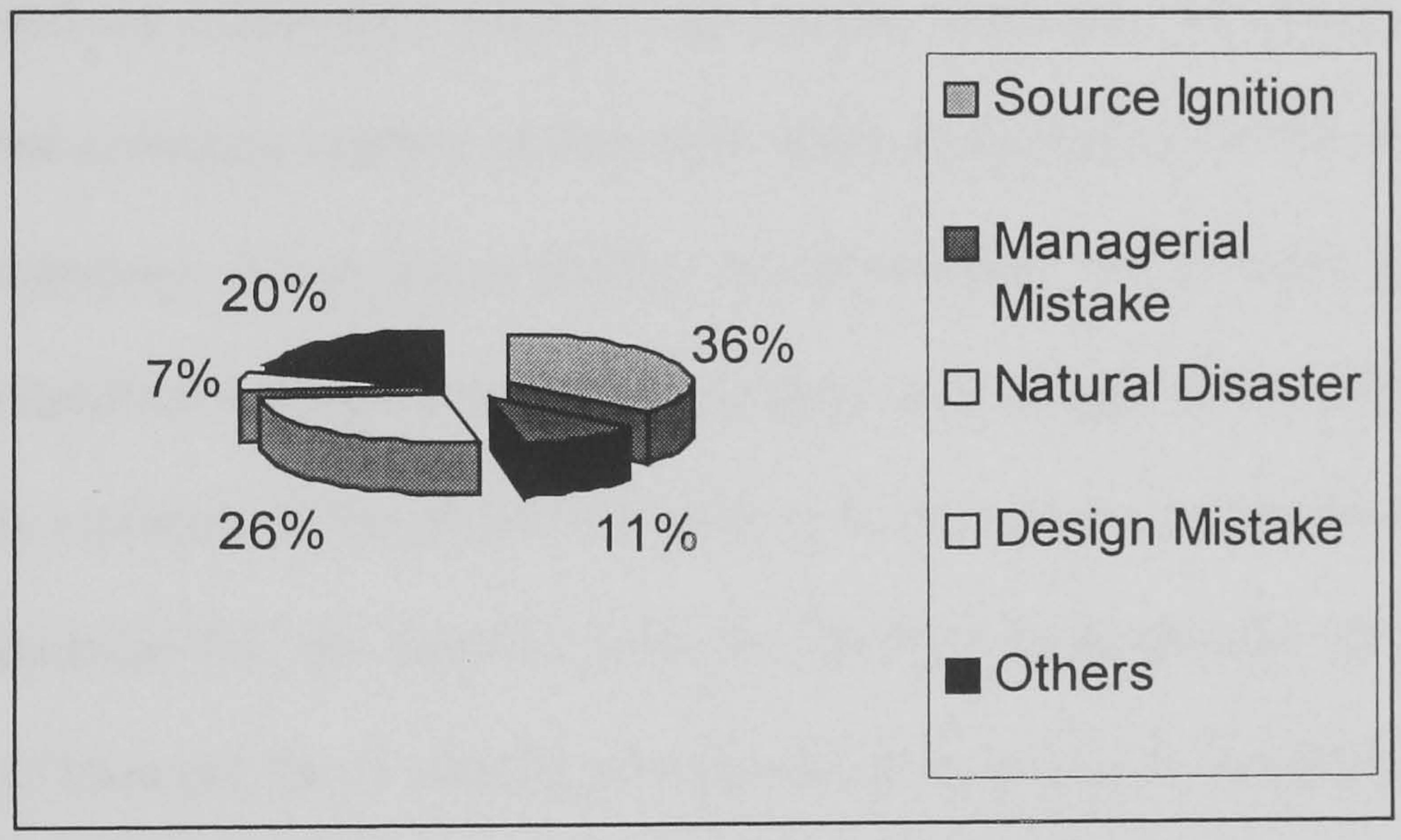


Figure 3.14: Generic distribution of the causes of fires

It also appeared that 43% of these fires were caused by negligence, and cost 33% of total fire losses for the insurance company. Arson fires cost to this insurance company 31% of the total fire losses.

Abbott (1991) reported that the causes of damages appear to range from technical defects, dangerous work not carried out with the necessary care, unpredictable combinations of perils, faulty operations, and negligent observance of safety regulations all the way to arson. Ebner (1994) argued that man occupies first rank among all perils - citing negligence, carelessness, overrating, overstraining, insufficient training, faulty estimation of consequences, also *intent* as the sources of most of the fire-related damage on construction sites.

An in-depth analysis by the UK Home Office Research and Statistics Directorate in 1997 (*UK 1995 Fires)* showed that 70% of the fire on construction sites are initiated by arsonists. This has also become a general concern across Europe, for instance the Arson Prevention Bureau (1997) revealed that *"at least 40% of the cost of the total fire damage in Europe is due to arson. Arson is now recognised in more countries as their major fire problem –socially as well as economically."* **Clearly the causal side of the equation is complex, locally unpredictable, and may include a degree of deliberation**.

Initial causes aside, the total *direct* financial damage to business caused by site fires could be very costly of course – and in addition there was the potential for the imposition of contract time penalties (and the inflationary costs of replacement materials and labour). Focusing on this issue, the real economic impacts of fires were analysed by Rullier (1992) on behalf of a French insurance company. According to Rullier, the distribution of fire losses is estimated to be a 20%/ 80% distribution respectively for *direct* losses and *indirect* losses. However this approach only reveals a portion of the picture, and may under-emphasise the significance of *indirect* site fire consequences for the business and the Facilities Management domain. For instance, continuity of business, the availability of core and non-core process facilities, and/ or supply and flow of resources (including facilities and people). From the perspective of business continuity (particularly so for businesses which are particularly sensitive to process interruption or seasonal peaks), the real impact of a fire may reside in the *indirect* consequences rather than the *direct*.

Rullier went on to argue that the control of fire loss and business interruption should be considered for its prime or direct importance. In a special report about fire prevention, Ebner (1994) expanded the context and argued that there was a temporal relationship between construction losses and business impact that broadly correlated with the phases of construction. There are several possible reasons for this - in relation to the scale and nature of exposed combustibles, combined with the co-operation of a combinations of hazardous activities in increasingly-confined and (sometimes rushed) operations – there is also quite obviously greater amounts of added value at risk on the site as the building nears completion, and the fire load may pose a greater threat to the remainder of the existing premises towards the end of its construction. If the passive and active fire protection provisions are incomplete or not fully operational (or not yet integrated where they should be with the existing systems), then the risk and provision could be imbalance.

Ebner continued by observing that concerns are given to large-scale damage occurring either during or immediately after installation of construction site as well as damage during the final phase of construction or assembly works. The distribution of risk throughout the construction project would therefore vary between a low risk and a high risk of fire. Abbott (1992) insisted that the sort of material damage losses the insurance market has seen at Broadgate Phase 8, UK, 1990 (which accounted for £35m+ loss alone); and Minster Court, UK, 1991 (£120m+ loss) is to say nothing of the associated and consequential losses, i.e. the *indirect* cost (80%) associated with fire. These latter issues appear to be relatively unprobed areas for Facilities Management.

The limited availability of statistical data on fires on construction sites demonstrates a dearth of research in this scientific area and proves to be a major barrier to develop a quantitative analysis of the study. A probabilistic approach is excluded and empirical data would need to be obtained to redirect the research towards a qualitative approach.

3.5 Analysis of publications on fire safety management on construction sites

Research on fire safety on construction sites was not widely published in the literature. Merchant (1976) was the first author to publish a detailed review on building and fire safety. The author attempted to show that fire conscious thinking needed to be applied to building during each of the five major phases of the building life cycle. The technical note aimed to discuss those aspects of fire safety design and technology which have a direct influence on the design and cost of building. Marchant reviewed each of the five phases, detailing which issues need to be considered to prevent fires during construction works.

From 1976 to the mid 1980s, this area of research in fire safety was left aside and major researchers tended to concentrate on complex scientific and engineering research to improve life safety in existing buildings. This dearth of research was later realised when large fire losses occurred on construction sites at the beginning of the 1990s. The industry then realised the major gap and started to initiate major investigations on the subject. The aims was to understand the fire mechanism and its development on construction site and which measures could be taken to minimise and reduce fire outbreaks and limit their impact. The UK led this movement by publishing in 1992 a Code of Practice for fire prevention on construction sites. This professional guidance developed by the Building Employers Confederation and the Loss Prevention Council and supported by major fire association and the insurers, answered the immediate need of construction participants and provide them some guidance on how to organise their sites to control fire outbreaks. The Munich Reinsurance seemed to be the only organisation who had realised the potential problem of fire on construction sites, when they started to publish in 1987 (Munich Re., 1987) a series of articles in the Schadenspiegel which led to the publication of a Technical Guide (1987) which intended to provide guidance to their insurers. The Guide proposed a review of fires on construction sites from 1979 to 1987, and presented a model for fire prevention. It recommended the implementation of a series of fire safety measures during construction, and issues related to insurance. Munich Re. Recommended the use of a brief Code of Practice or Guide for fire safety on construction sites, combined with a checklist to control the implementation of fire protection measures on sites. To enhance the use of these documents, they have been translated in 6 different languages. The ICE organised in 1992 a major conference on minimising the risk on construction sites where Abbott, Kidd, Smith, Barber, Wright and Evans (1992) looked closely at the problem, giving a professional insight. Abbott (1992) proposed a review of the current insurer's perspectives on fires on construction sites, presenting the true picture of the problem. Abbott presented the possible explanation for the recent series of major fires: recent trend in modern building design and the use of modern methods of construction. The discussion explored methods to transfer or manage the risk of fire. It proposed the implementation of a strict fire safety procedure imposed through the contractual agreement and the insurance policy. Abbott also insisted on the need to consider a fundamental cultural change for the construction industry in order to sustain the implementation of a fire safety procedure to recognise, control and reduce all aspects of construction site fire exposure. The paper of Kidd (1992) reviewed the insurers' position and their requirements for fires on construction sites and in building undergoing renovation. Kidd reviewed the implementation of the BEC/LPC Code of Practice and its practicability. The Insurers' requirements could be split into three categories: the management of fire safety, site organisation and fire precautions. The paper of Smith (1992) proposed the combination of measures to take on construction sites to meet life safety and financial loss objectives. The paper discussed these aspects highlighting practical solutions. Toone (1992) described the Broadgate's fire and the damage caused. The paper also examined the safety and managerial system in place on the site. Toone proposed **the implementation of safer use of materials, working practices and methods** under four headings:

i. Reduce fire load,
ii. Plan out fire risk,
iii. Improve warning of fire,
iv. Awareness and audits

Rimmer (1992) proposed a review of the devastating effect of fires on construction sites on a client's business and his project. The paper reviewed the **implication of disastrous fires for clients and their duties and responsibilities to secure their business through the implementation of a rigorous fire safety procedures and measures by contractors**. The paper presented a series of measures and common goal for reducing fire damage costs through the contractual agreement, agreed procedure, co-operation between clients and insurers. Barber (1992) proposed **to improve the fire protection of buildings under construction through the implementation of a fire safety strategy report** for issues to contractors relating to the final design. The content of the fire strategy report was discussed in relation to high rise and atrium buildings. In his paper, Wright (1992) presented a review of the needs of the fire brigade when attending a fire on construction sites. It also highlighted specific issues the **contracting organisations** should consider to ease the intervention of the fire services. Technical problems faced by the Fire Brigade are described and issue affecting their fire fighting action on site. The author also deplored **the lack of partnering between the FB and the site management to improve awareness**. Finally Evans (1992) explored some of the **legal complexities concerning fire safety on construction sites** and refers to the recent draft publication of the EC Directive Temporary and Mobile Construction Sites. The legal difficulties associated with the regulations are detailed. The author highlighted the need for good liaison between the various interested parties. Hinks (1992) presented **the conflicting perspectives of the various parties involved in the maintenance of fire safe building operations**, and discuss **the implementation of site fire safety policy on site** using checklists. Hinks explored **the impact a fire during the construction process** would have on the contracting organisation and its business continuity. He argued that "fire safety planning will have to become an integral part of project planning and site attitudes." And that the "practical application of such policies and plans was of course their implementation."

In 1993, the Munich Re. Pursue their investigations and Quast (1993) proposed **a review of fires on construction sites from 1985 to 1991**, and analysed major construction sites fires. The author recommended the enforcement of fire safety measures during construction through the insurance contract and the clause "Particular Conditions regarding fire fighting equipment" which has been reviewed and improved. Later in 1995, Vetters proposed **a review of the damages from fires during the construction process and their impact on reinforced concrete structure**. Major construction sites fires were analysed and recommendations formulated on the systematic use and application of fire safety measures during construction works. Meanwhile, Ebner (1994) at a EAR and CAR risks conference in Scotland presented a major report for insurers. The report proposed a detailed review of the current concern of insurers on fires on construction sites and analyses what measures could be taken to reduce the number of losses due to fire and to lessen their consequences. In the first sections, the report briefly dealt with the phenomenon explored the relevance of a fire risk assessment and management approach. Finally the report proposed some measures to improve the level of fire safety during construction works.

However the problem was not only significance in the UK, the effect of major fires on construction sites is also discussed by the industry in the US and the rest of Europe. Sadler in 1995 published an article on how to prevent construction fires. The article proposed a review of the problem of fires on construction sites in the US. The author presented **a strategy to control and reduce the number of outbreaks.** The author considers how construction fires start and spread and specify the implementation of a Fire Safety Plan. He concludes by highlighting the four basic elements of the FSP: prevention, inspection, training and firefighting. In France, the CNPP (Centre National de Prévention et de Protection) published a series of articles on the problem. In a paper Baratin (1997) reviewed the fires caused by hot works and gave reference to a wide list of major fires in France between 1990 and 1995. The author argued that minimum fire measures could be taken to avoid these fires and their consequences. Baratin proposed a short statistical analysis of the distribution of accidents and their consequences. Brett (1997) reviewed the welding and cutting operations involving hot works and sparks which would lead to fire ignitions during construction works. The author presented **a critic of the current legislative requirements and proposed a safe approach towards hot works** and recommended the systematic use of a Hot Work Permit during construction works. Following a series of major fires in France, Fabre (1997) addressed the responsibilities of contractors engaged in construction works to control the outbreak of fires, and those of the facilities owners. In the first part of this paper, the author reviewed the responsibilities of the parties under the law. **The French law differentiate obligations when**

an external enterprise carries out works in an existing facility with its own equipment, and when this enterprise use its equipment. The responsibilities for losses and damages would be under the contractor's responsibilities as possession of the site has been given, and this until hand-over or partial completion. In 1997 the CNPP organised a seminar (Brett, 1997) on the problem of fire and safety on site and gathered major representatives of the industry. Brett (1997) related the findings of this seminar and in his paper addressed the implementation of fire safety measures on site under the French law. Information were extract from a debate gathering safety manager from major French organisations (Danone, Paris-Expo, Generali-France, Usinor, La Redoute, BSPP, CNPP, Abaq). The paper gathered a wide range of interesting comments on the **integration of a fire safety approach in organisations**. The debate covered six aspects of safety: integration of safety in the project, scope of safety, safety process in the organisation, SME approach, limitation of the regulations, recommendations and conclusions thoughts.

Meanwhile in the UK, several papers addressed the same problem. Carey (1997) reviewed the specificity of fires on construction sites, some statistical data and their significance and measures to put in place on site to prevent fires. The author proposed a critical review of the Joint Code of Practice and its requirements. He concluded his paper by highlighting the significant lack of information on statistical data, combined with a higher pressure on contractor to work to tight budget and deadlines which impact on the level of safety. In a special edition of major articles on construction sites disasters published in Schadenspiegel, Munich Re. insisted on the necessity to control the risks, and especially fire. Puybaraud & Barham (1997) reviewed **the need for fire management systems on major projects** in order to reduce the risk of fire and its consequences to a minimum. They argued that the problem of fire safety awareness was often exacerbated by **the plethora of different regulations**. The emphasis, in this paper, was on the importance of an early consideration of the possibility of a fire during the construction phase. Research was being carried out to establish the extent to which the procurement process might be adapted and lead to an extension of supervision systems might lead to provide a more fire-safe construction environment. The importance of an early stage assessment of fire risk for any construction or refurbishment project was particularly stressed; best practice management guidance for fire-safe on-site activity, coupled with adequate legislative provision, was essential and major research was necessary to underpin all of these activities. Puybaraud & Barham (1997b) argued in a later paper for a review of **the economic impact** of fire on construction site in the UK and the position of insurance companies, as well as the **economic necessity of a management system to ensure fire safety** during the construction process. The importance of an **early stage assessment of fire risk** was particularly stressed; best practice management guidance for fire-safe on-site activity, coupled with adequate legislative provision, was essential and major research was necessary to underpin all of these activities.

At this stage, the industry understood not only the necessity to address the problem of fires on construction sites, but also realised the major impact on businesses involved in the construction process.

In a research paper on Fire Safety Attitudes and Management Culture in the Construction Industry, Puybaraud et al. (1999) proposed three different examples and a discussion engendered as to how **enhanced fire safety attitudes and management culture** could reduce the risk of fire on construction sites. It was argued that some construction companies were moving towards the development and reinforcement of a Positive Fire Safety Implementation Process. The **influence of the management culture** of the company on employee behaviour and its impact on the control of the risk of fire has been identified as vital and critically analysed. Later Hinks & Puybaraud (1999) reported some interim findings from organisational research into site fire safety which looked at **the relevance of Contractor and Facilities Manager attitudes to safety as a component of the overall safety process**. The authors consider the practical problems associated with construction sites safety during alterations and change-in-use of building facilities. The authors proposed a Project Safety Model for review.

Reference:	Subject of research:	Objectives of the paper:
Marchant, E. (1976) Building and Fire Safety, 1: Fire safety and the building life cycle, Society of Architectural and Associated Technicians (SAAT) Technical.	The author attempts to show that fire conscious thinking needs to be applied to building during each of the five major phases of the building life cycle.	The technical note aims to discuss those aspects of fire safety design and technology which have a direct influence on the design and cost of building. Marchant reviews each of the five phases, detailing which issues need to be considered to prevent fires during construction works.
Munich Re. (1987) Les incendies et la sécurité incendie sur les chantiers, Schadenspiegel, 1195-S-f, Munich Re.	The paper proposes a review of fires on construction sites from 1979 to 1987, and presents a model for fire prevention. It recommends the implementation of a series of fire safety measures during construction, and issues related to insurance.	Munich Re. Recommends the use of a brief Code of Practice or Guide for fire safety on construction sites, combined with a checklist to control the implementation of fire protection measures on sites. To enhance the use of these documents, they have been translated in 6 different languages.
Abbott, P (1992) The insurer's perspective, The implementation of insurers' requirements, ICE Conference, 3 March 1992.	The author proposed a review of the current insurer's perspectives on fires on construction sites, presenting the true picture of the problem. Abbott presents the possible explanation for the recent series of major fires: recent trend in modern building design and the use of modern methods of construction.	The discussion explores methods to transfer or manage the risk of fire. It proposes the implementation of a strict fire safety procedure imposed through the contractual agreement and the insurance policy. Abbott also insists on the need to consider a fundamental cultural change for the construction industry in order to sustain the implementation of a fire safety procedure to recognise, control and reduce all aspects of construction site fire exposure.
Kidd, S. (1992) Fires on construction sites and in buildings undergoing renovation: The implementation of insurers' requirements, ICE Conference, 3 March 1992.	The paper reviews the insurers' position and their requirements for fires on construction sites and in building undergoing renovation. Kidd reviews the implementation of the BEC/LPC Code of Practice and its practicability.	The Insurers' requirements can be split into three categories: the management of fire safety, site organisation and fire precautions.
Kander, K. (1992) Avoiding costly construction fires, Constructor, July 1992.	The article proposes a review of the problem of fires on construction sites in the US. The author presents a strategy to control and reduce the number of outbreaks.	The author considers how construction fires start and spread. He reviews the fire fighting resources needed to support a proper fire safety program and strategy.
Hinks, J. (1992) Fire safety on construction sites: perspectives and implementation.	The paper presents the conflicting perspectives of the various parties involved in the maintenance of fire safe building operations, and discusses the implementation of site fire safety policy on site using checklists.	Hinks explores the impact a fire during the construction process would have on the contracting organisation and its business continuity. He argues that "fire safety planning will have to become an integral part of project planning and site attitudes." And that the "practical application of such policies and plans is of course their implementation."
Draper, D. (1992)	A review of the current and forthcoming new legislative	

The professional risk, The Health and Safety Practitioner, March 1992.	enactment content of the EC Temporary and Mobile Worksite Directive.	
Smith, I. (1992) Identifying and minimising fire risks during construction, Fires on construction sites – Minimising the Risk, ICE Conference, March 1992.	The paper proposes the combination of measures to take on construction sites to meet life safety and financial loss objectives.	The paper discusses these aspects highlighting practical solutions.
Toone, B. (1992) Broadgate Phase 8, Fires on construction sites – Minimising the Risk, ICE Conference, March 1992.	The paper describes the Broadgate's fire and the damage caused. It also examines the safety and managerial system in place on the site.	The paper proposes the implementation of safer use of materials, working practices and methods under four headings: Reduce fire load, Plan out fire risk, Improve warning of fire, Awareness and audits.
Rimmer, B. (1992) Achieving common goal, Fires on construction sites – Minimising the Risk, ICE Conference, March 1992.	A review of the devastating effect of fires on construction sites on a client's business and his project. The paper review the implication of disastrous fires for clients and their duties and responsibilities to secure their business through the implementation of a rigorous fire safety procedures and measures by contractors.	The paper presents a series of measures and common goal for reducing fire damage costs through the contractual agreement, agreed procedure, co-operation between clients and insurers.
Barber, C. (1992) High-rise and atrium buildings, Fires on construction sites – Minimising the Risk, ICE Conference, March 1992.	The paper proposes to improve the fire protection of buildings under construction through the implementation of a fire safety strategy report for issues to contractors relating to the final design.	The content of the fire strategy report is discussed in relation to high rise and atrium buildings.
Wright, D. (1992) Meeting the operational needs of the fire services, Fires on construction sites – Minimising the Risk, ICE Conference, March 1992.	The paper presents a review of the needs of the fire brigade when attending a fire on construction sites. It also highlights specific issues the contracting organisations should consider to ease the intervention of the fire services.	Technical problems faced by the Fire Brigade are described and issue affecting their fire fighting action on site. The author also deplores the lack of partnering between the FB and the site management to improve awareness.
Evans, R. (1992) Health and safety – UK Legislation and the new EC Requirements, Fires on construction sites – Minimising the Risk, ICE Conference, March 1992.	The paper explores some of the legal complexities concerning fire safety on construction sites and refers to the recent draft publication of the EC Directive Temporary and Mobile Construction Sites.	The legal difficulties associated with the regulations are detailed. The author highlights the need for good liaison between the various interested parties.
Quast, J. (1993) Les Incendies sur les chantiers – un risque permanent, Schadenspiegel. 36eme année (2). Munich Re.	The paper proposes a review of fires on construction sites from 1985 to 1991, and analyses major construction sites fires.	It recommends the enforcement of fire safety measures during construction through the insurance contract and the clause "Particular Conditions regarding fire fighting equipment" which has been reviewed and improved.
Ebner, G (1994) Fire Prevention for EAR and CAR risks, IMIA, Scotland,	The report proposes a detailed review of the current concern of insurers on fires on construction sites and analyses what	In the first sections, the report briefly deals with the phenomenon, explores the relevance of a fire risk assessment

September 1994.	measures can be taken to reduce the number of losses due to fire and to lessen their consequences.	and management approach. Finally the report proposes some measures to improve the level of fire safety during construction works.
Vetters, S. (1995) Protection incendie sur les chantiers – Pourquoi faire, puisque le béton ne brûle pas? Schadenspiegel, 38eme année (2). Munich Re.	The paper proposes a review of the damages from fires during the construction process and their impact on reinforced concrete structure.	Major construction sites fires are analysed and recommendations formulated on the systematic use and application of fire safety measures during construction works.
Sadler, J. (1995) How to prevent construction fires, Occupational Health & Safety, July 1995.	The article proposes a review of the problem of fires on construction sites in the US. The author presents a strategy to control and reduce the number of outbreaks.	The author considers how construction fires start and spread and specify the implementation of a Fire Safety Plan. He concludes by highlighting the four basic elements of the FSP: prevention, inspection, training and firefighting.
Barber, C. (1996) Managing construction sites, Fire Prevention, 286, pp28-30	A summary of the duties of responsibilities of the designer to respond to their fire safety responsibilities on construction site under the CDM regulations	
Baratin, H. (1997) Points chauds: un risque sous-estimé, Face au Risque, n. 330, Février 1997.	The paper review the fires caused by hot works and gives reference to a wide list of major fires in France between 1990 and 1995.	The author argues that minimum fire measures could be taken to avoid these fires and their consequences. Baratin proposed a short statistical analysis of the distribution of accidents and their consequences.
Brett, Y.B. (1997) Souder, couper, meuler en sécurité. Face au Risque, n. 330, Février 1997.	The paper reviews the welding and cutting operations involving hot works and sparks which would lead to fire ignitions during construction works.	The author presents a critic of the current legislative requirements and proposes a safe approach towards hot works and recommends the systematic use of a Hot Work Permit during construction works.
Puybaraud, M-C & Barham, R (1997) Procurement Systems and the Economic Provision of Fire Safety during the Construction Process, CIB 97, W92 (Procurement) Conference Proceeding, pp 643-654.	Puybaraud & Barham (1997) reviewed the need for fire management systems on major projects in order to reduce the risk of fire and its consequences to a minimum. They argued that the problem of fire safety awareness was often exacerbated by the plethora of different regulations.	The emphasis, in this paper, was on the importance of an early consideration of the possibility of a fire during the construction phase. research was being carried out to establish the extent to which the procurement process might be adapted and lead to an extension of supervision systems might lead to provide a more fire-safe construction environment.
Puybaraud, M-C & Barham, R (1997) Addressing the Risk of Fire during the Construction/Refurbishment Process by Better Management, COBRA 97 Conference, RICS.	A review of the economic impact of fire on construction site in the UK and the position of insurance companies, as well as the economic necessity of a management system to ensure fire safety during the construction process, is set out in this paper	The importance of an early stage assessment of fire risk is particularly stressed; best practice management guidance for fire-safe on-site activity, coupled with adequate legislative provision, is essential and major research is necessary to underpin all of these activities.

Fabre, B. (1997) Incendie en cours de travaux: quelles responsabilités? Le Moniteur, n. 4889.	Following a series of major fires in France, the paper addresses the responsibilities of contractors engaged in construction works to control the outbreak of fires, and those of the facilities owners.	In the first part of this paper, the author reviews the responsibilities of the parties under the law. The French law differentiate obligations when an external enterprise carries out works in an existing facility with its own equipment, and when this enterprise use its equipment. The responsibilities for losses and damages would be under the contractor's responsibilities as possession of the site has been given, and this until hand-over or partial completion.
Carey, P.W (1997) Construction site fire safety: practical problems, KENT 1997 Conference, pp42-46	Carey reviews the specificity of fires on construction sites, some statistical data and their significance and measures to put in place on site to prevent fires.	The author proposes a critical review of the Joint Code of Practice and its requirements. He concludes his paper by highlighting the significant lack of information on statistical data, combined with a higher pressure on contractor to work to tight budget and deadlines which impact on the level of safety.
Brett, Y. B. (1997) Incendie et Construction. Face au risque, n. 336, October 1997.	The paper addresses the implementation of fire safety measures on site under the French law. Information are extract from a debate gathering safety manager from major French organisations (Danone, Paris-Expo, Generali-France, Usinor, La Redoute, BSPP, CNPP, Abaq).	The paper gathers a wide range of very interesting comments on the integration of a fire safety approach in organisations. The debate covers six aspects of safety: integration of safety in the project, scope of safety, safety process in the organisation, SME approach, limitation of the regulations, recommendations and conclusions thoughts.
Munich Re. (1998) Sinistres et Prévention – Hors Série tous risques chantiers, Schadenspiegel, 41 eme année.	Special edition of major articles on construction sites disasters published in Schadenspiegel. Munich Re. Insists on the necessity to control the risks, and especially fire.	
Puybaraud, M-C & Barham, R (1999) Fire Safety Attitudes and Management Culture in the Construction Industry, CIB 99, W99 (Health & Safety) Conference Proceeding.	In this paper three different examples are presented and a discussion is engendered as to how enhanced fire safety attitudes and management culture can reduce the risk of fire on construction sites.	It is argued that some construction companies are moving towards the development and reinforcement of a Positive Fire Safety Implementation Process. The influence of the management culture of the company on employee behaviour and its impact on the control of the risk of fire has been identified as vital.
Hinks, J. & M-C. Puybaraud (1999) Facilities Management and fire safety during alterations, change-in-use, and the maintenance of building facilities – a management model for debate, Facilities, 17 (9/10), 377-391.	This paper reports some interim findings from organisational research into site fire safety which looks at the relevance of Contractor and Facilities Manager attitudes to safety as a component of the overall safety process.	This paper considers the practical problems associated with construction sites safety during alterations and change-in-use of building facilities. The authors proposed a Project Safety Model for review.

Table 3.7: Publications: Fire Safety on Construction Sites

3.6 Analysis of Fire Safety Guides

The availability of guidance notes to support the actions of the parties involved in the construction process was somehow restricted to a few valuable documents. However, the UK seemed to be well ahead compared to other EU and worldwide countries.

The first guide was published in the UK in 1975. P5: Standard Fire Precautions P5 by Department of Environment Property Services Agency, Directorate of Building Development. The P5 Guide recommended a set of standard fire precautions to be taken by the contractor engaged in building and engineering works and maintenance for the Department of the Environment Property Services Agency. It required the contractor "to comply with the following instructions in addition to any other conditions of contract relating to fire precautions." This document waited on the shelf to be fully recognised and used until 1990s, when the UK construction industry realised the significant problem of fire on construction sites and updated and re-published a new guide: BEC/LPC Joint Code of Practice (1992). The Joint Code of Practice on the Protection from Fire of Construction Sites and Buildings Undergoing Renovation applied to construction sites including those where demolition, alterations, fitting out, renovations, refurbishment or repair work was being carried out, to minimise the risk of accidental or malicious fires. The publication of this Code was supported by most of the industry representatives and especially the Fire Brigade which published in 1991 a Brigade Guidance Note on fire safety measures recommended for adoption: The LFCDA Recommendations: Fire safety Measures recommended for adoption in buildings during the course of construction. Since the Code publication in 1992, it has been updated 4 times until 2000 (last edition) to reflect the needs of the industry and adapt to the growth of new technologies and technical requirements. In 1998 the Joint Contract Tribunal amended their standard forms of contract (JCT98) to address fire prevention during construction works and adopt the Joint Code of Practice (Fire Code). Compliance with the JCOP was a requirement under the terms of the contract. The JCTs forms of contract were the most common form of contract in the UK and has been widely used and recognised by the industry.

The impact of the Joint Code was still being verified, since the lack of statistics couldn't demonstrate a major reduction in the number of fires and their damages. The FPA (1999) admitted that their figures can show that fires "can wipe out a business in a matter of minutes." The FPA Director argued that "the prevention of fire through risk assessment should be an essential part of any business strategy."

The CNAC (*Comité National d'Action pour la sécurité et l'hygiène dans la Construction*) in Belgium published in 1983 a Guidance Note on safety and fire risks on construction sites (*Notes de Sécurité Construction. La Prévention des Risques d'Incendie dans la Construction*). The Guidance required the implementation of specific fire safety measures on construction sites and aimed at raising the awareness to contractor and organisation engaged in construction works. This Guide was in accordance with the Article 54-quater of the Workplace Regulation (*Règlement Général pour la Protection du Travail*).

The reinsurance organisations like Munich Re. And Swiss Re. who always had an interest in fire safety on sites, have been very active in publishing reports on this issue and special guides to their insurers. In 1987, Munich Re. published a "***Guide Technique à l'intention des Assureurs: La sécurité sur chantier***" comprising the Endorsement: Special conditions concerning fire-fighting facilities and fire safety on construction sites. Swiss Re. in 1992 published a CAR Insurance guide, later updated in 1998. The brochure aimed to give a good introduction to the subject and aimed at encouraging contractors and clients to consider a CAR insurance cover for construction projects. In 1992 and 1993, Swiss Re. published their first guides on the fire protection of construction sites, later actualised in 1998. The 1992 publication (in French) reviewed fire prevention on construction sites and provided recommendations for insurers. The 1993 guide (published in Spanish) explored the evolution of fires, their causes and consequences on sites. It recommended the implementation of fire safety measures.

Historic buildings present very specific characteristics which would contribute to increase the potential fire load and would allow a fire to spread more rapidly. A higher potential of sources of ignition within a historic facility during refurbishment and/or maintenance work activities increased the risk of fire outbreak. The integration of fire protection measures was often difficult and limited to a minimum in most of the cases. The Crown was a major owner of historic buildings around the UK and initiated the publications of a set of standard aimed at works in Crown buildings only. The HMSO standard (1995) addressed a range of fire protection measures against fire during construction works. The Contractor was required to comply with the Standard in addition to any other conditions of contract relating to fire precautions and he should ensure compliance by his sub-contractors. The Standard presented a set of instructions for contractors engaged on building and engineering works and maintenance in all Crown premises both civil and military.

In 1997, the Health & Safety Executive published a HSE Guidance: Fire Safety in Construction Works. This Guidance was produced for clients, designers and those managing and carrying out construction work involving significant fire risks. The Guidance aimed at construction projects involving substantial fire risks and is relevant to all who have a role in the development, management and application of fire safety standards on construction sites. This Guidance was part of HSE's revised series of health and safety guidance for construction.

The US has a long history of standard all their industries. The fire safety industry is under the authority of the National Fire Protection Association (NFPA) which has the duty to develop standards in fire safety. The NFPA published a wide range of standard which apply to fire safety in construction and some specifically apply to site works and construction works with a high risk of fire outbreak. The NFPA 241: Standard for safeguarding Construction, Alteration and Demolition Operations was one of them and was first published in 1933 and revised in 1942. Adopted by the NFPA in 1958, and subsequent revisions in 1968 and 1973. The 1986 Edition represented a complete rewrite. This edition of the NFPA 241 was approved as an American National Standard in 1996. This comprehensive and detail standard provided specific guidance and requirements for fire safety and protection during construction works. It was the most comprehensive Guidance available. NFPA 241 required "the owner shall designate a person who shall be responsible for the fire prevention program and who shall ensure that it is carried out to completion" under 5-1.1*. Specific chapters of interest and relevant to fire safety measures are highlighted below: Chapter 3: Process and Hazards, Chapter 5: Fire Protection, Chapter 6: Safeguarding Construction and Alterations operations, Chapter 8: Safeguarding Demolition Operations, Chapter 9: Safeguarding Underground Operations. The Standard refers also to a series of additional standards on specific safety issues like the NFPA 51B: Standard for Fire Prevention in Use of Cutting and Welding Processes.

Finally, South Africa seemed to propose a short guide to contractors. FPA Bulletin (1990): A Fire Prevention Inspection Guide, published by the Fire Protection of Southern Africa offers a brief checklist on measures to take for fire safety on construction sites.

Guide:	Country	Published by:	Date:	Description:	Observations:
P5: Standard Fire Precautions P5	UK	Department of Environment Property Services Agency Directorate of Building Development	1975	Standard fire precautions to be taken by the contractor engaged in building and engineering works and maintenance for the Department of the Environment Property Services Agency.	"The contractor is required to comply with the following instructions in addition to any other conditions of contract relating to fire precautions."
Munich Re.: 1987 Guide Technique à l'intention des Assureurs: La sécurité sur chantier	Germany EU WW	Munich Re, Reinsurance	1987	Guidance for Insurers on fire safety on construction sites	Endorsement: Special conditions concerning fire-fighting facilities and fire safety on construction sites
LFCDA Recommendations: Fire safety Measures recommended for adoption in buildings during the course of construction.	UK	London Fire and Civil Defence Authority London Fire Brigade	1991	Brigade Guidance Note on fire safety measures recommended for adoption.	
BEC/LPC Code: Fire Prevention on Construction sites: The Joint Code of Practice on the Protection from Fire of Construction Sites and Buildings Undergoing Renovation	UK	The Building Employers Confederation (BEC) The Loss Prevention Council (LPC) The National Contractor's Group Guidance supported by the Association of British Insurers (ABI), the Chief and Assistant Chief Fire Officers Association, and the London Fire Brigade	1992 Last Edition: 2000	The Code applies to construction sites including those where demolition, alterations, fitting out, renovations, refurbishment or repair work is being carried out, to minimise the risk of accidental or malicious fires.	In 1998 the Joint Contract Tribunal amended their standard forms of contract (JCT98) to address fire prevention during construction works and adopt the Joint Code of Practice (Fire Code). Compliance with the JCOP is a requirement under the terms of the contract.
HMSO Standard: Standard Fire Precautions for Contractors Engaged on Crown Works.	UK	HMSO	1995	The Contractor is required to comply with the Standard in addition to any other conditions of contract relating to fire precautions and he shall ensure compliance by his sub-contractors. The Standard present a set of instructions for contractors engaged on building and engineering works and maintenance in all Crown premises both civil and military.	For contractors involved in Crown buildings works only.
HSE Guidance: Fire Safety in Construction Works.	UK	Health & Safety Executive (HSE)	1997	Guidance for clients, designers and those managing and carrying out construction work involving significant fire risks The Guidance is aimed at construction projects involving substantial fire risks and is relevant to all	This Guidance is part of HSE's revised series of health and safety guidance for construction.

				who have a role in the development, management and application of fire safety standards on construction sites.	
NFPA 241: Standard for safeguarding Construction, Alteration and Demolition Operations	US	National Fire Protection Association	1996	First published in 1933 and revised in 1942. Adopted by the NFPA in 1958, and subsequent revisions in 1968 and 1973. The 1986 Edition represents a complete rewrite. This edition of the NFPA 241 was approved as an American National Standard in 1996. This comprehensive and detail standard provides specific guidance and requirements for fire safety and protection during construction works. It is the most comprehensive Guidance available.	"The owner shall designate a person who shall be responsible for the fire prevention program and who shall ensure that it is carried out to completion." 5-1.1* Chapt 3: Process and Hazards, Chapt 5: Fire Protection, Chapt 6: Safeguarding Construction and Alterations operations, Chapt 8: Safeguarding Demolition Operations, Chapt 9: Safeguarding Underground Operations. The Standard by a series of additional standards on specific safety issues like the NFPA 51B.
NFPA 51B: Standard for Fire Prevention in Use of Cutting and Welding Processes.	US	National Fire Protection Association	1994		
Swiss Re.: La Protection contre l'incendie sur les chantiers	Switzerland EU WW	Swiss Re, Reinsurance	1992	Review of fire prevention on construction sites and recommendations for insurers.	Endorsement: Special conditions for fire prevention on construction sites amending the general conditions of the insurance contract.
Swiss Re.: La proteccion contra incendio en las obras. Seguro de todo risgo de construccion/montaje.	Switzerland EU WW	Swiss Re, Reinsurance	1993 1998	Explores the evolution of fires, their causes and consequences on sites. It recommends the implementation of fire safety measures.	
Munich Re.: 1993 Guide Technique à l'intention des Assureurs: La sécurité sur chantier	Germany EU WW	Munich Re, Reinsurance	1993	Updated 1987 Munich Re's Guidance for Insurers on fire safety on construction sites	Endorsement: Special conditions concerning fire-fighting facilities and fire safety on construction sites.
CNAC: Notes de Sécurité Construction. La Prévention des Risques d'Incendie dans la Construction	Belgium	Comite National d'Action pour la sécurité et l'hygiène dans la Construction	1983	Guidance notes on fire safety measures to implement on construction sites. Awareness to contractor and organisation engaged in construction works.	In accordance with the Article 54-quater of the Workplace Regulation (*Règlement Général pour la Protection du Travail*).
FPA Bulletin: A Fire Prevention Inspection Guide	Southern Africa	Fire Protection of Southern Africa	1990	Brief checklist on measures to take for fire safety on construction sites.	

Table 3.8: Review Fire Safety Guides

3.7 Fire Safety Strategies: A review of current practices

Attitude to risk in construction was mainly affected by two factors. The first was the awareness of the possibility of a catastrophic event to which all employees were exposed to. The second was the extent to which individuals, both employees and employers, believed that they were capable of controlling the risks that they faced. The management team would have an active role throughout the whole project. In this chapter three different examples were presented and a discussion was engendered as to how enhanced fire safety attitudes and management culture could reduce the risk of fire on construction sites.

3.7.1 Background

Fire losses on construction sites in the UK between 1984 and 1995 were estimated to be £152.4 million. During this period two specific large fire incidents should be noted. Both fires occurred during construction and they alone accounted for 90.87% of the total cost of fires in the UK over the whole period (FPA, 1992).

At first sight it might be argued that these two incidents should be considered as exceptional or due to some special circumstances of the period. However, studies revealed **a lack of attention to prevention** of fire on building sites. **Action to promote fire safety** in a construction company should not be seen as a legal embarrassment to plague already overburdened managers, but as a normal and necessary part of the company's activities in which workers and management have a common interest. Davies & Tomasin (1996) argued that small contractors have neither the time nor the inclination to keep abreast of legal requirements and technical developments in safety matters. **Risk Management could be a significant contributor to the success of a company in identifying the potential sources of risk** on a site during the construction of a project and, hence as a consequence, help in reducing potential costs by avoiding fire.

This approach towards fire safety during the construction process has been greatly improved since 1991. First with the introduction in 1992 under the pressure of insurers of a new Code of Practice (BEC,LPC, NCG, 1992) and recently with the introduction of a new amendment to the JCT80 Standard Form of Contract regarding Fire Protection during the construction process (JCT, 1980, Amendment 17: Fire Protection, 1997) now part of the newly republished JCT 98. Following a series of site investigations, those regulatory improvements have been widely recognised and applied on-site by most major contractors in the United Kingdom through the written Fire Safety Plan (FSP) and/or through site practices. Small size companies were still facing a major financial barrier (Davies & Tomasin 1996) and change was therefore slow and cost targeted. But Carey (1992) was arguing that the lack of readily available statistical data made it difficult accurately to assess what affect, if any, the Code of Practice (BEC, LPC, NCG, 1992) has had on construction fire safety.

The Construction (Design & Management) Regulations 1994 (HMSO, 1994) which came into force on 31 March 1995, required the implementation of a Health & Safety Plan during the construction phase. A set of arrangements should be set out in this Plan for the management and organisation of the project. This could include: **management, standard setting, communication and co-operation, identification and effective management of activities with risks of health and safety, emergency procedures, information and training for people on site, consultation with people on site etc**. Many authors emphasised the behavioural approach to prevention (Mattila, 1988, Sluzer-Azaroff, 1990). The study developed by Sluzer-Azaroff (1990) proved that **the behavioural programme was affected by safety even in the difficult setting of building**. The results showed that behaviour modification might also be an effective tool in companies' own programme. Mattila and his colleagues (1988) obtained **"powerful improvement" by determining where major safety "hot-spots" were located and intervening there first**. Recently, studies carried out by Marsh (1992) revealed that behavioural goal setting and feedback on construction sites were an effective method to improve safety level. It appeared that, generally, intervention works through increasing awareness of safety issues and increasing and improving communication between management and the workforce. Also, Allen & Blackburn (1992) argued that more and **more organisations adopted a proactive approach** in order to manage the risk of their business.

In this paper, it was argued that some construction companies are moving towards the development and reinforcement of a Positive Fire Safety Implementation Process which was be generalised in the following Figure 3.15.

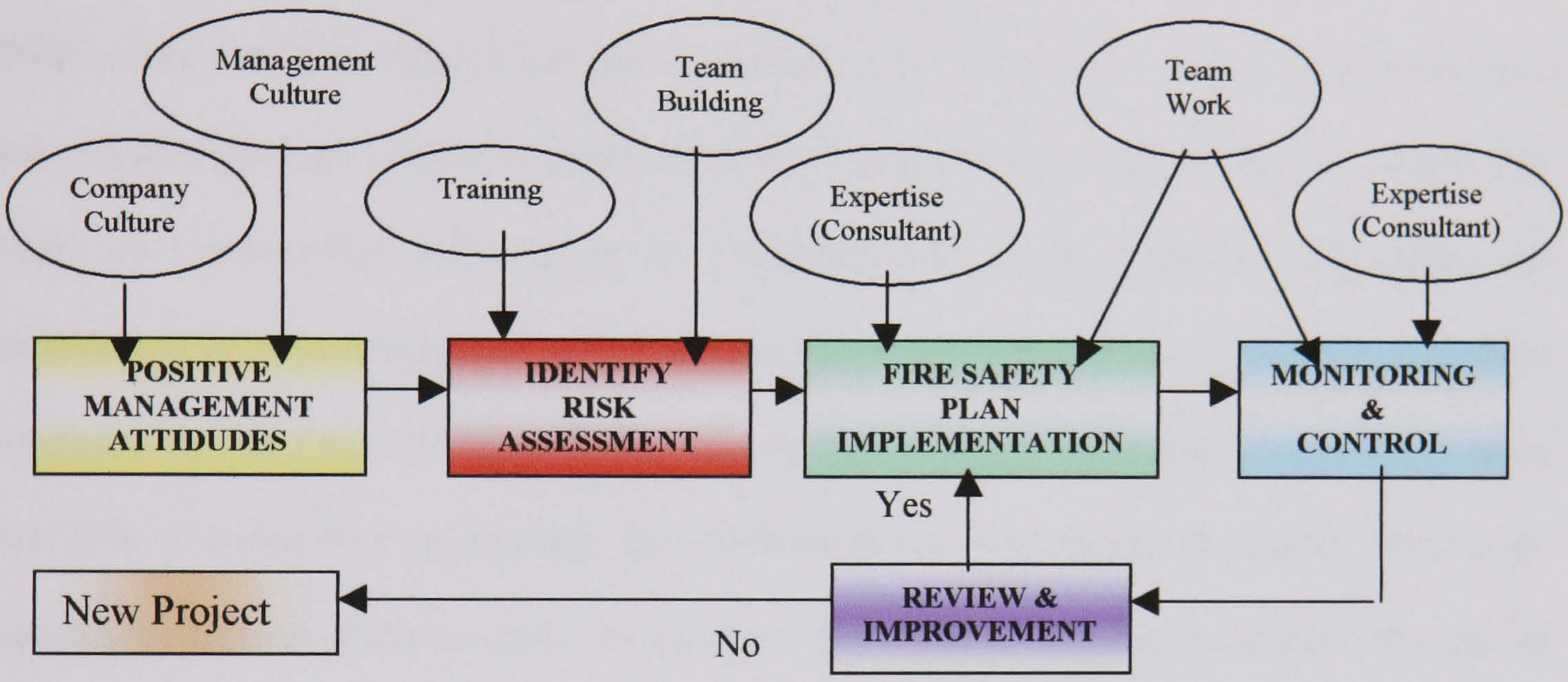


Figure 3.15: Positive Fire Safety Implementation Process

There was no evidence yet to demonstrate that all companies were following the model proposed in Figure 3.15. However, **the influence of the management culture** of the company on employee behaviour and its impact on the control of the risk of fire has been identified as vital. Marsh (1992) identified **management attitude as a "central" issue to safety on UK construction sites**. Balckburn & Allen (1992) argued that managing the risk to business involved taking a positive approach to the management of safety, starting with the very top of the organisation. Therefore, Figure 3.15 illustrated a positive fire safety implementation process. **The development and implementation of an accurate assessment strategy for identifying performance is now becoming necessary to provide evidences of the effectiveness of such a model.**

3.7.2 Fires on Construction Sites: a process of fire occurrence

There were more than 3,000 construction fires annually in the UK. Approximately 100 of them cause more than £50,000 of damage and usually resulted in complete dislocation of project schedules (HSE 1997a). The HSE estimated that there was one fire per working hour on a construction site somewhere in the UK every working day. This represented, on average 11 construction fires per day (HSE 1997b).

Fires on construction sites were a new area of research and there are no information about the subject. However following a two year investigation and analysis (Puybaraud 1997a, 1997b, 1998) of the available data, it has been concluded that at least 50% of the fires could have been avoided through a better or more effective managerial approach. Attitudes towards Fire Safety on Construction Sites played an important part in the control of risk during the construction process and lack of attention seems to be the major cause of those fires. Studies conducted by the FPA (1992) on major fires in the UK (loss >£50,000) revealed that more than 22% of major fires on building sites were deliberate or probably deliberate. Moreover, more than 26% involved a source of ignition that could have been controlled through an effective management process. There are still more than 28% of all major fires where the sources of ignition are unknown. The Foreword to the Code of Practice (BEC, LPC, NCG, 1992) stated that **the majority of fires could be prevented by designing out risks, taking simple precautions and by adopting safe working practices.**

Most construction fires had a simple cause and could be dealt with simple precautions. A simple **chain of effects** that plays a very important role in the break out of a fire. As mentioned earlier, lack of attention could lead to a combination of circumstances that, almost inevitably would result in a break out of fire during the construction process. In the past two decades most research into construction safety had primarily emphasised procedural, behavioural and social aspects (Hadipriono, 1992). Fault-tree models were very often developed to explain the aetiology of construction incidents. Hadipriono (1992) defined a fault-tree as a graphic model that shows parallel and sequential causes or events that contribute to a predetermined undesired event. The fault-tree analysis approach for fires on construction sites (Figure 3.16) were based on a model developed by Barry (1995), the general fault-tree support framework.

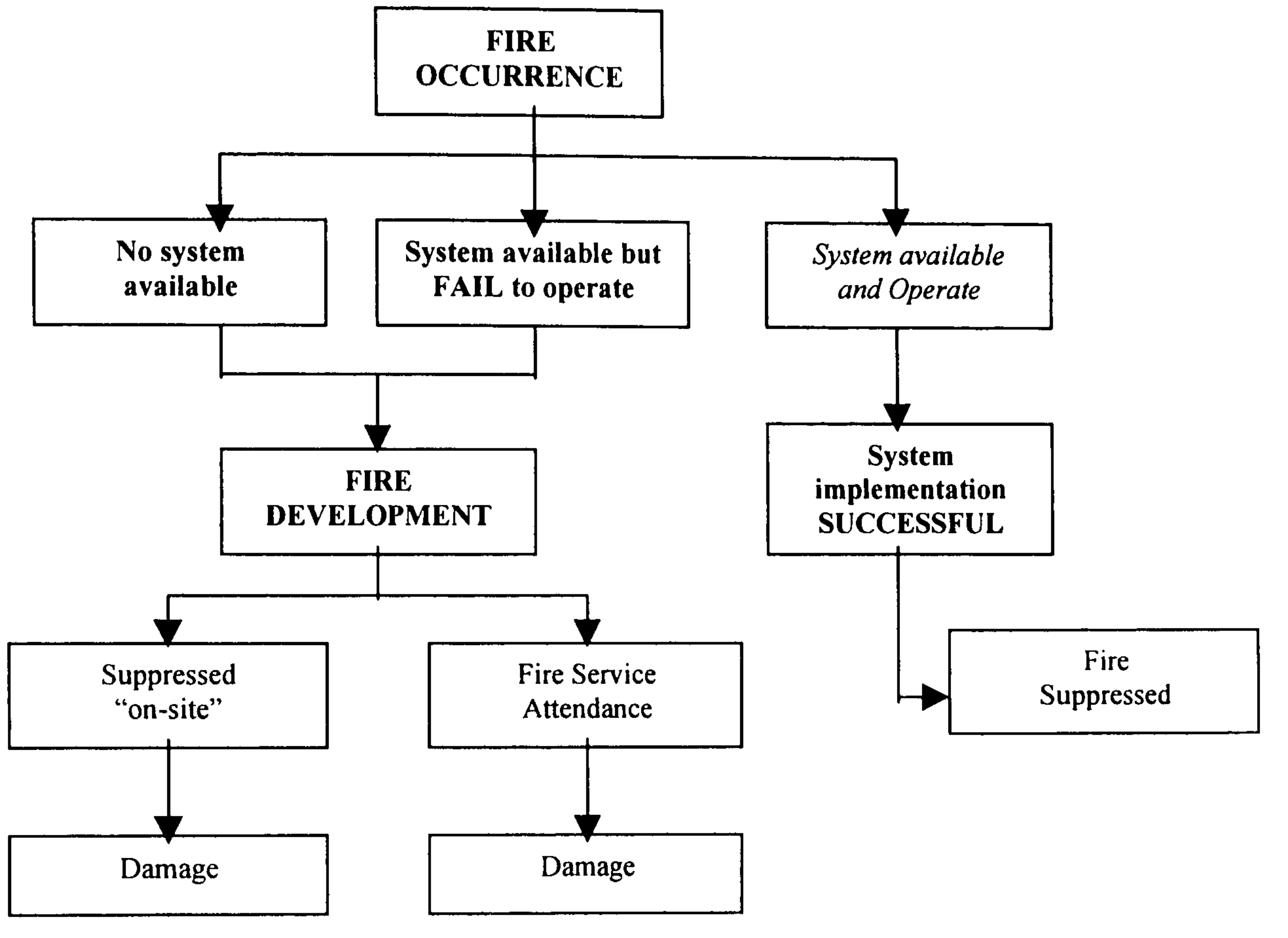


Figure 3.16: Fault Tree Analysis Approach – fire on construction sites.

Depending when the failure was discovered, it might not be too late to control the situation, but it was never too late **to reflect on the process of action to adopt** for a future site. This was the philosophy adopted by Bovis after the Broadgate Fire in 1990 and Minster Court Fire in 1991.

3.7.3 Broadgate Phase 8 fire (1990)

On the 23rd June 1990, a fire developed in the partly completed fourteen storey building in the Broadgate development under the responsibility of Bovis. The fire began in a large contractor's hut on the first floor and smoke spread unchecked throughout the building. The fire lasted for 4 ½ hours with excess temperature of 1000 degree Celsius for 2 hours.

The chain of events leading to the fire demonstrates many managerial failures which contributed to the development, growth and spread of fire in the facility. In 1990, no statutory document provided guidance to the contractors on how to prevent fires on construction sites. Basic health and safety requirements were implemented and the CDM Regs had not yet been brought to light.

The complexity of the project, its location and restricted space distribution forced contractors to installed site huts inside the uncompleted building (site huts in the first floor of the facility). The structure of the building was a steel frame with composite deck/concrete floors. The steel structure was partially unprotected at the time of the fire (The Steel Construction Institute, 1991). The report by the Steel Construction Institute demonstrated that the design of the building was in accordance with the current codes and approved document. However, the occurrence of a fire at this stage of the construction could have been prevented through better managerial actions and decisions. Also the implementation of a proper fire protection system during the construction works (detection, warning and extinguishment) and especially in the huts could have prevented the disaster.

The Steel Construction Institute (1991) formulated a series of recommendations as a consequence of their studies of the fire, its development and damages. However, most of the formulations at the time were on the structural failure of the building and how the structure behaved during the fire. (examination of the structure, frame action and structural behaviour, thermal modelling, connections, steel deck, cleaning…). Recommendations 8 and 9 covered some managerial aspects, such as "the measures to improve general fire safety and reduce financial losses for building sites", and on temporary accommodation on sites; "all forms of construction for temporary accommodation inside buildings should adopt low combustibility materials which only release small quantities of smoke when exposed to fire." Addendum 1 of the Report (The Steel Construction Institute, 1991) covered some basics principles of fire precautions during the construction phase: legislation (it is worse mentioning again at this stage that the Joint Code of Practice for fire prevention did not exist at the time of the incident), objectives, site access, position of office accommodation and means of escape, building construction works (early installation of fire protection measures like doors, staircases…), fire fighting facilities on site and their proper installation, housekeeping, management and communication (responsibility of the site management, security patrol) and some recommendations for "the use of additional comprehensive guidance on fire precautions measures." The Institute also stressed the **"matter of urgency" of the situation** and the implementation of these measures.

So how effective were these recommendations? It didn't seem that Bovis completely realised the **red alert message** this fire was sending out. The objective of the report was to focus on the structural survey of the building and how it responded during the fire. The recommendations formulated on the managerial approach to adopt were quite superficial. History confirmed that Bovis didn't have the time to react before another major fire occurs: The Minster Court fire in 1991.

3.7.4 Minster Court Fire (1991)

This major construction site occurred in London in 1991, and is a prime example of the kind of devastation that such incidents can create. The total losses for this fire were reported by the FPA (1996) to be £105million. The source of ignition has not been clear identified by the Fire Brigade (North Area Fire Brigade, 1991), but from the available evidence it was likely that an introduced ignition source in the form of a naked flame was the most likely source.

Following the fire, the Building Contractor prepared a document to set out the Fire Protection Plan for Base Building Reinstatement Works. The Construction Industry, around that time, had been expressing concern at the particular vulnerability to fire of building in the course of construction or fitting out. The earlier catastrophic fire at Broadgate Phase 8, London, in 1990 had raised specific issues in the respect and Bovis (the Minster Court contractor) had been involved in the full investigation and assessment of the fire damages in partnership with other major organisations. Therefore, Bovis was particularly aware of the devastating effect of fire during the construction process and its risk. But at the time of the Minster Court fire, no Fire Protection Plan (FPP) or Fire Safety Plan (FSP) under the form of a Guidance or Code of Practice has been developed. The FPP later developed by Bovis Construction Ltd for the Minster Court site draws attention to the importance of a co-ordinated and integrated approach with the Contract of reinstatement and completion of fitting out works.

In 1992 Bovis was engaged in the European Year of Safety, Hygiene and Health Protection at Work. Improving safety and health on European Construction Sites was a vital necessity following the 1987 assessment of accidents on construction sites which revealed a cost to the Community of approximately ECU15,000 million, including indirect costs (Commission of the EU 1993). In January 1992, Bovis presented a Guidance "Fire Prevention during Building Operations" (Bovis, 1992).

3.7.5 Construction Companies responses

3.7.5.1 Large Organisations (e.g. Bovis)

The efforts of Bovis to promote good practice and address new managerial issues have not yet been proven successful. Bovis has not, itself, present any results. However by promoting fire safety within the company at all levels, Bovis seemed to have moved towards a new Management Culture by:

i/ Developing Fire Awareness,

ii/ Making fire safety a Policy statement,

iii/ Promoting Fire safety benefits inside and outside the Company,

iv/ Implementing appropriate Guidance,

v/ Monitoring the implementation and running process of the FPP;

But again, there was no evidence provided, as far as the author know, either by Bovis or the FPA or HSE, to demonstrate any real improvement on construction sites. To date in 2001 the construction industry did not experienced major construction site fires and the JCOP implementation seems to be successful. The integration of the fire prevention concept in organisations involved in construction works seemed to have taken 6 years, between the publication of the first JCOP for fire prevention in 1992 to the integration of the Fire Code in JCT98. Even now in 2001 there was no evidence to suggest the JCOP was complied with on every construction projects as some contractors and clients are still working with the JCT80. Watson (1994) argued that **changing cultures in organisations has become central to management thinking**. Promoting job safety in building has been proven to be successful. The results of the study of Mattila & Hyodynmaa (1988) demonstrated that a behavioural safety programme contributed to improving communication in the organisation. They also showed that behaviour modification might also be an effective tool in companies' own safety programme. However, no one has demonstrated that, by adopting a behavioural safety programme the risk of a fire occurrence would reduce. This is an issue that will need to be address in the near future.

3.7.5.2 Medium size companies (e.g. Wimpey and Withey)

Companies like Wimpey Construction UK developed, in 1994, a **Positive Safety Management Concept**. At the time this innovative concept demonstrated a new approach towards the problem of fire safety, and health and safety in general, in the Construction Industry. Increasing pressure from the Government and the European Commission, to improve the level of safety in the construction industry, reinforced the pressure on contractor through the implementation of new Directive setting new Safety Standard. **This new approach should push the Construction Industry to adopt a new vision and attitude to fire safety**. First with the introduction of the Construction (Design & Management) Regulations 1994 (HMSO, 1994) and secondly with revisions of Codes of Practice and standard Forms of Contract (in the late 1990s with the new edition of JCTs forms of contract). The Safety Plans developed by Wimpey for a site sets out the principles for a positive management of safety in contract. The objectives of this Safety Plan was:

- To plan and implement safety control procedures appropriate to the project.

- To avoid accidents and dangerous occurrences and to promote safe and healthy working environment.

As an example of fire safety concern in a refurbishment project contracted by Withey in London has been reviewed. The work involved was the complete refurbishment of all floors of a four storey building on Leicester Square in London. Withey sought to implement proper standards of fire safety during all aspects of building development. The management have a stated policy of encouraging all those involved in the construction process to achieve a high standard of safety. Locke Carey & Associates Limited were appointed as consultants to develop a Fire Safety Plan (FSP) and carried out on a regular basis site inspections on behalf of the company. The FSP incorporates all those matters specified in the Joint Code of Practice on the Protection from Fire on Construction Sites and Building Undergoing Renovation. Notwithstanding this, the attitude of the "on-site" personnel was common to a large number of other site management teams in the UK:

i. Fire safety an obligation imposed under pressure of insurers (or clients).
ii. "There is nothing to burn on a construction site" is a very common idea.
iii. The impact of a fire during the construction process is low.

This demonstrated that knowledge of fire safety and of the devastating impact of fire in economic, technical and social terms is often unrecognised or wrong.

3.7.6 Discussion

Post 1992, a number of similarities have been identified in the three companies presented above:

Positive management attitude: a strong positive philosophy has been implemented in company structure. Means for communicating and passing information between the project team and the contractor and its workers on site despite a resistance or lack of appreciation by the latter.

Responsive Management: Arrangements for securing co-operation between participants for fire safety purposes, arrangements for monitoring systems to achieve compliance with the FPP or FSP, developing training and consultation with all levels.

Efficiency, Control and Monitoring of on-site standards are key issues in the implementation and development of fire safety culture in construction company. Wimpey members of staff had a responsibility for monitoring safety generally and bringing infringements of safety regulations to the attention of those responsible for enforcement. Transfers of responsibility and awareness were key issues in the positive implementation of a new Management Culture.

In contrast, the fire safety philosophy developed by Withey was user-orientated. By appointing an external consultant, they relied on its expertise to provide the best FSP adapted to both the client's and the contractor's needs and requirements. There was **a general awareness of the global problem of fire safety** by most site employees. However they seemed to have problem to understanding the need to implement it strictly. The necessity of a FSP was seen as an obligation rather than a necessity but site managers generally had no objections to its implementation, control and monitoring. The role of the consultant as an advisor was positively welcomed and suggestions for improvement of fire safety standards were respected. Improvement and modification of Management Culture was usually developed only with time and experience. Preconceived ideas and existing knowledge about fire safety was very often wrong. Davies & Tomasin (1996) argued that the managerial knowledge of many small contractors was based on experience and often lacking in theoretical background. This could be interpreted as a cultural problem. How do you convince a site manager of 20 year's experience that fire is a major problem on his site if he believes fires never occur on site because he never witnessed one? This could be interpreted in different way. **It did not prove that fire was not a problem but that there was a difference in the perception and interpretation of fire during the construction process.** Further research will try to demonstrate that it was through the implementation of simple measures and a **slow modification of attitudes that the perception and awareness** of the problem of fire during the construction process was improved.

Attitudes to fire risks involved a large number of issues (Figure 3.18).

Figure 3.17: Attitudes to Fire Risk

Each issue if not taken into account at an early stage of the preparation of the FSP could lead to a major problem. As explained earlier, fires occur on construction sites most often because of "Lack of Attention" – it is what seemed to be the conclusion drawn from the low number of data available through the FPA and the research carried out within the past three years by Puybaraud (1997a, 1997b, 1998). In order to prevent it, it is necessary to consider the issues raised in Figure 3.18.

Within the last years, the construction sector has been the subject of EU attention. Progress seems to be made in parallel. On one hand the UK Government was concerned about the problem of safety in the construction Industry and improving safety standard (HM Treasury 1996, HMSO 1996). Its actions were reinforced by a strong pressure from the EU (EAHSW 1997). On the other hand no efforts were made, in the UK at least, to improve the existing data and create new ones in order to appreciate the complexity of the problem of fires on construction sites and its real economic, social and technical impact. Basing the approach on assumptions and few evidences did not slow down the production of new standards and regulations to improve fire safety during the construction/refurbishment process or improving the existing documents. So far, this was what happened. Even now it is difficult to identify a clear link between what happened and the series of modifications and/or amendments made to the texts. The Joint Code of Practice for Protection, 1992 (BEC, LPC & NCG, 1992) was a direct consequence of two major fires in London in 1990 and 1991. Puybaraud (1997a) argued that this document was an improved version of the document "Standard Fire Precautions (P5)" published in 1972. The Amendment 17 of the JCT80 Standard Form of Contract did not seem to be justify and added again more pressure on the contractors' shoulders and not especially the clients. The last and not least publication of the HSE is another "Guidance" (HSE, 1997a) which was even more confusing for the participants and is again not justify.

In such circumstances, it would be difficult to improve the actual level of protection and fire safety on construction sites. **It was time to move towards a harmonised approach in line with the requirements of the contractors – cost benefit and safety based approach, the clients – cost targeted and a satisfactory end product, i.e. a building, the insurance companies carrying the risks, the Government willing to improve the situation and finally the EU concerned by the harmonisation of regulation within the Member States.** Therefore, three major issues would need to be addressed. The first is **to provide a detailed range of evidences** to assess the causes and consequences of fires on construction sites. Secondly, **to address a response through the legal documents** either by improving the existing documentation or producing a set of new regulations. Finally, it is of primary importance **to measure the impact of any new measures implemented**.

3.7.7 Conclusion and Recommendations

Bovis and Withey recommend that procedures should be drawn up for any project in accordance with the Joint Code of Practice for Protection, 1992. However, Carey (1997) suggested that there has been some improvement in site fire safety and he believed this to be a direct result of the introduction and application of the Code. This may be pure sophistry. Statistics were still not available to support this suggestion and, therefore, this was an area where further investigation was necessary. Only on the basis of the full investigation it would be possible to assess accurately the impact of the Code and how the participants in the construction industry perceive it.

Much of modern UK health and safety law was goal setting –setting out what must be achieved, but not specifying a single method by which it must be done. This allowed the Contractors a lot of flexibility into their managerial approach. Employers must comply with the law and failure to do so is a criminal offence (Section 33 Health and Safety at Work etc. Act 1974).

Bovis used this, in 1992, to develop its own guidance and implement a new Management Culture. However, this work was of little significance for small companies. At least 50% of small companies work for large companies, i.e. as subcontractors, specialist contractors, etc. **Small companies have been forced to change and develop a new corporate approach** towards the problem of fire safety on site. Eleven fires a day on construction sites couldn't be ignored. This was especially so **when more than 96% - 2900 fires out of 3000 in total result in a fire loss <£50,000 – and potentially affect 92% of UK construction companies**. Small companies were asking for simplified legislation, better regulation and more guidance as illustrating good practice (EAHSW 1997). It was widely accepted, at least in the UK, that a cost-benefit approach to regulation is appropriate (HM Treasury 1996). Small companies were very concerned about the cost implication of new standards (Davies & Tomasin 1996), but as described in this paper and others (Puybaraud 1997a, 1997b, Carey 1997), simple measures could be taken without a great financial investment. Davies & Tomasin (1996) also argued that the financial resources of small firms were generally insufficient to provide the necessary standard of safety training carried out by many large firms.

The Government has been determined, since 1996, to make implementation and enforcement of regulation more business-friendly. The Government has also adopted three principles of good regulation (HM Treasury 1996):

i/ **Think small first**: no regulation without first making sure that firms can cope,

ii/**Proportionality**: no regulation unless the benefits really justify the costs to business and others,

iii/ **Goal-based:** no detailed rules when you can simply specify the objectives.

3.8 Conclusion Chapter 3:

For the last 10 years we have been witnessing a **slow change of management Culture**. However, even from the sparse information available it would appear that contrary to popular belief, fires on site were a major problem. Preliminary statistical information points to the continuance of losses. The low number of examples used and discussed in this chapter indicated **a dearth of research in the evaluation of fire safety on construction sites**. Clearly, part of the problem was the lack of published data. The identification of causes, such as "attitudinal negligence" was fraught with problems because of the rarity of major fires and the long periods taken to assess the causes of the incident. The published works reviewed did not provide a solid framework or foundation upon which the current vast problem of fire safety on construction sites can be confidently built. No definite conclusion could be drawn about the relative impact of management on the reduction of risk of fire during the construction/refurbishment process of buildings, neither about the effectiveness of different managerial techniques (Fire Safety Plan, Consultant work, developing a Positive Safety Attitude) nor its impact on fire safety attitude. The small number of examples studied largely limits present conclusions. However, additional avenues of investigations were presenting themselves. These include a **review of the process of organisational change and its management for effective fire safety on site incorporating factors such as culture, communication, and adopting new management philosophies**. It is now, therefore, important to orientate this research towards the **effects of major organisational change on safety culture**. The clear need for a study of fire safety during the construction process has now been identified and a thorough investigation of the problem in more depth through a series of field-based studies is now planned.

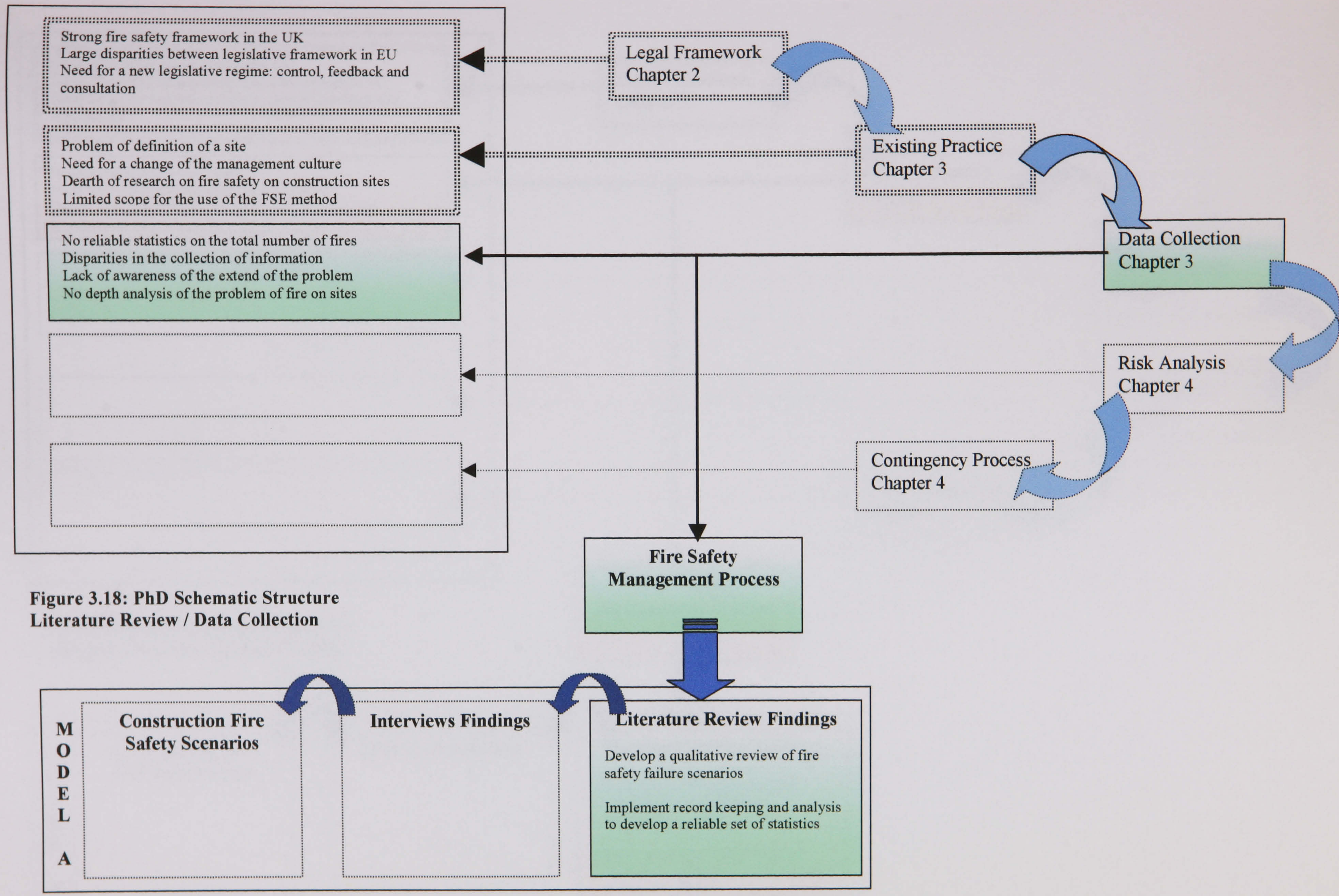


Figure 3.18: PhD Schematic Structure
Literature Review / Data Collection

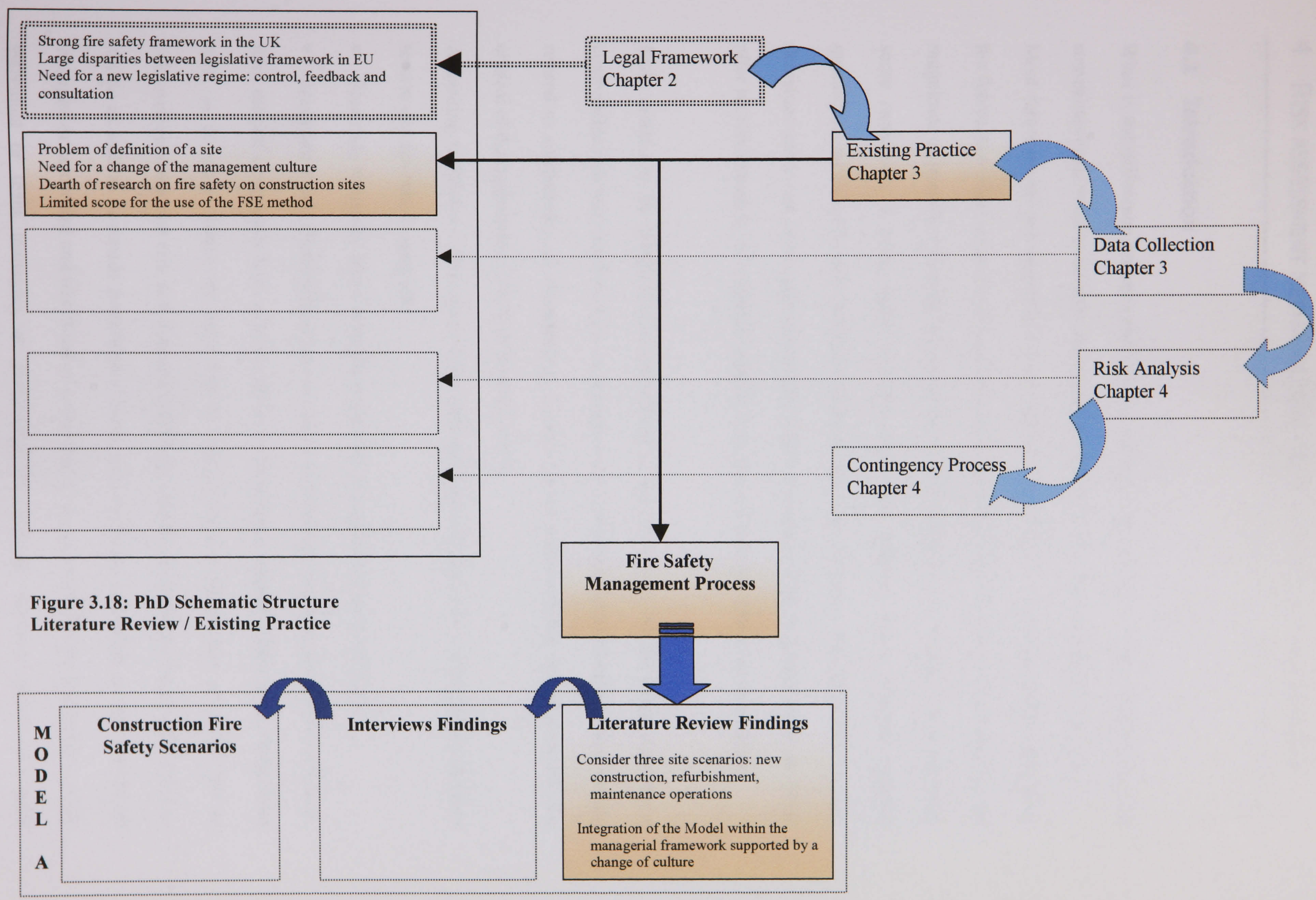


Figure 3.18: PhD Schematic Structure
Literature Review / Existing Practice

4 Risk Assessment Methodologies in the Construction Industry

4.1 Introduction

What is the difference between risk and uncertainty? The terms are often used together and sometimes considered to be interchangeable and synonymous, the concepts are very close. Most future events are uncertain to some degree since there is no perfect information about the future, but when some sort of consideration is given to their likelihood of occurrence, and magnitude of possible financial loss, uncertain events can be said to become risk events since some expression is being made on their probability, whether this is formally (explicit quantification) or informally (intuitive assessment). It is obviously more desirable to make decisions under risk than under uncertainty since more knowledge is gained about the event after its consideration. As a general rule the term risk encompasses the term uncertainty.

Risks could also be categorised as controllable or uncontrollable. As the terms suggested a controllable risk was one that could be managed and controlled and its likelihood was directly related to competency of management. Conversely an uncontrollable risk was outside the control of the organisation (Kelly & Bowles, 1999).

According to Pilcher (1996) there were different types of risk, however most practitioners tend to put this into 2 categories:

- Pure risk: Normally arised from the possibility of accident or technical failure.
- Speculative risk: Possibility of loss or gain, which may be financial, technical or physical.

Risk did not necessarily have a downside to it; **there were opportunities to be made from risk**, as in many things we hope that it would turn out better than predicted. So an acknowledgement that risk was inherent within the overall environment focused the mind to upside as well as downside possibilities. Some risks could be controlled, in that it could be managed or controlled and likelihood of occurrences was correlated to the competency of the individual or team managing or performing the process, however some risks were uncontrollable. **A risk management framework was nominally comprised of a sequential number of activities that can assist the organisation in reviewing various risks that arise from different strategies or decisions**.

Regulation in the UK did not directly require the contractor to implement a Fire Safety Plan in respect of a site but was content merely to recommend the implementation of fire safety measures to protect the contractor's employees; thereby incidentally providing a degree of protection for the building under construction. The new CDM Regulations, emphasised health and safety on construction sites but do not directly address fire safety.

Abbott (1991) previously anticipated a cultural change which would profoundly reshape attitudes towards construction site safety. Is there scope in considering the Facilities Management perspective on the indirect cost of site fires, probably through a business continuity planning lens (and temporarily placing aside the possible overbearing legal implications associated with any contractual or other assumed liabilities), can a Facilities Management input help protect the business against the *indirect* disruption costs of site fires? Is there potential in a role for the Facilities Manager as the liaison officer and co-ordinator to the development of the operational *Fire Safety Plan* (as a separate document in the *Health and Safety Plan*)? If so it will be necessary to bear in mind a number of perspectives when considering the wider picture of the problem presented in this chapter, for instance:

1. The parties to the contract: the Client/Owner, the contractor (and his subcontractors),
2. The parties occupying the building premises: the Facility Manager (acting as the liaison officer), the employees (working in the premises and exposed to the risk of fire), the workforce (working on site and also exposed to the risk of fire),
3. The third parties: Fire Brigade (offer guidance to supplement legislation, in close liaison between the site management and client/owner), and in the UK the Local Authorities (imposing a special set of rules), the HSE/HSC (ensuring the compliance with applicable

legislation and check compliance, issue Fire Certificate[15]. Also act as an advising body), the Government (imposing a set of applicable legislation[16]); the insurance companies (imposing compliance with a set of rules or Code of Practice[17]); and

4. The general public, exposed to the risk of fire in the premises.

This chapter examined the characteristics of risk in construction site fires and how to develop a sound project safety case to control and manage the risk of fire during construction activities. The risk of fire is spread throughout the complete life cycle of the facility from its conception and construction through its life and occupation and maintenance, and finally through its demolition.

4.2 Risk Assessment

4.2.1 Fire Risks

A professional approach to Health and Safety on construction sites should take a wider view and place more emphasis on dealing with the problem of fire on site. Two important activities in a system for fire prevention were fundamental to fire safety management:

i. the collection of information about fire risks; and
ii. the analysis and summarising of this information.

As explained in previous chapters, in the UK, this data is mostly collected and published by the Fire Prevention Association (FPA). This organisation regularly publishes fire reports and some very detailed studies have been completed about major fires within the last 12 years.

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[15] According to the Fire Certificate (Special Premises) Regulations 1976, a Fire Certificate will not be required if either:

- Not more than 20 persons are employed at any one time in the building or part of the building; or,
- Not more than 10 persons are employed at any one time elsewhere than on the ground floor of the building or part of the building.

[16] Building Regulations 1991, Health & Safety at Work Act 1974, The fire Certificates (Special Premises) Regulations 1976, Fire Precautions Act 1971, Construction (Design & Management) Regulations 1994.

Surprisingly, fires on construction sites are a new subject of research. In the published documentation, the lack of information about fires during construction reflected, and increased, the lack of awareness of the significance of the problem. The necessity for awareness training and preventative measures was not seen, and would remain in this situation as long as the different "accidents" did not represent major losses for the construction industry in terms of material loss, business loss and, unfortunately, human loss.

It is often regretted that people only seem to learn by making mistakes and that important safety lessons are learned - or at least acted upon - only after major disasters. Indeed if there were no fires, it would not be necessary to study fire safety. However, accidents gave experience that often can be gained in no other way. Reference has already been made to the Fire Prevention on Construction Sites Joint Code of Practice, jointly published by the Building Employers' Confederation, the Loss Prevention Council and the National Contractors' Group. This Code resulted from a reaction to the consequences of two major incidents in London, in 1990 and 1991 respectively. An in-depth analysis by the Home Office Research and Statistics Directorate about the UK 1995 Fires showed that 70% of the fire on construction sites are provoked by arsonists (Arson prevention Bureau, 1997). The Arson Prevention Bureau (CFPA Europe, 1994) revealed that "at least 40% of the cost of the total fire damage in Europe is due to arson. Arson is now recognised in more countries as their major fire problem –socially as well as economically." Most of these arsonists could be considered as opportunists or casual arsonists. Even if a 'Zero Philosophy' was an unachievable goal in health and safety, it was believed that fires of this nature could have been prevented. Modern technologies and management should be developed to respond to this problem. The introduction of a systematic risk assessment should be the most effective way to evaluate at an early stage of the project the risks of a fire. The Fire Safety Plan should therefore consider this problem and implement an effective safety plan to prevent any fire to occur on site.

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[17] Joint Code of Practise on the Protection from Fire of Construction Site and Buildings Undergoing

4.2.2 Some Issues Arising from Previous Cases of Site Fires.

As discussed earlier, the nature of the phenomenon and consequences which may benefit the business from a proactive fire safety management approach probably reside within the indirect consequences category, and may be usefully illustrated by some documented cases.

In the UK, two major construction-related site fires in London in 1990 and 1991 had significant economic consequences alone (Broadgate Phase 8 and Minster Court). These have been well-documented. It is also worth reviewing another important site-related fire which originated during some maintenance works in Dusseldorf Airport, Germany, on the 11 April 1996 (the source of following information is ANPI (1996)). This fire not only caused important material damages to the building structure but more importantly lives were lost. 16 persons died in this fire and a large number of other miraculously escaped from what was described by the witness as an *"unavoidable death"*. According to the Airport Fire Brigade Department, investigators from the police department (NFPA, 1996) determined that the fire was started by a welder who was working on expansion plates in the roadway over the lower level of the terminal. They believe that he ignited blocks of polystyrene insulation (8cm thick) which were adhered to the underside of the concrete deck in the void above the ceiling on the first level. The fire was able to spread upward through unprotected openings such as escalator, stair opening.

The report (NFPA, 1996) into this fire established that the source of this fire was linked to human error: "**failure of workmen to take adequate precautions** during welding operation...". But it is beyond any doubts that we can say this fire could have been avoided or at least its consequences minimised with an adequate Fire Safety Plan implemented both by the contracting company carried out the maintenance work and the Airport Management liable for the safety of the passers-by, i.e. passengers and general public and its employees. The NFPA Fire Investigation Report (1996) quotes a "lack of adequate communications capabilities between the command staff and the fire fighting units..., insufficient radio

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Renovation (1992)

frequencies available..., inadequate means of egress capabilities..., unprotected vertical openings, transmission of erroneous information..." **A risk assessment has not been carried out and potential consequences of a fire not evaluate**. Prevention and awareness combined with an early response of the persons directly involved in this fire could have saved the lives of 16 persons. In this case, every circumstance were present for a fire to occur:

- Highly flammable Ignition Source: hot work.
- Lack of awareness from the workers involved in the maintenance work, i.e. nobody thought about fighting the fire at an early stage.
- Fire Detection and Protection System non-operative during the maintenance works.
- Inadequate evacuation system in the Airport, i.e. evacuation procedures, means of escape, etc.
- High fire load in the building

The risk of fire was high and no precautions have been taken to eliminate or at least reduce this risk to minimise its consequences.

Unfortunately Dusseldorf is not the only fire where the cause of fire the construction related. In order to set up a broader picture of the issues of fire safety in occupied premises, three significant case studies have been analysed, highlighting the strengths and weaknesses of each of them and the lessons learnt and proposing a framework of good practice.

In the Sight and Sound Theatre fire in Pennsylvania, 1997, USA (FEMA, 1997): The storage area was undergoing renovation and the theatre was closed to the public. However 200 construction staff and employees were in the building at the time the fire started. The fire was caused by a construction worker welding steel plates on the stage floor decking directly above the point of origin. During the removal of the floor covering, screw holes were exposed which allowed sparks and/or a molten arc-welding rod to fall onto combustible props stored below. Two theatre employees who went to the storage area for equipment and saw a stored stage prop on fire at three points discovered the fire. At approximately the same time, "the welder smelled smoke but disregarded it, thinking it was the welding and the hot steel burning the soles of his boots" (FEMA, 1997). The fire caused the collapse of the state-of-the-art, seven-year-old theatre and resulted in structural damage to most of the connecting buildings. The total loss was valued at over $15m, and clearly the business continuity issues were immense.

Following this fire, the FEMA (1997) in their technical report, identified an important number of Fire Safety Facilities Management issues: **the inadequacy of staff training** was expressed through the lack of collective training, "...the theatre staff and the fire department had not trained together on managing a fire emergency..." Also contributing to greater loss, was "the **failure of the alarm system** to notify the fire dispatch communications centre and the lack of an adequate, readily available water supply." If such issues had been assessed before work proceeded on the stage floor, the Facility Manager and contractor would likely have **recognised the potential hazard** and could have suggested fire prevention measures within and around the work area.

There are also Fire Safety Facilities Management lessons from the Frigecrème factory fire which occurred in November 1998, France (CNPP, 1998): An ice-cream factory in an industrial area along the Nantes-Saint-Nazaire city bypass, in June 1998, was subject to a major firebreak out. **Hot works** carried out by some welders working on the highly insulated **sandwich panels** caused the origin of the fire, i.e. negligence as quoted in the report "*l'origine de l'incendie résulterait d'une imprudence*" (CNPP, 1998). A hot work permit has been issued and the work was nearly completed without any incidents. The fire spread very quickly while the construction workers tried to extinguish the fire before raising the alarm (CNPP, 1998). An hour later, 3,000m2 of the factory are completely destroyed. The factory evacuated 250 employees and managed to save all its stock of ice cream through **the careful implementation of a Disaster Recovery Plan** (CNPP, 1998).

Figure 4.2 indicates some emergent principles for fire safety management from these cases, - issues which may be relevant for the Facilities Manager as well as the contractor.

ıre 4.1: SOME EMERGENT PRACTICE ISSUES

FACTS

CS1: DUSSELDORF AIRPORT, 1996, Germany:

- Fire origin: welding operation (Negligence)
- No Fire Action Plan
- Slow fire growth: delayed discovery of fire
- Transmission of erroneous information
- Inadequate emergency procedures
- Lack of awareness of building layout
- No detection system
- Lack of adequate communications capabilities
- Rapid spread of fire in airport premises
- No compartmentation
- Lack of awareness of employees

CS2: SIGHT & SOUND THEATER, 1997, Pennsylvania, USA:

- Fire origin: welding operation (Negligence)
- Rapid spread of fire.
- Employees delayed report of fire
- 200 Employees at risk at the time of fire
- Alarm system failure
- Sprinkler system waived
- NO water supply
- Structural failure
- Lack of compartmentation
- Inadequate staff training
- No pre fire planning

CS3: FRIGECREME, Ice cream industry, 1998, France:

- Fire origin: welding operations (Negligence)
- Rapid spread of fire
- Employees and public at risk
- Fire Emergency plan operational and successful
- Business interrupted + 100 employees off work.
- Structural failure: sandwich panels.
- Use of compartmentation to stop spread, by zoning
- 500m security perimeter to protect public
- Complete evacuation of factory plus another neighbouring building.
- One hospital at risk (smoke and fumes pollution)

LESSONS LEARNT

- Need for a detailed assessment of the risks and hazards before and during the construction stage.
- Implementation of an operational emergency plan and test it.
- System of control and monitoring of FSP during the construction stage.
- Develop training and awareness among employees and the workforce about the danger of fire, its consequences and line of conduct in case of fire.
- Improve communication and liaison between the Contracting company and the FM: compatibility of the project safety information
- Liaise with local fire services and fire brigade
- Improve fire safety by design (fire engineering approach)
- Pre-construction meeting necessary
- Improve Structural fire resistance and compartmentation to limit the spread of fire in the building premises.

FRAMEWORK OF GOOD PRACTICE

- PROMOTE PREVENTION
- SYSTEMATIC RISK ASSESSMENT & HAZARD IDENTIFICATION
- ADAPT EMERGENCY PLAN
- DEVELOP TRAINING AWARENESS PROGRAMMES
- IMPLEMENT A PROPER AND OPERATIONAL COMMUNICATION NETWORKS
- CONTROL / MONITOR / TEST THE HSP, FSP, EMERGENCY PROCEDURES
- UPDATE BCP
- LIAISE WITH LOCAL FIRE BRIGADE AND EMERGENCY SERVICES.

To integrate in the
FIRE SAFETY PLAN

4.2.3 Assessing the Risk of Fire:

The Department of Environment reported in March 1996 that 35 employees have been exposed to fire in 1994/95 (DEO, 1996). This figure was lower than 1992/93 results (DEO, 1995), where 38 exposure to fire have been reported to the Health & Safety Executive's Field Operations Division Directorate and Local Authority in Great Britain. The HSE reported in its last publication, Fire Safety in Construction Work (Scones, 1994) 4000 reported construction fires annually. Unfortunately, the lack of detail of these accidents did not permit us to draw a clear analysis of the causes and consequences of these exposures to fire. Nevertheless, the risk of fire has been identified and recognised by the main Health and Safety body in the UK.

Construction/demolition sites were already considered as places of risk but normally, only in relation to the construction activity itself. As a result, there was awareness amongst managers and reasonably good safety attitudes exist. However, managing fire safety on construction sites required two additional, but fundamental, attitudes:

i/ **the assimilation of fire prevention measures into management routines**; and

ii/ the promotion of the **importance of fire awareness**.

Unless attitudes change in respect of these points, fires on site will continue. Planning for, and implementation of, **construction site fire safety needs to be addressed as part of the procurement process**.

A typical example to reinforce this view of the importance of construction site fire safety is that of Minster Court, London, in 1991 (LFCDA, 1991), an 8-storey building (70 x 60m) with 2 underground levels. A fire incident was discovered at 7.30am at an upper ground floor; later investigation revealed that the fire began in rubbish accumulated in the atrium (which was still scaffold). This incident, alone, accounted for approximately 90% of all fire losses in that year. The cause of the fire was assumed to be a discarded match in rubbish. In this case, human error is, therefore, believed to be the main cause. However, what is more surprising is that, even after this major disaster, only three weeks later another fire was reported which had been ignited by a carelessly discarded cigarette. Fortunately, this second incident did not kill anyone, but two persons were badly injured.

4.2.3.1 Roles and Obligations of the Parties:

A key decision for any client was the **choice of mechanism that will best manage these inter-organisational relationships during the procurement process** to ensure an early stage fire safety contribution. It is in this context that the first component of a proposed model for fire safety Facilities Management is presented.

Figure 4.3: Project Safety Strategies illustrates some issues in the preparation and implementation of a fire safety strategy, for a project managed on-site by a designated project manager or planning supervisor, is likely to be one of the most effective single measures that can be taken to mitigate the potential losses due to fires during construction and refurbishment. However, while accident prevention was understandably given top priority, both management and workers frequently overlook fire safety.

The London Fire and Civil Defence Authority (LCDFA, 1991; HMSO, 1995), and the Loss Prevention Council (1992), for instance, recommended the formulation of a fire safety plan on construction site. Specifically, the Loss Prevention Council (1992, 2000) Fire Code required that "all parties involved must work together to ensure that: adequate detection and prevention measures are incorporated during the contract planning stage; and, the work on site is undertaken to the highest standard of fire safety thereby affording the maximum level of protection to the building and its occupant [employees, general public, workforce…]".

It was recommended that the **Fire Safety Plan (FSP)** can, and should be (LPC, 1992, 2000), an **integral part of the overall safety program** required in project specifications and should be addressed as part of the overall procurement process. A *Fire Safety Plan* should set out the objectives of the plan, propose a strategy to be adopted and, finally, indicate what action could be taken to achieve these objectives. It should be **in accordance with the existing emergency procedure and the Business Continuity Plan (BCP).**

By use of **risk assessment on the construction site** at an early stage of the project, the contractor would be able to:

i. identify any potential risk of fire at an early stage;
ii. quantify the risks for each of the stages of the construction/refurbishment programme;
iii. allow fire safety decisions to be made within the constraints of the time and resources; and
iv. provide an adequate solution and develop the scope of the analysis by specifying a set of measures (FSP and Contingency Planning).

It was possible, however, that, in some circumstances, the depth of this type of assessment will not be enough to provide to the user with a wholly reliable solution. In such circumstances, it would, of course, still be necessary to seek advice from an expert who will be able to compare the alternative solutions and decide on the most suitable.

As a **business user, the client/employer** would usually require different benefits. Nevertheless, the client is the future user of the property whose main interest is to be able to move into his property. Therefore, if the client is aware of the risk of fire during the construction or refurbishment of the project, this assessment will be important and will be viewed in a different perspective. The main concerns would be to:

- ensure that the asset will be completed on time, on cost and to the quality specified; and
- appreciate the level of consciousness of the contractor and the effectiveness of his management to control any risk of fire prior to handover.

This type of **short method risk assessment, if proposed by the insurer** as a compulsory first assessment, would be of use in different way. The main benefits for the insurance company will be to:

i. ensure that the client is aware of the risk of fire on site;

ii. provide a simple and reliable method of assessment;

iii. propose immediate solution to the contractor and supply a suitable alternative, if required; and

iv. use this method as a basis of calculation of the premiums.

Nevertheless, a risk assessment should not be considered as a purely commercial tool. It is also a useful method to ensure the identification of hazards, evaluate their potential consequences and finally provide a set of solutions applicable immediately.

4.3 Contingency Planning and Business Continuity:

Prior to reviewing a brief outline history of business continuity the reader should familiarise themselves with some of the terms. The Business Continuity Institute (BCI) describes business continuity management (BCM) and business continuity planning (BCP) in the following terms:

Business Continuity Management

- Those management disciplines, processes and techniques which seek to provide the means for continuous operation of the essential business functions under all circumstances.

Business Continuity Planning

- The advance planning and preparations which are necessary to identify the impact of potential losses; to formulate and implement viable recovery strategies; to develop recovery plan(s) which ensure continuity of organisational services in the event of an emergency or disaster; and to administer a comprehensive training, testing and maintenance programme.

However, the one that encapsulates the overall business processes and attempts to position business continuity as a pro-active process has defined Business Continuity as (Herbane et al. 1997): "the planning that identifies the organisation's exposure to internal and external threats and synthesises hard and soft assets to provide effective prevention and recovery, while maintaining competitive advantage and value system integrity."

Business Continuity Planning (BCP) is different from Disaster Recovery Planning (DRP) and this is best explained by the following terms:

- Business continuity is the process of planning to ensure that an organisation can survive an event that causes interruption to normal business processes.
- Disaster recovery is the process that takes place during and after an organisational crisis to minimise business interruption and return the organisation as quickly as possible to a pre-crisis state.

However, Survive! The international user group for business continuity and disaster recovery planning professionals agrees with the BCI explanation of BCP, however it states that Disaster Recovery is:

- The process of returning a business function to a state of normal operations either at an interim minimal survival level and/or re-establishing full scale operations.

4.3.1 Disaster or Crisis?

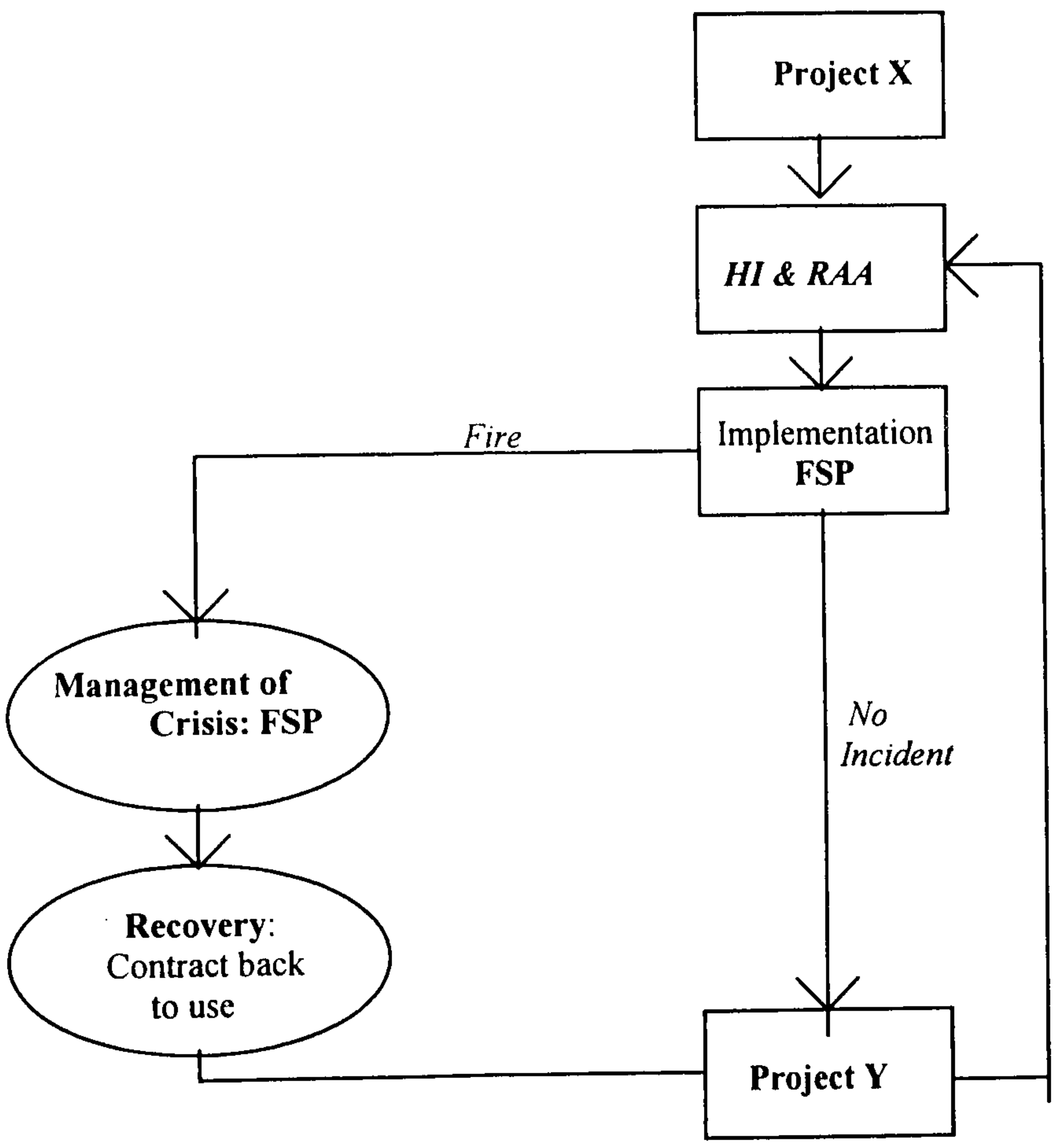
People's perception is that a disaster or crisis is something that results in considerable physical damage, usually accompanied with substantial numbers of casualties, both injuries and deaths. Examples of this would be earthquakes, hurricanes, floods, aircraft crashes and explosions and bombings. It is unlikely that this word would be applied if an earthquake destroyed a remote uninhabited island in the Pacific. Whereas a letter bomb that injured staff would be by comparison classified as a disaster. A disaster is a sudden and extraordinary misfortune, a calamitous event, especially one occurring suddenly and causing great hardship or damage.

It has been suggested that disasters do not occur and are the result of a number of events – preconditions that can turn a simple non-hazardous event into a chain reaction, almost like the escalation of a disease.

Crisis management literature suggests that there are a series of phases (Fink, 1986; Shrivastava, 1992; Turner, 1994)

For example Fink (1986) suggests the following four phases:

i. A pre incident or "prodromal crisis" – warning stage of an impending crisis;
ii. The incident itself – "acute crisis";
iii. Post-incident phase of recovery or clean up -"chronic crisis" –; and
iv. Goal of the previous -"crisis resolution" ,



Key:
HI & RAA: Hazard Identification and Risk Assessment Analysis
FSP: Fire Safety Plan, Development, maintenance, auditing and testing.

Figure 4.2: Planning for Fire Safety: example of a model.

In this last regard, planning a response to the eventuality of a disaster is not a simple task. Again the task has two parts. The first was to ensure that site layout, site operations and facilities would be supportive of first-aid firefighting and other intervention requirements. The second objective was to be able to manage any incident that affects the continuity of business. One way to achieve this task was to provide a fire recovery contingency plan. Contingency planning is not an option; it is essential. The procurement budget, therefore, should be sufficient to allow for its implementation or insurance provision should be made. Contingency planning must address the effect of a fire incident on the continuity of both the contractor's, and the client's, business as a whole.

There are four distinct phases involved (Reynolds, 1994):

- Review of hazards: assessment of the risks and their potential impact on the organisation and business.
- Development, maintenance, auditing and testing of the contingency plans.
- Incident management, implementation of plans during an incident and the immediate aftermath.
- Recovery to normal business operation.

If Contingency Plans were included in the planning for fire safety, we should noted that the plans initially will be formulated at the inception of the project - a long period before application is possible. They must, therefore be constructed with a long-term view of the future, and will need to include an analysis of needs for business recovery.

4.4 Risk Transfer:

4.4.1 The Insurance:

The building contractor would wish to ensure that he had insurance in respect of any potential liabilities to third parties arising from personal injury or damage to property occurring during the course of construction. The objective was to transfer the risks remaining that cannot be eliminated and which are too large for the Construction Company to carry itself. He would, therefore, contact an insurance company ones he agreed to insure the works. Generally, he would assume both the liability for damage to the works due to the risks, which he had agreed to insure against, and the responsibility for any uninsured costs arising by reason of any policy exclusions and excesses.

The objective of the contractor subscribing to an insurance contract was to attempt to protect against financial consequences. By putting an insurance contract into place, therefore, the potential cost of an incident or possible damage is minimised. For protection, the contractor would enter into an insurance contract that specifies the amount of indemnity in relation to the level of potential damage that might be suffered. In exchange for its obligation, the insurance company would require payment of a premium, calculated in relation with the amount of risk taken and, in respect of fire, the probability of that a fire might occur. The premium was based on the extreme monetary value of the indemnity provided, assessed at the time the contract is signed. The main difficulty, for insurers, was the evaluation of the premium at a level commensurate with the probabilistic risk of a fire occurring during construction and the end losses. Insurance required by a construction contract would generally be in two distinct areas: liability and property. The property insurance was generally known, as contractor's "all risks" and would cover the contract works together with unfixed goods and materials intended for incorporation therein. The contractor may cover his plant and equipment under this same policy. As mentioned before, the construction industry market was still reeling in the aftermath of several major fires on construction sites during the early 1990s. Not only were premiums rising and capacity falling, but the insurance market was starting to exercise a greater degree of risk management and loss control.

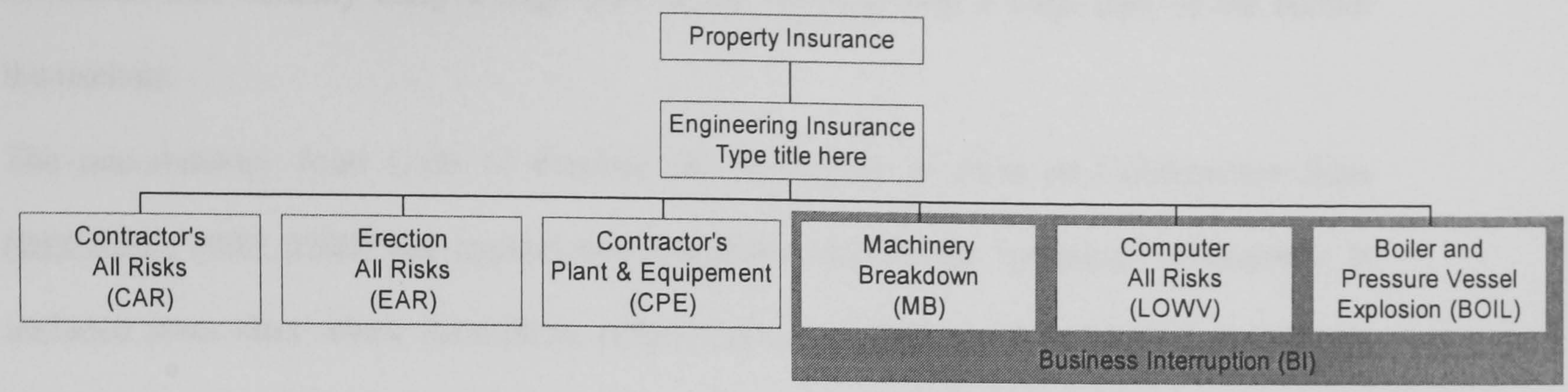


Figure 4.3: Type of Property Insurance

4.4.2 Procurement Strategy

Once the client is satisfied about feasibility within overall budgetary constraints, the design of the project can start. The type of contract and the procurement path was an important choice for the client. On the basis of professional advice the client decides how much risk to accept and, therefore, the client must be given a thorough and complete assessment.

The Latham Report (1994), Constructing the Team, recommended that choosing the procurement route should precede the preparation of the outline (brief). This must be determined by the nature of the project and the client's wishes regarding acceptance of risk, i.e. the results of risk assessment should determine the contract strategy. Latham also proposed a range of procurement and contractual routes that could be used to meet a client's wishes - each included within one of three different approaches to construction: "Standard Construction", "Traditional Construction" and "Innovative Construction".

Linking fire risk during construction with the choice of procurement route was a new concept. It was argued that, by the choice of an appropriate procurement route, it was possible to address the risk of fire. Until now, the risk of a fire incident during construction has been regarded as, generally, equal in all construction methods. Individually, however, it is mainly dependent on the risks presented during the whole of the procurement process. Therefore, in carrying out a risk assessment to define a procurement and contractual route, the client should also take into account the probability of a fire during the construction phase. This assessment should influence the decision as to the best procurement route, not only because the risks can be passed onto an insurer or contractor but also because both client and contractor also actually carry a large part of the risk and bear a large part of the burden themselves.

The non-statutory Joint Code of Practice for Prevention of Fires on Construction Sites (BEC/LPC, 1992, 2000) was applied to construction sites by the "pressure" of insurers. It included those sites where demolition, refurbishment or repair work was being carried out. Compliance with this code will minimise the risk of accidental or malicious fires. The Code stated that proper planning for fire, safety and health must be an integral part of the overall preparation and budgeting for the efficient running of construction projects. The Code suggested that the main contractor should appoint a Site Safety Co-ordinator who would be responsible for assessing the degree of fire risk and who should liase with the co-ordinator of the design phase (usually the architect).

In analysing the above two paragraphs, it would appear that, in order to comply[+] with the Joint Code of Practice, the main contractor needed to be appointed at an early stage of the project - specifically, before the design phase - as it is necessary for the main contractor to appoint a Site Safety Co-ordinator "for formulating and regularly up-dating the Site Fire Safety Plan as construction proceeds". In this case, a traditional procurement path was not possible as, in the UK, the contractor tenders in stage H, "Tender Action", of the RIBA Plan of Work. However, with two stage tendering as a variation of the traditional system, i.e. where the contractor bids on the basis of a brief description of the project, it was possible to appoint the main contractor who then becomes a full-member of the team under the general direction of the architect. The contractor was then able to make technical contributions, through the site safety co-ordinator, as envisaged in the Code.

This suggestion is by way of example only. However, it demonstrated that **a key decision for any client concerns the choice of mechanism(s) to manage these inter-organisational procurement process relationships in the best way to ensure an early stage fire safety**

[+] "Non compliance with the Code by the Construction Industry, by those who procure construction and by construction industry professionals, could result in insurance ceasing to be available or being

contribution. It is generally recognised that the contractual arrangements clearly established the stage at which each team member was able to be involved in the project. This timing also affected the development of the lines of communication and the allocation of responsibilities for providing information, patterns of co-ordination and control. The setting of project objectives and parameters to determine the appropriateness of Contract Strategy should, therefore, include consideration of required levels of site fire safety and of how it can be best achieved.

4.5 Managing Risk on Site:

Construction safety is a serious concern to most construction companies. Accidents not only reduce productivity and damage equipment but frequently also injure human beings. They affect both construction costs and profitability through delays, damage to equipment and materials, damage to the facility under construction or through compensation payable as damages for accidental injury or loss of life.

Globally, the approach to Health and Safety on construction sites should take a wider view and place more emphasis on dealing with the problem of fire on site. Two important activities are fundamental to fire safety management:

i/ the collection of information about fire risks and

ii/ the analysis and summarising of this information.

But without implementing drastic measures on site there are a number of simple and immediate methods to reduce the risk of fire. Vigilance and risk awareness are one of them; and should be accompanied by a series of activities to support an awareness programme. The existence of a company safety file ensures the provision and implementation of safety control procedures appropriate to the project. This plan should identify specific job hazards and address the educating of employees to enable them to conduct their work in a way that will

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withdrawn resulting in a possible breach of construction contracts which require the provision of such insurance...", Joint Code of Practice, p2.

minimise the risk of accident or incident (Bennett, 1991). There were a number of examples throughout the worldwide construction industry. The Japan was one of them in terms of general health and safety on construction sites. But a special example came to mind. The company Quasco (1996) in Bologna, Italy, implemented a simple and effective way to develop risk awareness throughout the construction phase. They developed a series of short Health and Safety training they carried out on site, in the working environment of the workers. This method was also extensively used in other countries but most of the time they are standardised. In this special case, each training was adapted to the needs of the company and the employees working on site. Prior to the training, Quasco would investigate the site and carried out a pre-health and safety assessment. The main objectives of this investigation were to identify the risks and record them. Once these risks have been identified and clear classify, the role of Quasco will be **to develop a certain level of risk awareness** within the workforce, i.e. made them aware of potential risks around them and suggest them solution to eliminate those risks or at least reduce them. They would then adopt the right attitude. This concept was especially designed and related to the massive problem of health and safety on site. There was nothing new in the content of these training but the concept was innovative even if Switzerland was using it now for a long time but at a bigger scale. Nevertheless, this concept was proved to be successful in Italy because it was implemented within the working environment and so retain its reality and Quasco was now developing it. This risk awareness approach was one important issue to consider when discussing the problem of fire safety on site. A study realised in 1995 by the Plan de Construction Architecture (PCA, 1995) with four companies in France (INPACT & GERN), Holland (TNO) and in Italy (QUASCO) compared the approach towards safety on site in three European countries. The results of these investigations showed that **training was an essential element to improve the level of safety in a construction company**. Italy was found to be the most successful example of risk awareness on construction site.

4.5.1 Risk Identification on Site

Risk management could be a significant contributor to the success of a company both in identifying the potential sources of risk on a site and during the construction of a project and, as a consequence, help in reducing potential costs by avoiding fire. Therefore, money and time was well spent assessing the risks in order to ensure that the fire risks inherent in a project or, at an early stage, were eliminated, controlled or transferred in the most cost efficient way. The assessment of the risk, therefore, involved both considerations of the risks themselves and the way in which those risks might affected the particular party concerned.

There were clearly a large number of potential risks around a site and on site, the control of which was difficult but with direct and indirect consequences of failure which could affect the client business. The employer had the duty to protect his/her employees by taking adequate measure in order to minimise, reduce and/or eliminate those risks. Nevertheless, it was sometimes difficult to clearly recognise those risks and especially to evaluate their consequences for the construction company and the client employees directly exposed to these risks, and also for the general members of the public who could suffer from a possible fire. **The key objective of a risk assessment was to identify potential risks and adequately quantify these risks and finally classify them**. Risk Assessment should not be regarded as a solution, rather the first phase of investigation before the implementation of a management strategy to control these risks. **Risk management was the adoption of a deliberate policy of risk control and improvement positively implemented by the contractor and other site operators and designed to minimise site fire risks** (Abbott, 1991).

Thus applied, risk management could be a significant contributor to identifying the potential sources of risk on a site and during the construction of a project and, as a consequence, may help reduce exposure to potential cost consequences of fire. Note that the indirect or otherwise internalised implications of fire possibilities for the business would not necessarily be within the scope of assessments carried out by externals, or necessarily of prime concern to them. Here **the Facilities Management link was clearly potentially valuable to the business**. Money and time may be well-spent assessing the risks in order to ensure that the fire risks inherent in a project or, at an early stage a proposal, were eliminated, controlled or transferred in the most effective and cost efficient way. It was important to set these against the total potential consequences of as site fire rather than just the immediate direct losses.

The assessment of the risk should involve both considerations of the risks themselves and the way in which those risks might affect the particular party concerned. Where risk management addressed the economics loss aspects of construction site fires to the mutual benefit of insurers, contractors and developers alike (Abbott, 1991). An effective risk management should aim to:

- i/ Identify potential risks
- ii/ Quantify and classify these risks
- iii/ Eliminate or Reduce these risks by a risk control activity
- iv/ Retain and transfer the risks remaining that cannot be eliminated and which are too large for the company to carry itself.

However, for the full scope to be achieved, planning for, and implementation of, construction site fire safety needed to be addressed as part of the procurement process itself. In turn, for this to be achieved it is necessary to understand how the contractual and actual roles of Contractor, Facilities Manager, and Client will inter-relate on a project.

The preparation of the FSP, itself, starts with a fire hazard analysis and it must be under constant review throughout the different stages of the procurement process and particularly during the on-site construction phase. These last can be grouped together for the purposes of the discussion, as:

- Substructure
- Superstructure
- Finishes: i/ Primary stage ii/ Final stage of completion iii/ Hand over/completion.

OBJECTIVES	STRATEGY	ACTION
PREVENTING IGNITION OF FIRES	Understanding the common causes of fires on construction sites and evaluating the risk - through a fire risk analysis Emphasis on managerial methods Better housekeeping Training staff Fire Safety Plan Awareness of the cost of fires	Fire Safety Education Involvement of insurance companies Fire safety Training Inspection (duties of the Clerk of Work and Project Manager) Health & Safety Adviser
DETECTING FIRES	Implementation of an effective Fire Safety Plan: - Security Systems (alarm, detectors, guards...) - First Aid Fire Program	Fire Safety Training Involvement of the Insurance Companies Inspections Health & Safety Adviser
FIRE FIGHTING METHODS	Manual: - Fire extinguishers - Fire Blankets Automatic - Early installation of Sprinklers First Aid Plan	Fire Safety Training Involvement of the Design Team Health & Safety Adviser
RESTRICTING FIRE SPREAD	Choice of Materials -slow burning and low combustibility materials. Reducing the number of storage areas on-site Protected Storage areas Early installation of a passive fire protection - fire doors and partitions to create containment, stairs for evacuation, etc.	Involvement of the Design Team Health & Safety Adviser Fire Safety Equipment Fire Safety Training Construction Team
PROFESSIONAL FIREFIGHTING	Access for Fire Brigade Fire detection systems Protection of storage areas Water supply	Construction Team

Table 4.1: Fire Safety Plan: an overview

For each phase of the construction, the fire hazards must be identified. This could be commenced at the design stage, through an assessment of materials and components for fire safety. Knowledge of the performance of building elements, assemblies, contents and materials in fire is necessary. Evaluation of hazards and their associated risks was a very complicated process. According to Williamson and Dembsey (1993) the objects of hazard identification are:

i. To identify combustible components and construction materials;

ii. To define the degree of hazard for content materials;

iii. To evaluate flame spread characteristics of "finish materials";

iv. To define the period of fire resistance for walls, structural frame, floors and doors and

v. To quantify the amount of "smoke" produced by a material.

It was also necessary assess, in relation to each of the identified hazards, a probability of occurrence from which the degree of risk can be seen. From this, comes the development of the site fire safety plan, i.e., as a response to the assessment. This fire contingency plan (FSP) would, of course, need to be reviewed and changed on a regular basis as the building morphography and fire load changes throughout the progress of construction. Similarly, evacuation routes and the first-aid fire-fighting plan would need to be regularly reviewed, updated and promulgated.

The preparation and implementation of a project's fire safety program, administered on-site by a designated programme manager, or planning supervisor, was the most effective single measure that could be taken to mitigate the potential losses due to fires during construction and refurbishment. However, while accident prevention was understandably given top priority, both management and workers frequently overlook fire safety. The Fire Safety Plan (FSP) could, and should be, an integral part of the overall safety program required in project specifications and should be addressed as part of the overall procurement process. Table 4.1 showed an overview of typical content that could be included in an FSP: set out the objectives of the plan, propose a strategy to be adopted and, finally, indicate what action could be taken to achieve these objectives.

4.6 Managing Risk in the Facility:

The management of facilities during the construction, refurbishment, renovation or maintenance of building facilities which remain occupied throughout the work brought to light several issues:

i. The need to ASSESS: at a pre-tender stage, pre-contract and post-contract award.

ii. The need to DEVELOP a fire safety plan, with all parties being directly involved: client/owner and designer, contractor and sub-contractors, facility manager, fire services authorities.

iii. The need to IMPLEMENT an operational fire safety plan.

iv. The need to REVIEW and UPDATE the fire safety plan, regularly and thoroughly throughout the construction phases.
v. The need of a mechanism of FEEDBACK between the parties, through the Facility Manager.

A proposed model was open to discussion and even if it was based on the review of existing models and operative models, it would not be possible to adopt such a thorough and detailed strategy with every project. A number of parameters would influence the development of the project safety case; the balancing of which seems to fall most naturally within the remit of the Facilities Manager:

i. **The Type of Work undertaken**: new construction, renovation, refurbishment, maintenance works, demolition, etc. The needs of the parties will vary from a type of project to another one. A place of the 'business' issue plays a very important role in every case.
ii. **The Category of Building**: offices, historic buildings, commercial, public buildings, manufacturing, schools, hotel, etc.
iii. **The Type of Business Organisation**: this includes whether there is a distinct Facilities Management role? If none, the designer or architect could act as the co-ordinator.
iv. **The Contracting Company** employed to carry out the work: small / medium / large company. It will determine the knowledge of the company in terms of fire safety, which in turn will imply the degree of input the client FM will have to make (to protect the client's self interest). It will also indicate the nature of the existing Contractor provisions to ensure fire safety (company fire safety policy, level of training of employees, existing practices, methods of assessment of risks, etc.).
v. **The Existence of a Fire Safety Manual** comprising (BSI, 1997): fire safety policy statement, fire safety specification of the building, safety management structure,

continuity control and audit procedure, fire action plan, housekeeping, planned maintenance procedures, staff training, security, contingency plans, record keeping.

vi. **Building, Environment and Occupant Characterisation**: building layout geometry, fire services facilities, fire protection systems, type of occupancy, evacuation procedures, facilities layout and occupancy layout, etc.

vii. **Knowledge and Expertise of the Parties**. This may benefit from a relational contract. Bear in mind also that the Facilities Manager is likely to be the common denominator in the range of contracts which a business undertakes for its support services provision, and therefore the control and imposition of a consistent and sufficient approach to the specific fire safety needs of the client can be managed by the FM.

viii. **Risk and Hazard Assessment**: low risk might mean minimum requirements and precautions, high risk might mean maximum precautions. Adopting a cost benefit approach would mean analysing the economic loss and decide on the appropriate precautions to implement. Sometimes paying high insurance premium combined with high risk is key decision-maker to assess the level of fire safety in buildings ... High potential losses = High Insurance premium = Maximum fire safety precautions?

These factors would greatly affect the design, style, and Facilities Management implementation of a detailed fire safety case for any facility. It is probably inappropriate, at this stage of the research, to suggest a more structured approach for general application, and the above model may be better viewed as simply an indicative checklist. Each fire safety case is unique and affected by an unlimited number of factors. Certainly, the list above highlights these major factors.

4.7 Fire Safety Process Management

All parties should be aware of the value of fire protection, not only under the pressure of insurance companies and legislative requirements, but also to safeguard their own business interest and "properties" which can't be insured, i.e. intellectual property, knowledge, public image and position. Clearly the owner would be involved long before the first contacts with the insurer are established. The influence the owner may have in the planning phase was rather large, but tends to be much less so in the building phase (Ebner, 1994).

4.7.1 Project Safety Case Approach

The HSE argued in 1997 that there were two ways to address fire in construction: to prevent it happening in the first place; and to prepare for and deal with the consequences if it does happen. Prior to this, Ebner (1994) had proposed a three-stage approach towards fire risk on construction site:

- Risk appraisal,
- Risk evaluation,
- Planning of the measures.

Clearly, **the practical application of these principles lied at the heart of achieving control over risk and consequences.**

First, the evaluation of these approaches and the review of a number of major client's practices highlighted **the need for a pre-contract and post-contract award strategy.** As Ebner identified, the majority of insurers prioritised on a number of approaches to the problem:

i. **Advice and information** for all parties involved in the construction project, including the gathering of adequate information, exchange information and seek advice.
ii. Know-how transfer towards fire risk management, such as the **systematic risk assessment** at an early stage of project development and throughout the project.
iii. **Selective underwriting,** in the context of pre-tender selection of a suitable contractor with proven safety records.
iv. **The need for contractual obligations** to reduce risks, through a legal agreement.

v. **Monitoring the compliance with these obligations**, via audit approach, review and the updating of Fire Safety Planning throughout construction phases, etc.
vi. **Sanctions for cases** involving the disregard of these obligations.

Figure 4.4: **Project Safety Plan indicated a broader model** which develops these concepts further, in order to extend the considerations in pre-planning to better reflect the bespoke indirect consequential issues of site fire safety management. It was presented as a three-stage process, including who is involved.

Figure 4.4: Project Safety Plan Approach

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Within this model, the production and implementation of the Project Safety Case (Hinks and Puybaraud, 1999) was sub-divided into an eight stage process, whereby all parties would work jointly to prepare it:

Project Remit: this was a document outlining the safety procedure to be adopted by the parties and highlighting all the safety requirements. Mainly the client's requirement translated by the FM in one single document. This allowed for some scope for site assessment to be extended into pre-contract issues, and also to look at the indirect core business priorities. The strategic vulnerability of the core business continuity could be considered this stage of the process.

Project Safety Strategy (Figure 5.5): this was a document which described the safety policy, organisation and project safety management arrangements applicable to the project. Reference to relevant regulations, code of practice and legislation outlined in this document. In particular this would be relevant to smaller sites – relevant also because the CDM Regulations (1994) were not applicable to all sites. Minor works were exempted and therefore there were no requirements to appoint a planning supervisor. This would be very often the case for maintenance work, unless explicitly required by the client or insurance companies, i.e. compliance with the Joint Fire Code would be an example.

Pre-tender HSP with separate FSP: Where CDM Regulations (1994) applies, a planning supervisor must be appointed to produce a pre-tender HSP incorporating a separate Fire Safety Plan. This pre-tender Health and Safety Plan was produced for prospective contractors who shall take this into account in their tender bids. Where a Planning Supervisor was not appointed, the FM, on behalf of the client would produce such a document.

Contractor's safety case approval: upon reception

i. the pre-tender Health and Safety Plan from either the planning supervisor or FM, the contractor would prepare a construction He*alth and Safety Plan* with a separate *Fire Safety Plan* and submit this proposal to the client for approval. The suitability and status of the contractor was assessed based on the contractor's safety case, prior to the contract award. The contractor's safety case would comprise the company safety policy and its track record. The client (via the Facilities Manager) would be able to co-ordinate the *Health and Safety Plan*, the *Fire Safety Plan*, and the *Business Continuity Plan*.

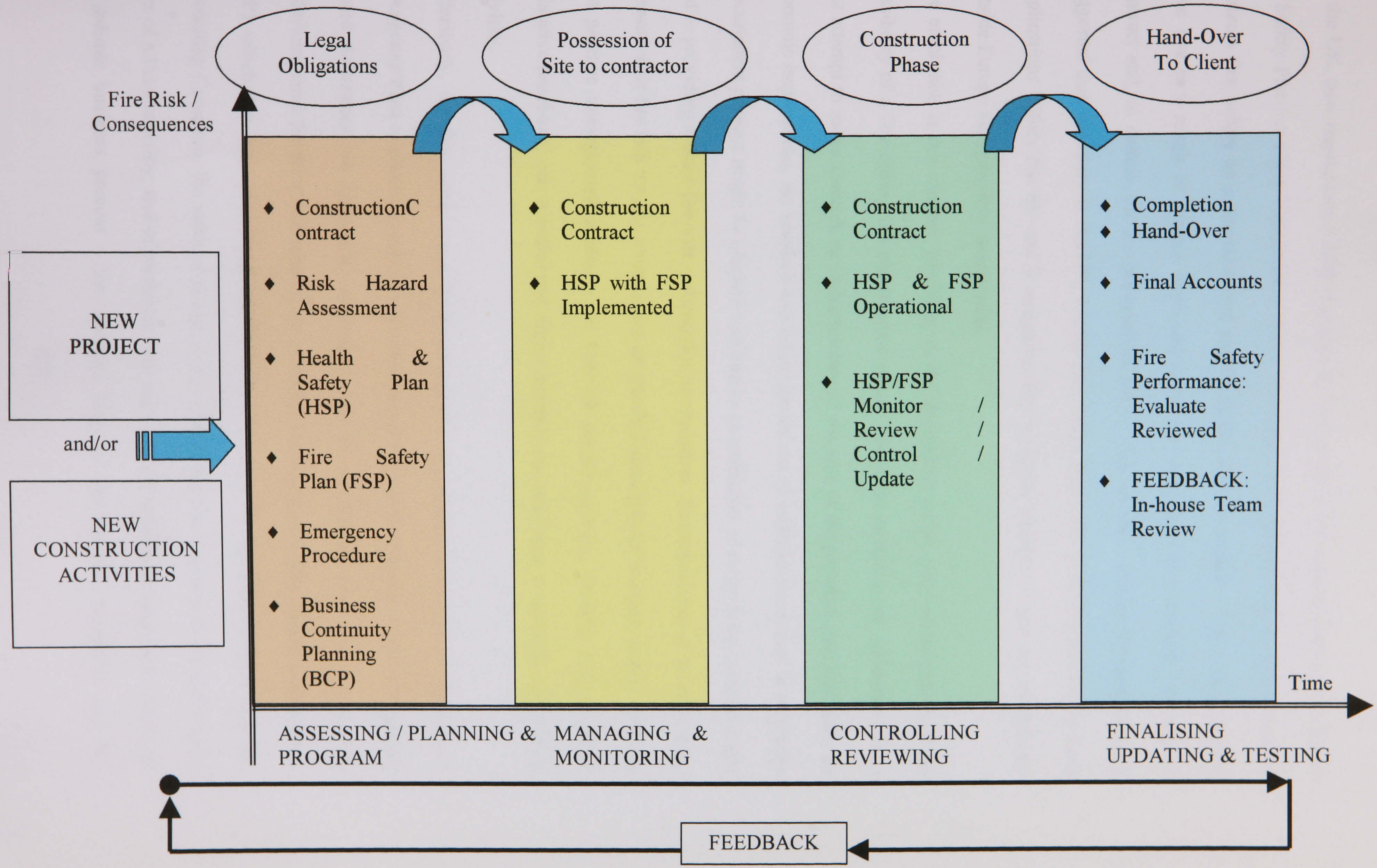
ii. **Contract HSP with Separate Fire Safety Plan**: at tender stage and prior to the contract award, the contractor was required to submit an 'outline' of the *Health and Safety Plan* and *Fire Safety Plan*. This document would demonstrate the ability of the contractor to produce a satisfactory construction safety plan (*Health and Safety Plan*, and the *Fire Safety Plan*). As above, there was the opportunity here for the Facilities Manager to overview the co-ordination of the *Health and Safety Plan*, the *Fire Safety Plan*, and the *Business Continuity Plan* together with any other business process continuity or change issues. It must outline the proposed safety arrangements to be put in place to support the *Project Safety Case* (PSC) and ensure the requirements of the client (as developed by the FM) could be met: emergency plan with fire action plan essentially. Upon contract award, the appointed contractor shall fully develop his *Health and Safety Plan* and separate *Fire Safety Plan* and demonstrate compliance with the term of the contract and any relevant regulations and legislation which may apply.

iii. **Risk Log and Safety Risk Assessment**: tracking progress with the development and implementation of control measures for the hazards and associated risks identified will be the role of the FM. It was of primary importance to the FM to know the risks and hazards the business and the occupants are exposed to. Risk analysis and hazard identification should be considered as a way to monitor, review and update the *Project Safety Case*. This could be co-ordinated by the FM with the *Disaster Recovery Plan* and *Business Continuity Plan*.

iv. **A Health & Safety File** would be submitted to the client with information provided by the contractor (or planning supervisor where applicable, according to the CDM Regulations 1994).

v. **Feedback mechanism:** there was a need to review and update the FSP throughout the project phases and inform other parties on any variation to the initial plan. A feedback process involved the participation of all parties and clear communication links within the project. The role of FM as a co-ordinator of this review process was of major importance. It was also recognised that the Facilities Manager made a broad overview of the process after projects, in order to capture learning from controlled events (and the near misses), and any events which did develop as site fires. This should be considered using a structured scenario planning exercise involving business representation.

re 4.5: Project Safety Strategy



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4.8 Conclusion Chapter 4:

In the UK, new regulations (CDM) required the preparation and implementation of a Health & Safety Plan on every Construction Site. Therefore, by implication there was **a need to address fire safety as a fundamental requirement of such a plan**. This, automatically, gave rise to a range of serious implications for the method of procurement, the type of contract and, of course, for the management supervision of site. The preliminary research suggested that, certainly in the UK, France and Spain, there was little appreciation of these implications within the EC and it suggested that a similar situation could be encountered outside Europe and, possibly, world-wide.

The emphasis, in this chapter, has been on the importance of an early consideration of the possibility of a fire during the construction phase. The issue needed to be addressed. As a first attempt to move towards an understanding of the size of the problem, and especially its economic implications, the research was being carried out to establish the extent to which the procurement process might be adapted and lead to an extension of supervision systems might lead to providing a more fire-safe construction environment. The importance of an early stage assessment of fire risk for any construction or refurbishment project was particularly stressed; best practice management guidance for fire-safe on-site activity, coupled with adequate legislative provision, was essential and major research was necessary to underpin all of these activities.

Collectively, the fire safety cases demonstrated the importance of having an operational **Emergency Plan** to protect employees and the general public; the potential value of **Training of** and **Awareness in** (primarily) employees and the workforce, (and also the general public/customers for their own safety); the potential usefulness of a **Fire Safety Action Plan (FSP)** which has been developed and embraced by both by the Client/Owner and the Contracting Company; the value of advance liaison with the Fire Services in the unfortunate event of a fire occurring; and of particular relevance to the Facilities Management context of the indirect business process – the interface between the business continuity and the temporary site operations - hence the need for **Business Continuity Planning (BCP)** to ensure minimum interruption to the normal business operations.

In UK the Health & Safety Executive (HSE, 1997) published a new guide Fire Safety in Construction Work, guidance for clients, designers and those managing and carrying out construction work involving significant fire risks. At the launch of the guide, Nick Raynsford, Construction Minister said (Croner, 1997): "This guidance is aimed at reducing the number of fires on construction sites and thereby reducing risks to workers, fire-fighters and members of the public. It identifies the main causes of fires on a construction sites, as well as understand how to plan, organise and control fire precautions that need to be taken into account, from early procurement stages right through to final hand-over." Pressures from the European Parliament (DG III: Industry) in 1994 suggested that the problem of fire should be investigate where it is currently costing countries of the European Union approximately 1% of GDP. Unfortunately for most of the European Countries, the cost of direct fire losses does not go above 0.40% of GDP (i.e. for Belgium). The UK was far from this figure and therefore no European Directives would seem to be considered as an immediate and urgent measure for the European Union. However, the European Parliament urged the Council of Ministers to make a public announcement stating their concern over the level of fire costs in the EU, but directly towards the problem of fire on construction site. He also called the European Commission to establish a Working Party of fire experts whose terms of reference would be to recommend ways of tackling the fire problem. In 1996 one of the twenty proposed Motions put forward by a MEP to the Environment Committee stressed that fire resolution should "be recognised to be an issue of great importance", but it was not accepted. This was by no mean a definitive conclusion but it demonstrates that any measures to reduce or eliminate fires on construction sites will have to be implemented in each separate EU countries and so far there are no pressure from the European Commission to develop a common directive applicable in every member states of the EU. The large number of disparities between every EU countries made the approach to the problem quiet difficult and there are no good practice examples throughout the EU that could be used as a guide for a future European Directive.

More research and investigations will need to be carried out in order to identify best practice and create a Fire Safety model which could be adopted throughout the EU. The objective of this research was to develop such a model.

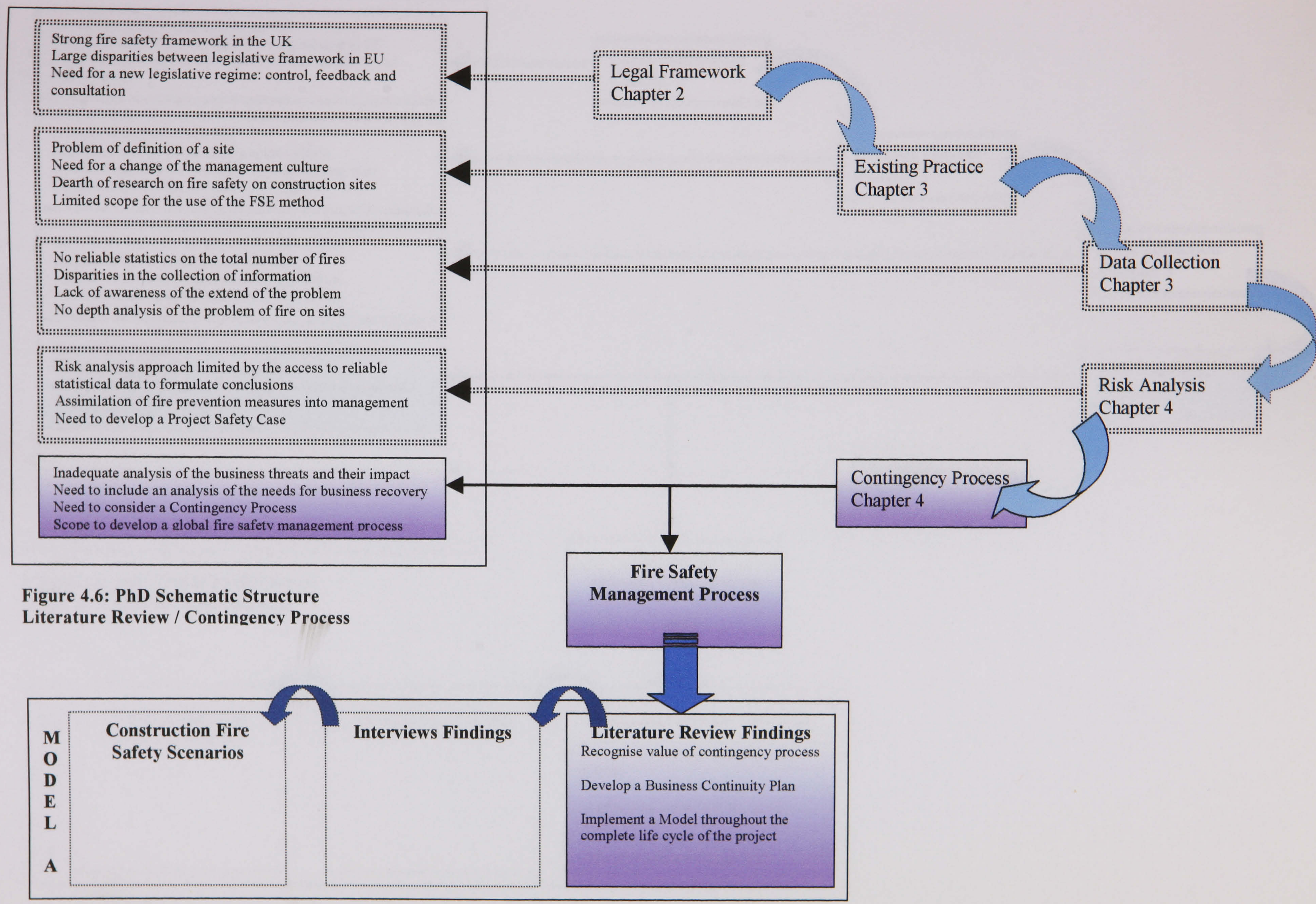

Figure 4.6: PhD Schematic Structure
Literature Review / Contingency Process

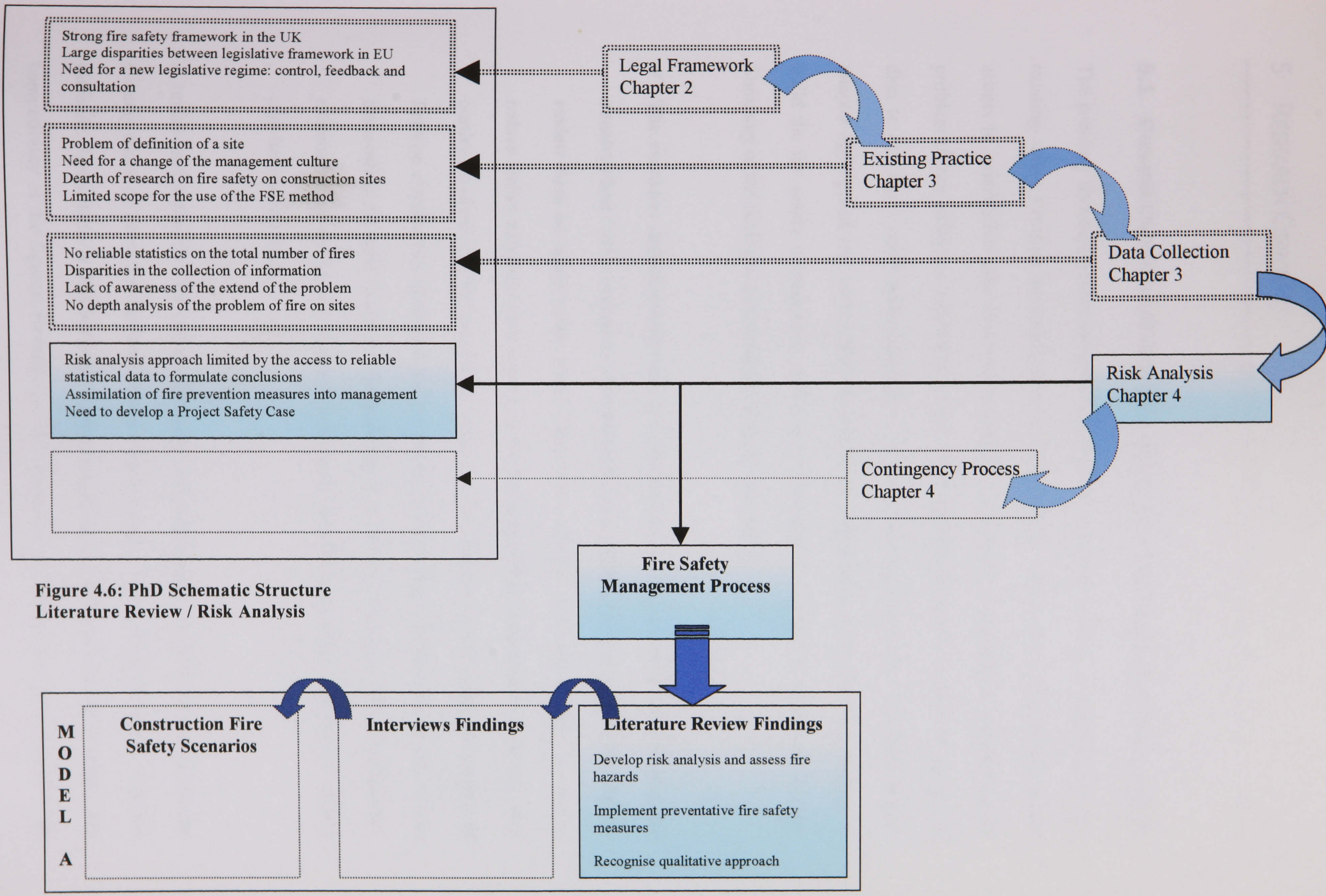

Figure 4.6: PhD Schematic Structure Literature Review / Risk Analysis

5 RESEARCH CONCEPT:

5.1 General Overview of the research project and purpose of the research

The previous literature review and analysis highlighted a large number of weaknesses in the existing safety structure summarised below. The specific nature of the project and limited access to quantitative data drove the researcher to consider a qualitative approach to the problem of fire safety on construction sites. However, further considerations on the use of data to develop a small scale quantitative analysis was nevertheless not excluded, a later chapter approached and investigated this issue. The contribution of the literature findings to build the fire safety management model were illustrated in Figure 5.1: Literature Review: Summary of the findings, and summarised in the next pages:

✓ **The statistics demonstrating the proportion and consequences of fires during the construction / refurbishment / maintenance process indicated a need to thoroughly review fires on construction sites.** There was a need to develop a strategy in order to reduce and/or minimise their impact on the business (client, contractor and the any other parties involved into the process of work.). An **assessment of the economic impact of fires** on construction sites both for the parties to the contract and the society as a whole, demonstrated a need to adopt a construction management strategy to reduce / minimise / eliminate fires during the construction process of building facilities. The need to adopt a cost benefit approach.

A review and analysis of the current literatures and public reports of the numbers, causes and consequences of fires demonstrated that access to reliable and detailed statistical data was difficult. Furthermore a detailed analysis and comparison of different sources revealed a non compatibility of the figures. Nevertheless the proportion of construction sites fires over the last decade revealed a need to research on the causes and consequences of these fires, their **impact on the business** of the parties to a construction contract and the society as a whole. Issues such as the **perception of the problem** by both contractors and clients, **the preventative measures** taken to reduce/avoid/minimise fire occurrence during the construction / refurbishment / maintenance process.

A review of current statistical sources revealed an unsatisfactory level of information on the direct and indirect cost of fires on construction sites. However the limited number of information revealed a **need to examine the economic impact** of fire to the parties to the contract and the society as a whole. The investigations revealed that the business impact should not be neglected and several cases demonstrated that issue.

- ✓ **Parties to the contract consider the problem of fire during the construction process as a serious issue**. By the pressure of clients and insurers and new regulatory requirements, contractors had to provide adequate fire safety measures in accordance with the current regulation and legislation applying and a specific number of codes of practice.

Following two major fires on construction sites in the UK at the beginning of the 90s, awareness of the problem of fire during construction works and the economic / human losses linked to a disaster on the business has been brought to light. The LPC/FPA in collaboration with the insurance companies offered a code of practice for the prevention of fire on site. This guidance has been implemented under the pressure of insurers, and contractors and clients were forced to implement it. The JCOP was assessed as an essential element of the fire safety framework and a good **operational tool**. However in order to reinforce the fire safety framework, the author would like to propose the development of an executive framework to support **the implementation and integration of the concept of fire safety in organisations and at a corporate level.**

- ✓ **The risk of fire was assessed prior to the commencement of the construction works and control and monitor periodically throughout the construction operations.** The methods of assessment and control of the risk should be described in the FSP which also comprised all the necessary information to monitor the risk of fire and test the FSP.

The research identified that the risk of fire varied throughout the completion of the works. The control of this risk was monitored through the FSP and proposed a clear fire safety strategy. The author argued for a **systematic risk assessment** at the conception stage and throughout the execution stage and exploitation.

- ✓ **The implementation of a detailed and practical fire safety plan through** a clear risk analysis was an efficient method of control to minimise and reduce fires during the construction / refurbishment / maintenance of construction facilities.

The control of fire during the construction process was expressed through the Fire Safety Plan. This plan developed prior to the commencement of the works considered all the risks and **proposed a strategy to prevent, minimise and/or reduce the occurrence of fires**. This research reviewed the use and efficiency of the fire safety management, compared and contrasted the way the concept was design and developed to be operational on site.

- ✓ **Attitudes towards safety and cultural differences** across the European construction industries had **a clear and positive impact on the management of fire safety** during the construction / refurbishment / maintenance process. This would be demonstrated through site investigations and interviews.

The research intended to identify **a change into the culture of construction companies** across Europe and particularly the UK and France. The parties involved into construction works were concern about the issue of fire on sites and as a consequence **modified their attitude towards the problem of fire**.

A detailed analysis of the implementation of EU directives in the Member State and its impact on fire safety on construction sites revealed a very different approach towards safety in general and more specifically fire safety. The comparative analysis revealed a number of discrepancies between the French and UK legislative procedure. The UK approach seemed reactive unless the European, whereby a pro-active politic had been slowly developed regarding fire safety. The track record of the publication of Council Directives answered a need to improve preventive health and safety measures, and specifically in certain cases (92/57/EEC) fire safety.

It was still too early to entirely appreciate the impact and benefit of the implementation of the EU directives in France and the UK. Furthermore, the Member States were still improving their current legislation and/or regulation. There was **a need to review the long term impact of the new directives** and how did they **contribute to improve the level of fire safety** on construction sites.

✓ **A standardised approach and fire safety management process** were a requirement to create an effective way to control fire during the construction / refurbishment / maintenance of construction facilities. The implementation of an operational fire safety management model needed to be develop into a project-specific working document (or guidance) and procedures.

Initiatives from the EU to harmonise the regulation across Europe forced the Member States to review their current legislation and regulations in order to provide an adequate level of fire safety on construction sites. The interpretation and implementation of specific EU directives had a positive impact on the overall improvement of fire safety on sites. The research and site investigation into the problem of fires on construction sites revealed **a need to develop a comprehensive set of rules or a standardised approach** to help construction participants to implement an operational fire safety plan. However the site investigation also revealed that due to the specificity of each construction site, the Model might need to be project-specific or at least adaptable and flexible.

The literature review provided superficial quantitative data on the number, cause and effect of fires, their patterns, cost and location which were indicative of a need to review the process of control of fire in such a situation. Unfortunately, the selective approach of the main fire bureau of statistics didn't reflect the full extend of the problem of fires on construction sites and there are to date a limited number of research reports and papers to support it.
The author explored the possibility of tackling the problem from an engineering side applying the Fire Safety Engineering Method. The Qualitative Design Review (QDR) was relevant and significant results were obtained when the three scenarios were considered (new construction, refurbishment/renovation, maintenance). However the lack of quantitative data was a major barrier to develop the second part of the method. The author argued that there was room for improvement within the approach but that at this stage of the research in the field of fire safety on construction sites, the FSE method wasn't the answer to the problem.

Eliminating a quantitative approach due to the lack of data on fires on construction sites left a **gap to explore in the research field**. The idea of a qualitative approach emerged based on the robustness of the data available from the industry and the aims and objectives of the research.

This chapter aimed to present the full research concept of this thesis and how the process of building theories was initiated and developed in the thesis. The chapter proposed a framework of the research methodologies and the method of analysis to compare and contrast data.

This research aimed at identifying and proposing a managerial model to prevent and control fires during construction works. The research was based on extensive review of relevant literature and an in-depth post analysis of major fires in the UK and France. The outcomes and research findings enabled the author to develop a Fire Safety Management Model highlighting the implementation of safety system throughout the project life and its cycle.
The next challenges were to propose a final FSMM for practitioners to implement the Model. The Managerial Model would address the problem of fire on construction sites. The aim was to provide to parties to a contract a strategy to assess areas of potential risks of fire on site and a procedure to remedy any hazard.

Figure 5.1: PhD Schematic Structure: Literature Review: Summary of findings

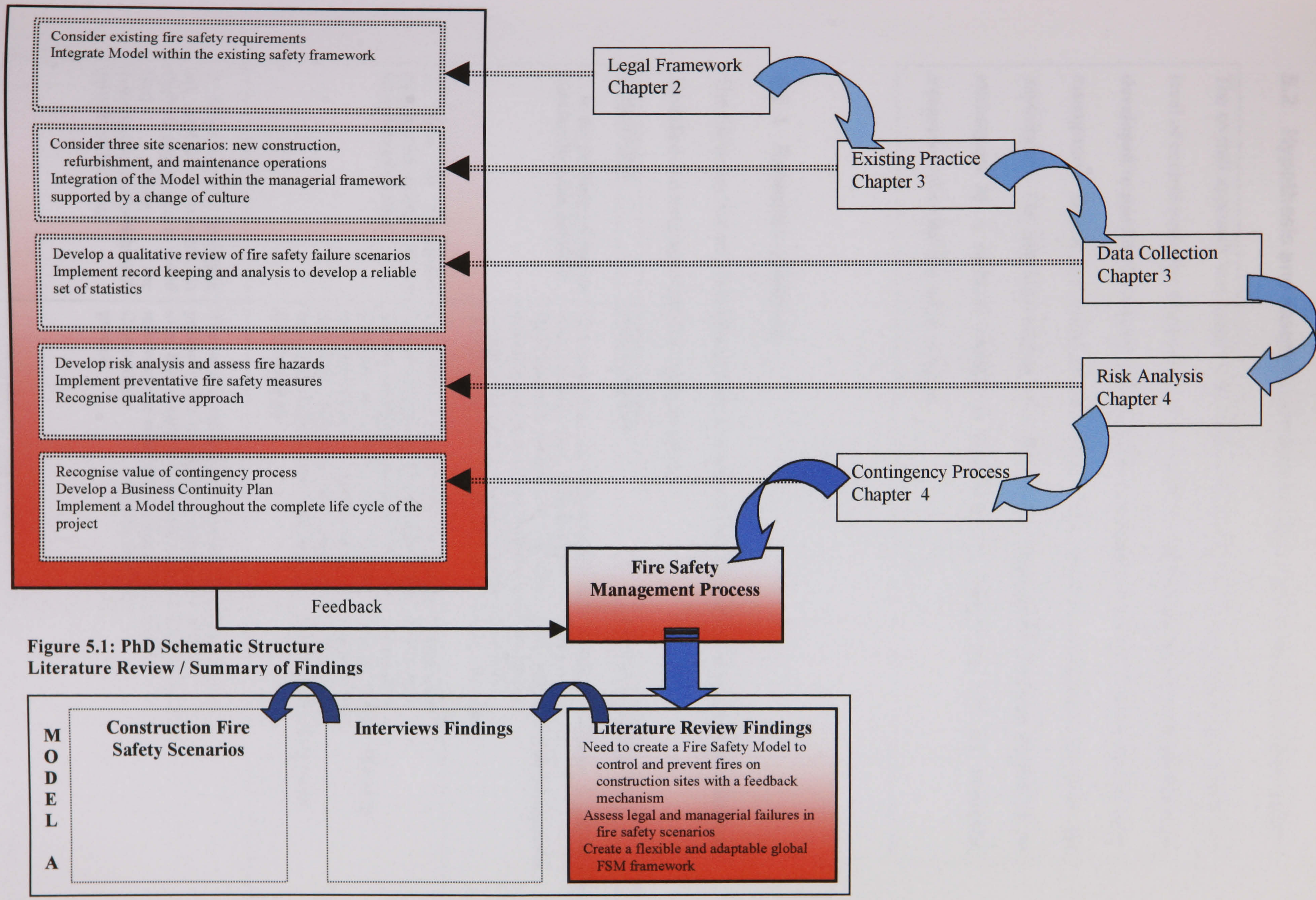

Figure 5.1: PhD Schematic Structure
Literature Review / Summary of Findings

5.2 Hypothesis and research questions, aims and objectives of the thesis

The overall approach was based on the concept that the JCOP did not provide a satisfactory level of control over the construction works, and that **a managerial framework needed to be developed in parallel to support a free fire environment** on site and address the fire safety management during the complete life cycle of the project: conception, execution and exploitation. The **implementation of a fire safety management system needed to be encompass by a cultural change** in organisation to support the full and successful integration of a total fire safety concept.

5.2.1 Research questions:

The following research hypotheses form the basis of the research. A set of questions has been identified and integrated into the research concept.

QUESTIONS	HYPOTHESES	Key words / Categories
1. Is the problem of fire on construction sites justified?	The proportion and consequences of fires during the Construction / Refurbishment process is important enough to be taken seriously. There is a need to develop a strategy in order to reduce and minimise their impact.	Statistical Evidence / Quantitative Analysis Risk Analysis / Risk Management Risk Control Economics Cost / Benefits
2. How do contractors perceive the problem of fire on construction sites?	Fire safety on construction site is now seen as a necessity and a major issue for any construction contract. By the pressure of clients and insurers, contractors have to provide adequate fire safety measures, and under the law a FSP (LPC Code, CDM Regs + EU Directive).	Management Government EU pressure External Forces / Pressures Internal Forces Enforcement Deregulatory / Regulatory
3. What specific strategies are used by contractors, in the UK and France, to avoid fires during the Construction/Refurbishment process of building?	The implementation of a detailed and practical Fire Safety Plan through a clear Risk Analysis is the best way to minimise and reduce fires during the Construction / Refurbishment process.	Management Strategy FSP / H&S Plan Control

4. What methods of Control and Assessment are used to monitor and test the FSP during operations?	The risk of fire is assessed before the construction operation and updated on a regular basis throughout the operations. The methods of control of the risk of fire are described in the FSP which contains all the necessary information to monitor the risk of fire and a test the plan.	Control Assessment Risk Control Prevention Safety Management / Safety Inspections / Safety Records Monitoring strategy Feedback
5. Will a move towards a standardised approach to fire safety on construction sites, i.e. harmonised regulation and/or standard in EU, be solved and/or improved the problem of fire during the Construction / Refurbishment period?	A set of standardised rules is a necessity to form a harmonised European Construction Industry however each construction sites being unique, the FSP will need to be develop into a project-specific working document of procedures. Cultural and attitudinal forces would not permit such a harmonised approach.	Standard Harmonisation EU / Directives Enforcement Deregulation Economics
6. How would safety attitudes and safety cultures impact on Fire Safety Management during the Construction / Refurbishment process of building?	Attitudes towards safety and cultural differences in the Construction Industry (France / UK) have a clear and positive impact on the management of fire safety during the Construction / Refurbishment process. This would be demonstrating through the investigations.	Culture Attitude / Behaviour Society Cultural Evolution Changes Progress
7. What are the benefits of a Fire Safety approach on construction sites?	A detailed analysis of the implementation of EU directives in the Member State and its impact on fire safety on construction sites revealed a very different approach towards safety in general and more specifically fire safety. The comparative analysis revealed a number of discrepancies between the French and UK legislative procedure.	Cost Cost Benefit Analysis Loss Economics

This project attempted to answer these research questions. These questions also aimed to structure the standardised interview. When it came to the real interview, stimuli were developed with the respondent in order to explore the questions in more depth. The objective was to drive each respondent to respond with the same key words in order to obtain a similar pattern for every interview. This required a greater flexibility in the role of the interviewer.

A pilot work was undertaken prior to run the interviews. In parallel, the author took great care to design a format of interview that would answer the needs of the qualitative analysis program (QSR*NUDIST4).

5.3 Methodology

5.3.1 Phases of the research:

The methodology followed to complete this research comprises six different stages. The initial formulation of basic ideas through the development of the research proposal, the specification of research design after the literature review, followed by the fieldwork (site investigations), then the data processing and statistical analysis and finally the writing of the final research report.

- A **detailed review and analysis of the literature** in the UK and France, then other European countries. This thesis presented the results of the literature review in the first part of the documents. A large part of the analysis has been developed around the fire statistical data available about the occurrence and consequences of fires during the construction process. Then a detailed review of legislative and regulatory requirements across Europe was developed, compared and contrast against the UK system.

- Extensive **site investigations** in the UK were first developed. These site investigations targeted three categories of sites: new built, refurbishment/change-in-use/renovation and maintenance works. 60% of the sites were in the UK, 30% in France and the remaining 10% in the rest of Europe. A standardised interview was first prepared and tested. The purpose of this standardised interview was to collect data across a large number of sites.

- A **qualitative analysis of interviews** carried out with every site was prepared with the support of a specialist software (QSR*NUDIST4: Qualitative Solution and Research Pty Ltd: Non-numerical Unstructured Data * Indexing, Searching & Theorising) whose aims were to aid users in handling non-numerical and unstructured data in qualitative analysis, by supporting processes of coding data in an index system, searching text or searching patterns of coding and theorising about the data. The results of the qualitative research were analysed and compared and contrasted. A hypothetical fire safety model was proposed for review.

- A **qualitative analysis of major construction site fires** was prepared to identify a generic profile of the fires, assess the chain of effects, the causes of fires across a large sample of failures, analyse the consequences (damages/losses) of these fires and what managerial action can be taken to eliminate/minimise/control these fires through a detailed managerial approach. A reviewed fire safety model was presented for critic and analysis to the expert panels (UK and France) and the testing of the model through a structured interview with selected practitioners.

- A **model/strategy** was presented following the qualitative analysis. An interactive framework was developed to promote best practice across sites.

- The final stage of the research comprised **a critical and academic review and analysis of the findings and outcomes** of the qualitative data. A managerial model will be presented and recommendations formulated.

5.3.2 Research Methodologies Framework

The research concept was illustrated in Figure 5.2 explained below:

- To build a *Hypothetical Model* **(Model A)** based on the outcomes of the literature review and a short qualitative review of interviews which **generated theories** and identify example of good practice.

- To *Review the Model* **(Model B)** following the analysis of failure scenarios of fires on construction sites, and generate further theories and identify bad practice. This analysis of fire reports enabled the researcher to define the **generic profile of fires**, to build a chain of effects, to assess the pattern of the cause of fires (Equipment failure, Human error, External Failure) and to identify the consequences and which managerial actions have been taken.

- To *propose a reviewed Model for a critical review by an expert panel.* **(Model C)** Following an in-depth analysis of the qualitative data, the researcher proposed a **reviewed Model** which will address good and bad practice identified in the research investigations.

- To run two *expert and critical reviews* of the Model **to test the model** with representatives and experts of the industry in France and the UK.

- To develop a *critical academic analysis* of the complete process of the research and built a **sound review of the proposed model.**

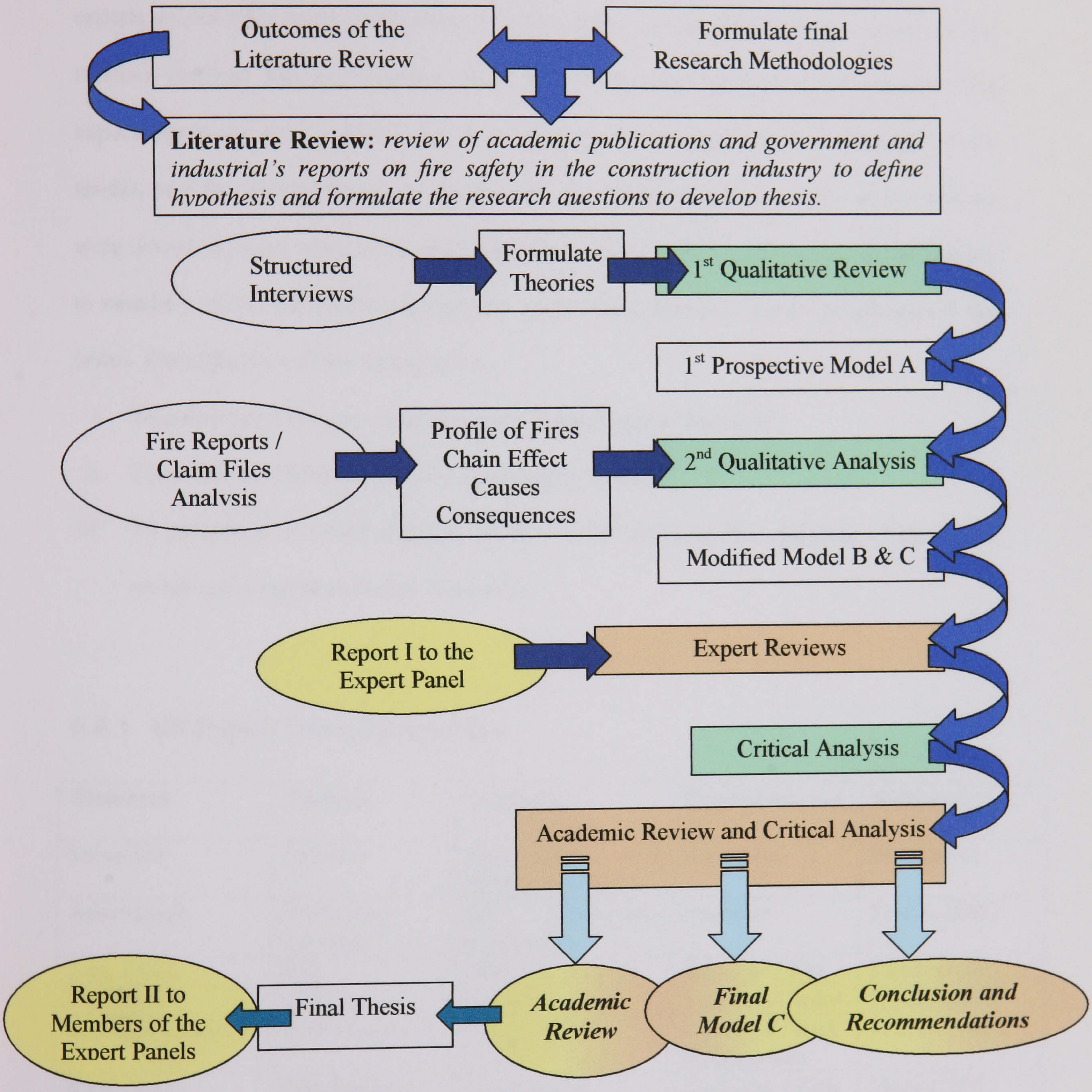

Figure 5.2: Research Concept Framework

5.4 Expert Committees

The findings of **the research investigations and analysis were tested through two expert seminars**, in the UK and France. The objective was to assess the validity of the findings with experts in the field and practitioners. The fire safety model identified and addressed the research findings and best practice, and took into account legislative requirements. **The expert seminars were used as a tool to identify the strengths and weaknesses of the model, and its validity for practitioners and the Industry**. The outcomes of the seminar were discussed in the main thesis and a final model and guidance was presented. References to members of the committee were directly made and referenced in text as indicated in the tables. The objectives of the review were:

i. To assess the efficiency of the proposed FSMM against the JCOP.

ii. To review the FSMM based on a hypothetical scenario.

iii. To propose a reviewed structure of the FSMM based on the outcomes of the initial review and to present a better framework.

5.4.1 UK Expert Team & Reviewers:

Members	Position	Company	Representation:	Reference:
Steve Birt	Director	Association of British Insurers	Insurance	Birt (2001)
Adair Lewis	Technical Director	Fire Protection Association	Engineer	Lewis (2001)
John Fisher	FM	Jabil	Engineer / FM	Fisher (2001)
Dr. Hinks	Director	CABER	Research Centre	Hinks (2001)
Alaistair Colvin	Risk Engineer	Underwriters	Insurance / Risk Management	Colvin (2001)
Keith Mapp	RM Engineer	Underwriters	Insurance / Risk Management	Mapp (2001)
Nick Ford	Risk Engineer	Underwriters	Insurance / Risk Management	Ford (2001)
John Foley	FM	Swiss Life	Engineer / FM	Foley (2001)
Harmut Reiner	Director	Munich Re	Reinsurance	Reiner (2001)
Olivier Hautefeuille	Technical Director	Axa Corporate Solutions	Insurance	Hautefeuille (2001)

5.4.2 French Expert Team & Reviewers:

Members	Position	Company	Representation	Reference
J.L Houee	Safety Manager	Centre Pompidou	Facilities Management	Houee (2001)
Dr.Tephany	FSE	Consultant	Fire Safety	Tephany (2001)
Mr. Polach	Director	CNPP	Fire Safety Training	Polach (2001)
Mr. Schaal	Safety Manager	Chateau de Versailles	Historic Building	Schaal (2001)
Mr. Bordas Mr. Celardo Mr. Baron	Risk Engineers	AXA Corporate Solutions	Insurance / Risk / Loss	Bordas (2001) Celardo (2001) Baron (2001)
Mr. Postic	Fire / Insurers Association	FFSA	Insurance / Loss	Postic (2001)
Mr. Landrin Mr. Paulczinsky	Risk Engineers	Munich Re.	Insurance / Risk	Landrin (2001) Paulczinsky (2001)

5.5 Method of analysis to compare and contrast data

This PhD investigated the problem of fire during the construction / refurbishment / maintenance of building facilities.

The statistics demonstrating the occurrence of fire on construction sites, the economic losses and the overall impact of a fire for the parties to the contract, their business and the society as a whole, revealed a need to investigate the problem of fire occurring during the construction / refurbishment / maintenance of building facilities. A thorough review of construction management practices across the UK and the rest of Europe (especially France) through site investigations identified best practice in the control of fires during the construction process. A model was developed and presented in the Report to the Expert Committee and was proposed as the way to prevent, control, reduce/eliminate and/or minimise fires on construction sites.

5.5.1 Structure of the Expert Panel Review:

Outline of the review framework:

i. Welcome and outline programme of the day.

ii. Research findings and review of proposed FSMM

iii. Aims and objectives of the Expert Panel Review

What I am trying to achieve through the review

What I am expecting from the Expert Panel

Anticipated outcomes of the review

iv. Structure of the review (Group A and B)

The Hypothetical scenario

Step by step guide to the review and Procedure

Presentation of the outcomes of the review of the FSMM to the other group.

Brainstorming session

v. Outcomes of the review and presentation of a modified FSMM

Debate and discussion on common grounds

vi. Summary of outcomes and closing comments

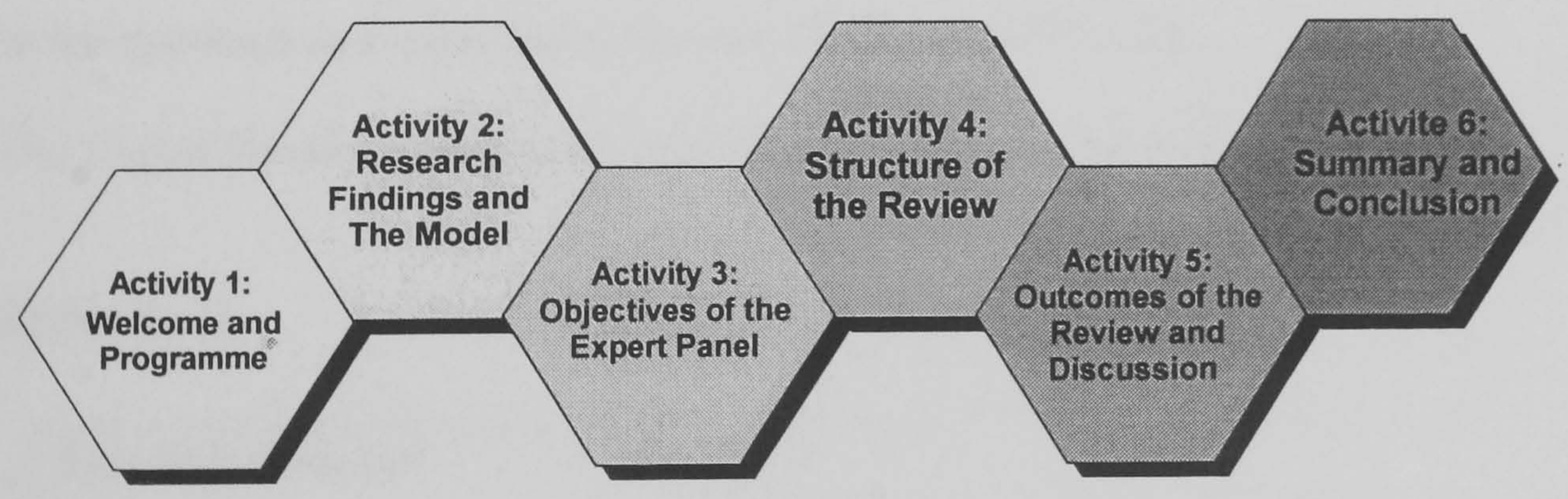

Figure 5.3: Expert Seminar's Activities Schedule

Activity 1:

Welcome and outline programme of the day. 30mins

A thorough process of selection of the members of the Expert panel was essential to ensure the success of the research approach and its outcomes. **Members were appointed based on the interest they expressed for the research, their professional knowledge and experience in the field of fire safety** (manager, client, contractor, fire safety engineer, facilities manager, risk manager, insurer, loss adjuster, underwriter, representatives of national associations and professional institutions...); **and the relevance of this research findings and outcomes for their profession and the community as a whole.** The members are considered to be professionals with an adequate knowledge and experience in fire safety and management, and construction works. Each member somehow participated to the research project and provided help on specific areas.

A round table to give the opportunity to each member to introduce himself, the reasons why they accepted to join the Expert panel and their expectations. Each member was requested to introduce himself/herself by his or her name, position and responsibilities.

A clear agenda was presented and distributed to be prepared and to provide enough directives to the members and what has to be done by the end of the day.

The Expert Panel was divided in two groups, each one having the same tasks.

Activity 2:

Research findings 40mins

The research findings were presented through a short but detailed presentation, first to identify the scope of the research and second to propose the hypothesis or research questions generated from the investigations. The FSMM was explained to clarify any ambiguities on its structure, function and purpose.

Activity 3:

Aims and objectives of the Expert Panel Review	15mins
What the researcher was trying to achieve through the review What the researcher was expecting from the Expert Panel Anticipated outcomes of the review	

The Expert Panel Review aimed at:

- assessing the efficiency of the proposed FSMM against the JCOP.
- reviewing the FSMM based on a hypothetical scenario.
- proposing a reviewed structure of the FSMM based on the outcomes of the initial review and to present a better framework.

Activity 4 (Group A and B):

Structure of the review (Group A and B)	90mins
The Hypothetical scenario	15mins
Step by step guide to the review and Procedure	15mins
Presentation of the outcomes of the review of the FSMM to the other group.	45mins
Brainstorming session	15mins

The hypothetical scenario (available in Appendix B) recreated a complex fire which illustrated the depth of the problem. It was anticipated that each member of the panel would be faced with an unknown issue in the scenario and that the FSMM was used as the tool to implement a successful managerial framework.

To enable a structured review of the FSMM, a review form was provided. They used the matrix of the Model and highlight anything missing in it. The step by step guide helped them to look at different aspects of the model.

The results of their review were then presented to the other group and compared against the other group findings. Throughout this session they were asked to gather any thought, comments or issues emerging from the review on a blank sheet of paper.

Activity 5:

Outcomes of the review and presentation of a modified FSMM	30mins
Debate and discussion on common grounds	

The brainstorming session was run to gather all the information addressed throughout the review and a modified FSMM created and proposed for final debate. The outcome of this review was a better managerial framework.

Activity 6:

Summary of outcomes and closing comments	30mins

A summary of the outcomes of the day was then presented and discussion for further development was engaged. What to do next?

5.5.2 Expert Panel Review Form:

Each member of the expert committee was required to complete a structured evaluation form. On the day of the seminar, each group was requested to complete the form and submit it. The expert seminars were also recorded with a camera and later analysed to extract the best outcomes and findings from the review, the expert's approach and thoughts, their process of analysis and any relevant information on their process of critical analysis. Table 5.1 presented the format of the evaluation form.

Issues to address in the review:	**Your observations and comments:**
Compliance with the JCOP: *Limits, scope of the JCOP, application, validity of the Code...*	
Hot Work Permit: *Necessity, control, application, effectiveness...*	
Fire Risk Assessment: *RA during the conception, execution and exploitation phases...*	
Global approach to Fire safety Prevention: *Conception Phase:* *Execution / Construction Phase:* *Post Construction / Life Cycle of facility:*	
Format of the FSMM: *Flexibility, adaptation to the structure of the organisation, validity of the Model (FSMM), scope, strengths and weaknesses...*	
Relevance of the Systems: *Planned System, Operational System, Active System, Recovery System, Continuity System.*	
Planned System	
Operational System	
Active System	
Recovery System	
Continuity System	
From your experience of the limitations of the JCOP, what do you see as the way forward for the FSMM to be used?	
What are your recommendations?	
Other observations?	

Table 5.1: Expert Panel Review Form

5.6 Conclusion Chapter 5

The research concept presented in this chapter emerged from a long literature review which highlighted the strengths and weaknesses of the existing fire safety structure. The objective was to determine the most suitable way to develop further this research and how to collect accurate and reliable information and data to build a fire safety management model to encompass the existing provisions (JCOP, Health and Safety regulations).

A move towards an extensive qualitative analysis opened new avenues of investigations and provided a sound research process to develop a model which would answer the needs of the industry.

The scope of this research limited extensive testing of the finished model but nevertheless the two expert seminar greatly contributed to test the validity of the model for the industry using the expertise and experience of professionals. The process of critical review and analysis was sound and proved to be extremely successful to develop the Fire Safety Management Model.

The next chapter will explore the validity of a qualitative approach against a quantitative analysis.

6 RESEARCH METHODOLOGY:

The objective of this chapter was to explore and compare and contrast various research methodologies suitable for this project, i.e. quantitative and qualitative. A literature survey of current and past research in the field of quantitative and qualitative research identified a need to consider both methodologies at different stage of the research. Gummesson (1991) identified qualitative methodology as providing powerful tools for research in management and business administration.

The process of building theory for this research project focussed on a review of current literature on the subject and an observation of major case studies where fires occurred during the process of construction, refurbishment or maintenance.

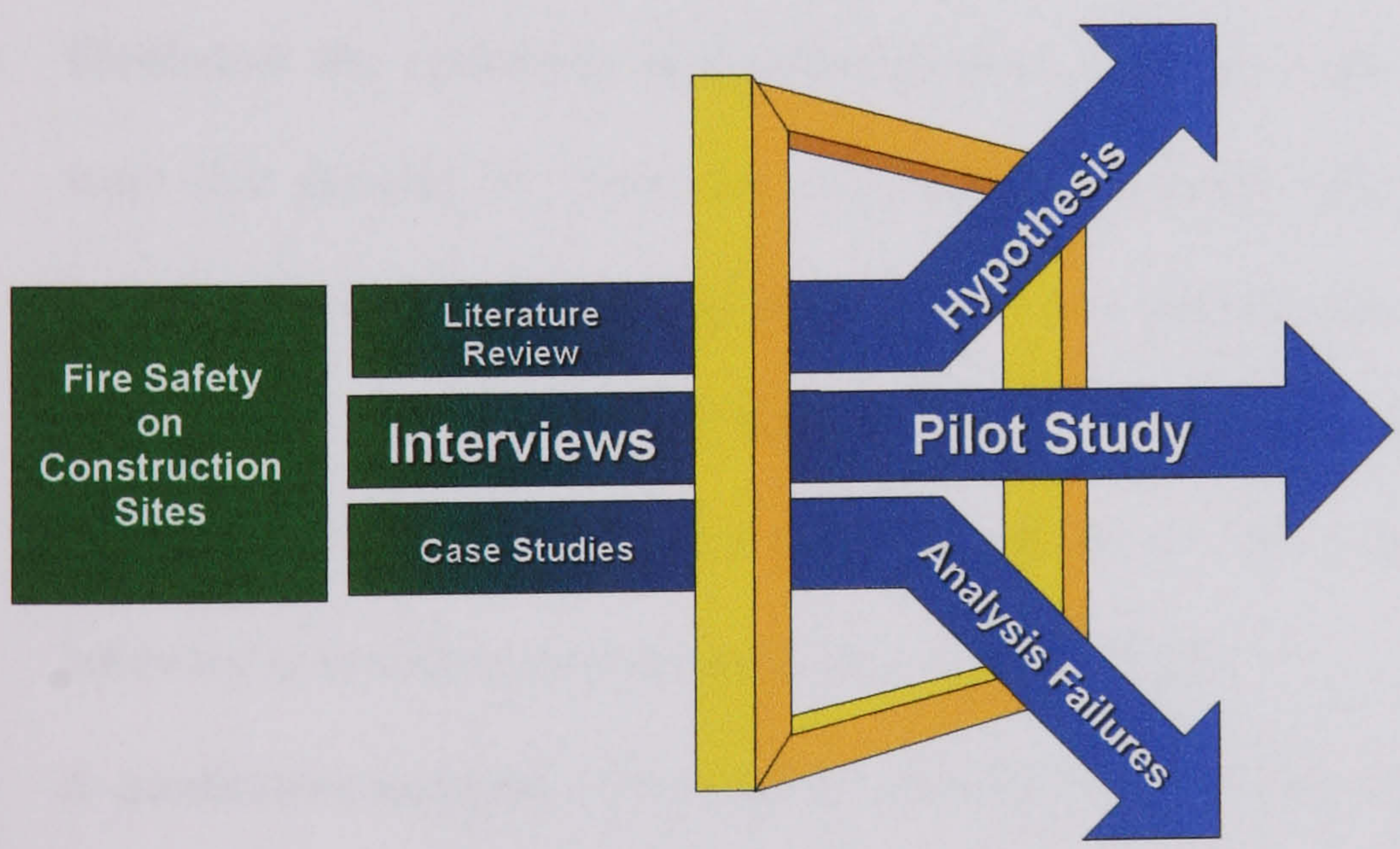

Figure 6.1: Research Approach

6.1 Principles and overview

The methodology followed to complete this research comprised five different stages. The initial formulation of basic ideas through the development of the research proposal, the specification of research design after the literature review, followed by the fieldwork (site investigations), then the data processing and statistical analysis and finally the writing of the final research report.

- **Conceptual framework and background research** (Qualitative and quantitative analysis): A detailed review of the literature in the UK and France, then other European countries. This thesis presents the results of the literature review in the first part of the document. A large part of the analysis has been developed around the fire statistical data available about the occurrence and consequences of fires during the construction process. Then a detailed review of legislative and regulatory requirements across Europe is developed, compared and contrast against the UK system.
- **Fieldwork for collection of qualitative data**: Extensive site investigations in the UK were first developed. These site investigations targeted three categories of sites: new built, refurbishment/change-in-use/renovation and maintenance works. 60% of the sites were in the UK, 30% in France and the remaining 10% in the rest of Europe. A standardised interview was first prepared and tested. The purpose of this standardised interview is to collect data across a large number of sites.
- **A qualitative analysis of interviews** carried out with every site was prepared with the support of a specialist software (QSR*NUDIST4: Qualitative Solution and Research Pty Ltd: Non-numerical Unstructured Data * Indexing, Searching & Theorising) whose aims is to aid users in handling non-numerical and unstructured data in qualitative analysis, by supporting processes of coding data in an index system, searching text or searching patterns of coding and theorising about the data. Results of the qualitative research are analysed and compared and contrasted.

- **Case study review and analysis** (Risk Assessment and Analysis): the objective of this investigation is to determine the cause and effect of major fires on site and identify common patterns of events. Again a case review and summary set of analytic comments will help to clarify the visual display of the event tree and focussed on the main patterns of the fire scenarios.
- **Producing report**: The results of the qualitative analysis will be summarised and an interim report will be presented to an expert panel, composed of professionals and practitioners who either participated to the project (through interviews) or selected for their particular knowledge and expertise in the field. Lo (1999) successfully used this technique to assess fire safety systems in existing buildings, and highlighted many criteria to take into account when formulating a research strategy using the input of an expert panel. Lo underlines the subjective evaluation as well as the question of credibility, according to him viewed as internal validity and external validity.
- **The final document will present a best practice.** A guidance is developed to promote best practice across European sites. Finally a conclusion is developed and a list of recommendations is presented. Consideration on the implications for theory, practice and action is also developed. A strategy to support the dissemination and use of the research findings will be presented.

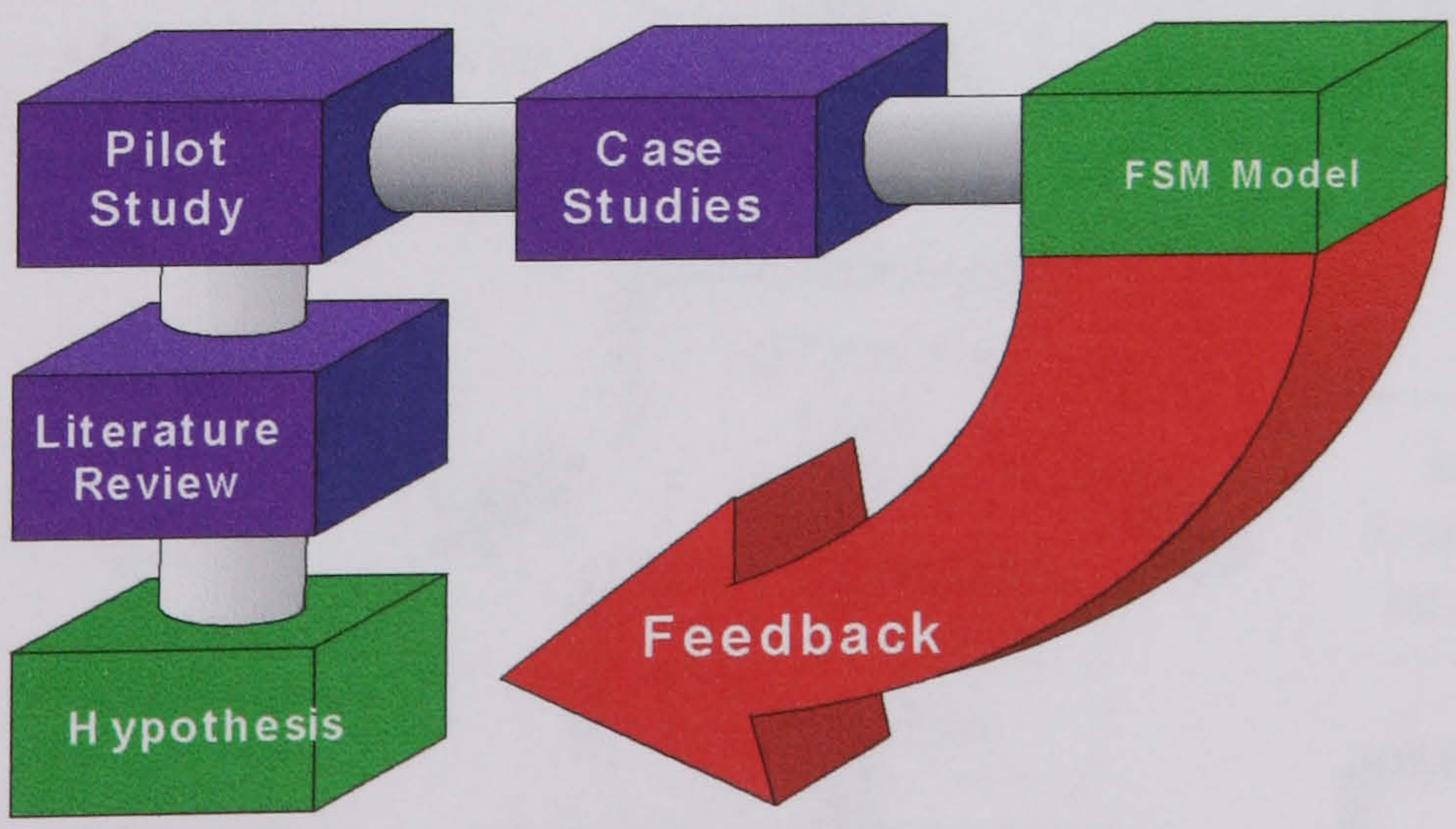

Figure 6.2: Process of Building Theory

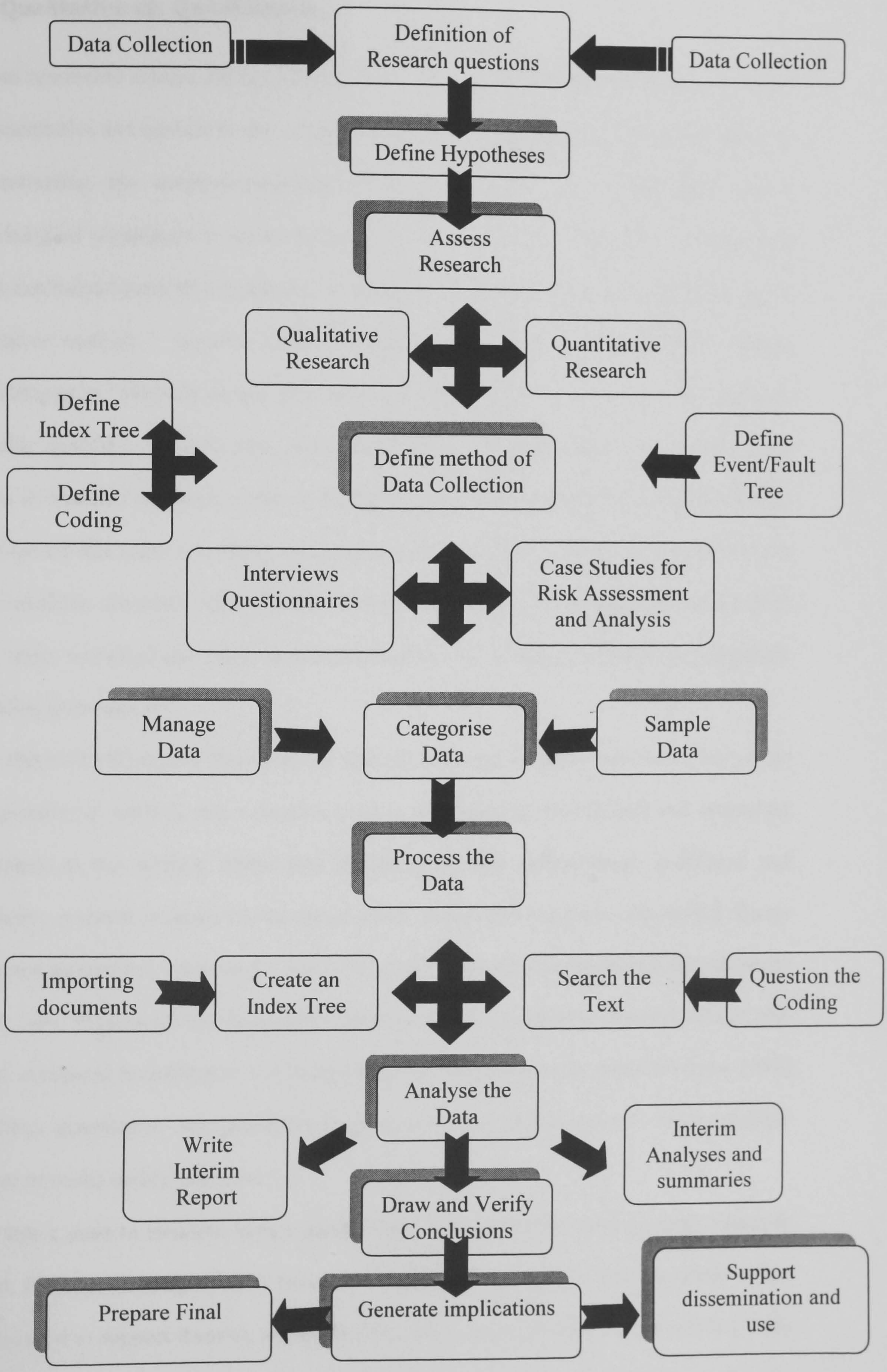

Figure 6.3: Diagrammatic process of building theories

6.2 Qualitative vs. Quantitative.

Previous researches (Quinn Patton, 1999; Carlson et al, 1999) identified a need to consider both quantitative and qualitative data analysis in research. Hammersley (1999) in his paper on "Deconstructing the qualitative-quantitative divide" views it as "a challenge and a methodological paradigms in social research." In their work on drug users, Carlson et al (1999) concluded "qualitative research is often a prerequisite to the appropriate application of quantitative methods." Bryman (1999) considered quantitative and qualitative research methodologies as "mutually antagonistic ideal types of research" and notes that the relevance and utility qualitative research was rarely denied by quantitative researchers, but was often view as an essential exploratory way of conducting social investigations. Strauss and Corbin (1998) quoted that many quantitative researchers see qualitative research as being little better than journalistic accounts. However he continued by saying "some qualitative researchers firmly reject statistical and others quantitative methods as yielding a shallow or completely misleading information."

Quinn Patton (1999) argued that statistical analysis followed formulas and rules while, at the core, quantitative analysis was a creative process, depending on the insights and conceptual capabilities of the analyst. Miles and Huberman (1984) differentiated qualitative and quantitative research in terms of the use of words rather than numbers. Gherardi & Turner (1999) saw quantitative styles as the 'hard' view of the research and qualitative approaches as a 'soft' view. Bryman (1999) defined the nature of data in quantitative research as hard and reliable, compared to qualitative as rich and deep. He concluded in his paper (Bryman, 1999) that "when quantitative and qualitative research are jointly pursued, much more complete accounts of social reality can ensue."

There was a need to consider both a quantitative and qualitative review in any research project. Previous investigations in research methodologies identified that quantitative data could be used to support theories, and qualitative data to develop theories. Descombe (1998) argued that qualitative analysis tends to be associated with words, description, small-scale studies, holistic perspective, researcher involvement and emergent research; when quantitative analysis was associated with numbers, analysis, large-scale studies, specific focus, researcher detachment and a predetermined research design. **This research focused on a collection of data for a limited quantitative review to demonstrate the credibility of the research strategy, analysing the number, cause and effect of fires during the construction process and proposed a hypothesis supported by a literature review. An extensive qualitative research was then developed to address the research questions and demonstrate the hypothesis.**

Quinn Patton (1999) insisted that "a qualitative researcher has an obligation to be methodical in reporting sufficient details of data collection and the processes of analysis to permit others to judge the quality of the resulting product." Marshall & Rossman (1995) and Quinn Patton (1999) considered the researcher was "the instrument" in qualitative research and inquiry. Denscombe (1998) underlined the importance of personal identity of the researcher and how the interviewee perceived the qualitative research approach. He noted particularly the sex, age and ethnic origins of the interviewer.

6.3 Collection of data and document management

In the previous part of this chapter, we considered the use of quantitative and qualitative research to investigate the problem of fire on construction sites. In the introduction, it was highlighted that access to quantitative data is limited in the field of research and therefore the quantitative analysis of them would be restricted. However this last one contributed to the process of building theory in the early stages of the research.

The collection of core data for the empirical analysis and formulation of recommendations and a final model required a detailed approach and strategy. Eisenhardt (1999) argued that the development of theory is central in organisational research and aims to put together a testable, relevant and valid theory. Chapter one and two of this PhD thesis focussed on the relevance of the research, the feasibility of the project and identified the coverage. The accuracy and objectivity of the research was assessed in later chapters.

The methods of collection of information and data for this research was summarised in the two following points:

- Quantitative data: gathering statistics and preparing a quantitative review of the materials;
- Qualitative data: observation, interviews, documents and questionnaires. These data were in the form of words attached to fieldwork experience. Identifying major case studies and analysing the cause and effect of fires and preventative methods and reactive strategy.

Words or numbers were the units of analysis (Denscombe, 1998). Miles and Huberman (1994) considered that the researcher is moving among four nodes during data analysis: data display, data collection, data reduction [sampling] and conclusions. They added that 'final' conclusions were not reached until the completion of data collection.

Quinn Patton (1999) presented triangulation of qualitative and quantitative data as a form of comparative analysis. Denscombe (1998) noted that "triangulation involves locating a true position by referring to two or more other coordinates." This technique was used to assess to link categories with data-coding and create a network of documents.

The method of collection of data for the qualitative analysis in this research has been completed through the following mean:

- **Short questionnaire**: this technique was used to pre-select the interviewees after contacting them by phone or by mail. A short description of the research and its objectives were attached to a reply form they were required to fill and return by post or send by fax.
    - Problem observed: number of respondents, quality of information forwarded, problems of access (geographical, time constraints, workload, security/safety issues...)
- **Face-to-face interview** of selected candidates: a careful selection of potential interviewees, based on their response to the proposal, their position within the firm and

responsibilities, their willingness to participate to the project (interview, site visit and provision of additional information, participation to an expert seminar) and authorisation from their management to get involved into the research (confidentiality, public image, workload, transfer of knowledge...).

- Problems observed: response to questions, format of interview (structured interview and set of questions run in an open format), location (on site, in house –single/shared offices, open offices, meeting/conference room), interviewee preparation for interview (prepared answer, spontaneous answer, structured answer, uncertainty of answer, hidden facts and information, restricted answer...), researcher preparation and interview technique (the researcher is the instrument and his/her attitude, willingness, mood, frustrations, behaviour, are the drivers and barriers to a successful data collection during interviews. Denscombe (1998) wrote that the researcher's identity, values and beliefs cannot be entirely eliminated from the process.

- **Observations:** the process of collection of data required a very strict approach by the researcher. Observations on how the interviewee reacted to the interview questions, their involvement, comments on the documentation, site visits, were all built up in a case review and used as data for the analysis.
    - Problems observed: each interview or case was different to any other one. The difficulty was to assess common ground and address them in the strategy adopted to collect data. Each case review highlighted the strengths and weaknesses of the data collected.
- **Documents**: part of the investigations into companies concentrated on the quality of documents used (fire safety plan, safety/fire policies, health and safety plan, fire instructions, fire plan, drawings / evacuation plans, form of contracts...).
    - Problems observed: the availability of documents for each case varied. Also the quality of documents will vary on scale from poor to very good. This type of data is considered as additional information to complete each case review.

Interviewing was the most intensively used methods of data collection. Bryman and Burgess (1999) argued that there was no typical approach to interviewing in qualitative research. Interviews involved a face-to-face survey and direct contact between the researcher and the selected interviewee.

- **Case Studies:** the most interesting part of the data collected in this research focussed on an extensive post analysis of fires on construction sites. Access to fire claims through insurance organisations and underwriters as well as loss adjusters enhance the quality of the research data and enabled the development of a detailed post analysis of construction fire safety failures scenarios.
    - Problems observed: access to the data had to be keep confidential and no information identifying the company and the names of the parties or location of the fire could be provided in this research. The author chose a strict referencing system, identifying the "type" of site, the date of the fire and the country of location (UK, France –FR, United Staes –US, Belgium -BE…).

6.4 Exploring and analysing data.

Two independent analysis were first developed in this research and then compared and contrasted in another chapter. The interviews were analysed using a qualitative software, and the case studies were reviewed and critically analysed in a separate section. Case studies have been grouped in different categories and analysed under three main headings: design and engineering, managerial strategy, contingency process. The conclusive findings were then interpreted into the development of a fire safety management model (Chapter 8) and all the findings discussed in Chapter 9.

In contrary to general belief, using a qualitative software did not mean the researcher could avoid to engage with the data. The researcher and the processes were the central area of activity and the role of the software was to enable the researcher to ask questions and seek answer to those questions they could not or dared to ask.

Miles and Huberman (1994) proposed a table which highlights the main properties of a computer software in qualitative studies:

Source: Miles, M.B. and Huberman, M. (1994) Qualitative Data Analysis: an expanded sourcebook, 2nd ed, Sage Publications.

1. Making notes in the field
2. Writing up or transcribing field notes
3. Editing: correcting, extending or revising field notes
4. Coding: attaching key words or tags to segments of text to permit later retrieval
5. Storage: keeping text in an organised database
6. Search and retrieval: locating relevant segments of text and making them available for inspection
7. Data "linking": connecting relevant data segments with each other, forming categories, clusters or networks of information
8. Memoring: writing reflective commentaries on some aspect of the data, as a basis for deeper analysis
9. Content analysis: counting frequencies, sequence or locations of words and phrases
10. Data display: placing selected or reduced data in a condensed, organised format, such as matrix or network, for inspection
11. Conclusion drawings and verification: aiding the analyst to interpret, displayed data and to test or confirm findings
12. Theory building: developing systematic, conceptually coherent explanations of findings, testing hypotheses
13. Graphic mapping: creating diagrams that depict findings or theories
14. Preparing interim and final reports

Table 6.1: Uses of Computer Software in Qualitative Studies

There was a growing number of computer software dedicated to assist researchers in qualitative analysis. Most computer softwares were a blend or a combination of word processors, word retrievers, text base managers, code-and-retrieve programs, theory builders and conceptual network builders (Miles and Huberman, 1994). According to Densombe (1998) the main advantage of using such software stemmed from "the superb abilities of computers to manage the data."

Some drawbacks of using a qualitative approach were recently highlighted by Point (1999) in a research paper where he discussed qualitative analysis of Petri Nets using ARABICA, a computer software. He identified two drawbacks: a large amount of time required to explore a sufficient number of scenarios, and a risk not to find critical sequences following the analysis of large number of scenarios. Miles and Huberman (1994) suggested that it was widely accepted to use a word processor to do qualitative research.

6.5 Showing results with QSR NUD*IST 4

Gahan and Hannibal (1999) saw QSR NUD*IST4 as a tool kit to assist researcher. QSR NUD*IST was a Qualitative Research Software for Non-numerical Unstructured Data with the properties of Indexing, Searching and Theorising. This software was shaped along three goals: managing documents, creating ideas and managing categories, and asking questions and building and testing theories about the data (QSR*NUDIST, 1997). The process of setting up a N4 project was in four steps: importing documents, creating an index system, searching text and questioning the coding. However, the first step required many stages before reaching a stage where your document was ready to be transferred into QSR NUD*IST. First the collection of data and processing of data and formatting to N4 standard, then the data reduction and selection (sampling).

6.5.1 Review of recent projects using QSR NUD*IST 4

The research presented in this thesis was based on the analysis of a set of qualitative data, collected through interviews with practitioners. The scope of these information were broad and necessitated to use a tool to enhance the analysis and support a deeper understanding of the data. The use of a qualitative research software was thought to provide a recognised professional tool which would enhance the part of this research. Qualitative software have been used for many years and NUD*IST was a well known software which proved to be successful in a large range of research, in social studies, organisational research, management... Table 6.2 proposed a selection of research project using NUD*IST.

It was important to accept that the software was a tool to help the researcher to explore his/her data and by no means provides an answer. The objective of the exercise was to track down accurate information and use the software to create links between different sources of data (interviews, documents...) and then used these data to compare and contrast the findings in the analysis.

In this research, a large sample of interviews was carried out with various practitioners. To enable a better analysis, the author decided to design a structured interview and extract similar pattern of answers between each of them. The success of this research method was demonstrated in this thesis and the outcomes of the qualitative analysis were used to develop the fire safety management model. Parallel could be drawn between the literature findings and interviews findings to support the validity of the research.

Subject/University **Date**	**Brief description**
Fire Safety Management Heriot-Watt University, UK 2001	Interview based with practitioners in CI
Risk and Uncertainty McMaster University, Canada 1998	Exploring the meaning of risk and uncertainty in an environmentally sensitised community
Decision Making RMIT, Australia 1998	Ethical issues and decision making in organisations
Network learning University of Sheffield 1998	The exploration of networked learning: a constructivist' approach
Organisational Leadership Monash University, Australia 1997	Enhancing adaptability: a grounded theory of organisational leadership as a social process
Architecture education University of Wollongong 1996	Learners as designers: computers as cognitive tools in architecture education

Table 6.2: A selection of recent theses using QSR NUD*IST Software

6.6 Interpreting and discussing the results

Interpretation of the results following a qualitative and/or quantitative analysis was one of the most important parts of the research. The previous part of this paper highlights the need to carefully plan the collection of data, data reduction and data display (coding, grouping) in qualitative analysis. The use of a computer software facilitated the analysis of data and coding process, and involves the braking down into units and categorising through the formulation of an index tree. The flexibility of a computer software for qualitative analysis allowed the researcher to improve its coding and add field notes, comments, reports, case reviews alongside the way and not worrying about losing data. In a later stage of the research all these documents were analysed with the interviews and **enabled a slow process of maturation of the analysis**. Denscombe (1999) defined the use of memos as acting as reminder throughout the development of investigations, and also as "a log of the developing line of thinking." With QSR NUD*IST there were three different way to reflect, revisit and review the documents: by storing reflections by changing text units and removing text units, by creating annotations, and finally by attaching a memo to a document or create a document and appending it to the project document.

6.7 Conclusion Chapter 6:

The art of interpreting, evaluating and critically analysing the qualitative data was a difficult exercise. The validity of the interpretation of the data lied within the ability of the researcher to extract significance findings and critically analyse these results to contribute to knowledge in the field.

The next chapter presents the results of the qualitative analysis of the interviews and a post analysis of the construction fires.

7 Current Practices: Site Investigations

The objective of this chapter was to demonstrate the process of building research data based on an extensive site investigation (through interviews) and a detailed analysis of major construction site fires and fires representative of the construction industry (losses >£50,000 and <£1m).

7.1 Data collection method

As it was expressed in the earlier chapters of the thesis, it was impossible to gather reliable quantitative data on fires on construction sites. The author aimed to concentrate on a qualitative analysis and observe the managerial system failures.

- A qualitative analysis of interviews
- Case study review and analysis

7.1.1 Qualitative Analysis of Interviews

The structured interview was designed along the lines of the research questions identified in Chapter 6. More than 50 contracting organisations and major clients wee contacted and invited to take part in the research. 15 major UK organisations accepted to take part in this investigation. For the purpose of this research, no information identifying their company has been disclosed except with their written authorisation. The members of the Expert Committees and collaborative establishment accepted to provide their full support and that their name and organisation be identified in this document. However, the organisation interviewed desired to retain their contact as some information provided in the interviews are confidential.

The site investigations and interviews of practitioners concentrated on three categories of sites:

i. New built facilities

ii. Refurbishment/Renovation/Change-in-use/Alterations

iii. Maintenance works (facilities being occupied).

It was estimated that a maximum of 6 sites and practitioners in each category would be necessary to analyse, compare and contrast the data with QSR NUD*IST4. A process of selection of the sites has been discussed with the supervisor, and three stages of investigation have been planned:

i. Pilot study with some good examples (5 sites)

ii. Selected site investigations of medium importance or relevance

iii. Compare and contrast and analyse the 15 best site investigations with QSR NUD*IST4.

The author expected to spend a lot of time indexing the data and investigating and browsing the documents in order to obtain the research results.

The most important stage of the qualitative analysis depends on how to investigate and browse the documents with QSR NUD*IST4. A three-stage process was identified:

i. Collecting data

ii. Making a document management system and indexing the documents.

iii. Investigating and browsing the documents: searching text, asking questions, analysing cases, importing and exporting additional documents and finally analysing, comparing and contrasting the results with QSR NUD*IST4.

The table 7.1 summarises the interviews carried out for this research and it also provides a short indication of the responsibilities of the interviewee.

1.	* **ARLOW**, Paris. France * Public Transport Facilities: New Construction / Refurbishment / Maintenance * August 2000 * Jean-Luc Martinez, Service Securité et Prevention.
2.	* **Le Centre**, Paris, France * Museum / Library / Cultural Centre: Refurbishment / Maintenance * August 2000 * Jean Luc Houee, Direction du Bâtiment et de la Securité, Service Securité, Coordinateur SSI
3.	* **Chastenet**, Paris, France * Historic Building: Refurbishment / Maintenance * 22 August, 2000 * Structured Interview with Michel Schaal, Responsable service securité incendie
4.	* **BUILDING AUTHORITY**, UK * Airport Facilities: New Construction / Refurbishment / Maintenance * 25 January, 1999 * Structured interview with Rob Stewart, Construction Manager for BUILDING AUTHORITY
5.	* **Ballast Construction**, Glasgow, Scotland, UK * Contractor for New and Refurbished Facilities * December 1999 * Structured interview with Andrew Vickermam, Regional Health & Safety Manager
6.	* **Barbour Homes**, UK * Home builder, Timber Frame Structure * Monday 14 June 1999 * Structured Interview with David Scott, Health & Safety Manager for Scotland & Robert Watt, Construction Director
7.	* **KELLY** Glasgow, Scotland, UK * New Cosntruction * August 2000, UK * Structured interview with the Health and Safety Manager.
8.	* **MORSE**, Edinburgh, Scotland, UK * New Construction and Refurbishment * 15 September, 1999 * Structured interview with the health & safety manager for Scottish Projects.
9.	* **Radiant 1.** Radiant Property (RP), Glasgow, UK * Radiant facilities: New Construction / Refurbishment * Wednesday 20 January 1999 * David Shirres, Safety Manager for Project Delivery & John Wood, Safety Manager
10.	* **Radiant 2**. Glasgow Central (GC), UK * Radiant facilities: Maintenance / Refurbishment * Friday 12 February 1999 * Structured interview: I. Glen, Station Manager, J. Lorimer, Safety Supervisor, Mr. Dennis, Fire Precautions Manager
11.	* **Fire Protection Association**, London, UK * Denney FPA * November 2000 * Structured Interview Jim Denney, Executive Director
12.	* **McLarens Toplis**, London, UK * Loss Adjusters: impartial claims specialist * October 2000 * Unstructured interview with Roger Preedy, Director.
13.	* **Fire Consultant**, Edinburgh, UK * Fire Safety Engineering Specialist * March 2001 * Unstructured interview with Dr. Eric Marchant, Fire Safety Engineer
14.	* **CNPP**, St Marcel, Vernon, France * Training Centre, Fire Safety * December 1999 * Unstructured interview with Alain Polach, Managing Director and Engineer
15.	* **Royal & Sun Alliance**, London, UK * Underwriters Department * November 2000 * Unstructured interview with Keith Mapp, Risk Engineer

Table 7.1: Interviews Details

7.1.2 Research samples and Case Studies:

The objective was to assess and identify where failures occur in a selection of fire safety scenarios. A survey of a selective number of samples has been analysed with the Technical and Survey/Loss Control departments of major UK and FR insurance companies. The following table provided information on the selected case studies used to develop this research and the Fire Safety Management Model. Through the analysis of relevant cases of fires originating on construction sites, a comparison was made between recognised good and bad practices, and a proposed Fire Safety Management Model to meet the requirements for *Fire Safety Plans* was presented later in this thesis.

Fire Report	**Site**	**Cause**	**Date / Country**
UK-Broadgate	New construction	Discarded material	1990, UK
UK-Minster Court	Refurbishment	Unknown	1991, UK
UK-Hampton Court	Refurbishment / Maintenance	Welding / Cutting	1986, UK
UK-Retail Store I	Refit/Refurbishment	Deliberate/Arson	04/2000, UK
UK-Retail Store II	Refit/Refurbishment	Deliberate/ Arson	05/2000, UK
UK-Hospital	Refurbishment / Maintenance	Hot Work	02/2000, UK
UK-Processing Factory	New / Refurbishment / Maintenance	Electrical short circuit	06/1998, UK
UK-Residential Facility	New Construction	Hot Work	03/1999, UK
UK-Bank	New Construction	Welding	10/1999, UK
UK-Education	Refurbishment	Hot Work	02/2000, UK
FR-Frigecreme	Maintenance	Welding / Cutting	1996, FR
FR-Retail Store Sama	Refurbishment	Hot Work	06/2000, FR
FR-Processing Factory	Refurbishment / Maintenance	Electrical Fault	07/2000, FR
FR-Bank	Refurbishment	Hot Work	01/2000, FR
FR-Residential /Offices Facilities	New Construction	Hot Work / Cutting	06/2000, FR
FR-Processing Factory	New Construction / Extension	Hot Work	12/1996, FR
FR-Factory	Refurbishment/Maintenance	Hot Work	02/1994, FR
D-Dusseldorf	Maintenance / Repair	Hot work	1996, D
B- Palais de Justice de Malines	Maintenance Building of the XVI century.	Naked Flame	16/10/1995
D-Dusseldorf	Maintenance / Repair	Hot work	1996, D
US- Sight & Sound Theatre	Refurbishment	Welding Operations	1997, US
US- Harrisson Building	Refurbishment	Cutting operations	1985, US

Figure 7.1: Construction Fires Case Studies

7.2 Data Analysis

7.2.1 Analysis of Interviews with QSR NUD*IST

There was a general belief that fires on construction sites did not happen, often because the frequency of these fires is lower than for general accidents and fortunately no deaths occur on construction sites. In the literature review the author identified a dearth of research in this area and a lack of quantitative data to support the hypothesis. The following chapter detailed the research findings extract from a qualitative analysis of data collected through interviews with practitioners. The objective was to draw some parallel with the literature findings and used these findings in the preparation of the fire safety management model.

7.2.1.1 Fires on construction sites? We don't have any... (???)

Major fires on construction sites were rare on paper. The first chapter of our literature review attempted to address the problem and demonstrates the extend of the problem. Amongst our interviewees, the majority experienced a fire on site: Le Centre (2000) had to deal with a major fire in the parking, aggravated by technical mistakes from the safety team (misuse of sprinklers systems and fire walls); Kelly (2000) explained that they were very unfortunate to spot a fire slightly too late ("the fire watch was asleep or he was doing something else and that's why the fire happened."). Arlow (2000) experienced some fires but they never took catastrophic proportions. The complexity of the construction and use of flammable material increased the risk of fire on site. The adoption of a strict waste management policy and non-smoking policy was a first step ahead, but mistakes happen. Barbour Homes (1999) remembered a major incident on a site involving gas and LPG and provoking an explosion, seriously injuring a worker. Those involved with historic properties were faced with a different set of problems. Chastenet (2000) lost part of its facility with a fire during the refurbishment of a copper roof, involving the use of a naked flame to complete the works.

The category of fires describe above were not always recorded and were part of this large part of the iceberg which is not classified. They would be recorded in-house but not with the Home Office or FPA. When losses were minimal and no injuries reported, there was no need to report fires to the authority. However, if the Fire Brigade was required on site, then a fire report was completed and forwarded to the Home Office. Unfortunately, it was down to the fire investigator to mention a category for the facility and often these fires are not recorded under a construction site but the final purpose of the facility (office, shop, library…). Morse (1999) argued that "safety records are not really worth the paper it is written on." We were still far from this ideal system of collection and classification of statistical data if this comment was representative of the construction industry. However the author didn't perceive it as a conclusive comment.

7.2.1.2 Safety Culture, attitude and perception:

Guldenmund (2000) in his paper on **the nature of safety culture**, reviewed 16 papers on safety climate and safety culture. Lee (1996) seemed to provide one suitable definition for the purpose of this research: "The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of, and organisation's health and safety management." This statement matched many comments raised in the interviews. Barbour Houses (1999) commented that "there is a safety culture. It is difficult to define what is a safety culture. We have an approach to safety which is quite structured, with defined responsibilities, with every individual within the company whoever they are or whatever role they fulfil. We have within a document a structure laid out and a set of responsibilities." The **notion of individual involvement and organisational (group) value** was presented as one of the driver to implement a safety culture. Building Authority (1999) argued that "safety features are quite highly in everyone – it is part of the culture – if you look at Building Authority's mission statement." Le Centre (2000) argued you "need of a full integration of safety in the organisation through the department down to each individual. Often people are in a safety post and are not competent to fullfil their responsibilities."

However involvement and commitment was key to success. Barbour Homes (2000) added that " they are "happy to put that attitude forward to the troops, our staff and our subcontractors, we were then put into partnerships with most of them. But not all or most of these people take that attitude on board and accept what we are saying to them. There are always difficulties, we have just got to assess and address and control." Morse (1999) also was commenting that " the safety culture on site is the big missing link." A lot of work was still to be done to improve the safety perception and raise awareness in-house and with external organisation (sub-contractors, suppliers...). Barbour homes (1999) later in the interview made a very strong statement that "the benefits are good, safety culture is best practised, it's habit forming, it lends itself if we get that right." Success seemed to lie within the **implementation of a good safety culture**, understood by everyone from the strategic end to the operational side through the tactical branch.

Perception was often linked to the way we, as individual or as a group or an organisation, we perceive risk. BS 6079 defined risk as a combination of the probability, or frequency, of occurrence of a defined threat or opportunity and the magnitude of the consequences of the occurrence (BS 6079). The perception of fire on construction site also followed this pattern: what is the risk of a fire on one of my construction site? Barbour Homes (1999) commented that "it's the perception that is at the soft end of the industry, and it's not always accurate." Accurate? Because we can't measure it, maybe, or maybe because the society doesn't recognise it as a major risk? When asked about the use of a fire safety plan, Morse (1999) answered that their subcontractors "are made aware of it." And added "the major risk is with accidents anyway." As a health and safety manager it sounded like a big shortcut towards disasters on site. On the other hand, organisation which were more concerned about the perception, and especially the perception of the general public or the society as a whole, due to their market position or success in business would have a different approach. Some managers would be more radical and admit: "I don't like when people say you will asses. Your opinion on a risk might be totally different from my opinion on a risk" (Barbour Homes, 1999). The Facilities Manager of Radiant 2 (1999) stated that "there is a lot of change awareness in the fire issues..." The major construction manager for Building Authority (1999) advanced that his organisation has been forced to change to improve the perception of the problem of fire safety. However it proved to be a success and Building Authority added that "one of the things we pride ourselves on is our safety performance in construction in comparison with health and safety executive standards for the UK and averages."

Transmitting this perception of safety and changing the safety culture of an organisation might takes years. The health and safety manager for Barbour Homes (1999) commented that "it is good to hear that safety culture is developed." However he thought that "the attitude of the management is more important than the attitude coming from him: "Everybody expects me to have a certain attitude to take reasonable hard line as I keep accident prevention. I am quite fortunate that the management is quite proactive." For Morse (1999) the health and safety manager did not believe so much into his management. He argued that "there isn't enough being done across the board safety wise... and by the sub-contractors using a largely incompetent safety wire." Kelly (2000) developed a "fairly complex and fairly rigorous safety regime..."

The conclusions emerging from this review of safety culture, perception and attitude across the organisations interviewed was broad. It seemed we could divide the group in two: those who are proactive and implement measures before they are asked to do it by law or enforcement. And on the other hand those who were reactive and forced to develop a new approach towards safety on site.

7.2.1.3 Regulation and legislation: how efficient is it?

One objective of the research was to find out if the current and existing set of legislative and regulatory requirements was sufficient to provide a minimum level of safety and if this minimum level was adequate and acceptable for the contractors, the workforce and any other party involved in the construction process.

Several issues were raised in the interviews: the idea of lack of safety, weaknesses in the existing system, the reactive approach of the industry, pressure from insurers...

Since the first edition of the JCOP, major construction bodies participated to update the document four times and apparently successfully. However, as stated in the literature review, there was statistical evidence to support this information. Barbour Homes (1999) believed that "there is a weakness in general fire control within our industry... and that the joint code of practice raised by insurers and the fire authorities are largely impractical for the type of work they are being asked to do." Later in this research, the strengths and weaknesses of the JCOP were analysed, and you will find that the **JCOP was definitely working and brought a positive culture in organisations**. Morse (1999) stated that "there is a lot more countries that are less advanced than us." Certainly in the first part of this thesis, the author reviewed and analysed the current legislative state in the EU and compared the EU approach against the Canadian and American framework. The author discovered **that the UK fire safety approach was more advanced.** However, the general health and safety regulations did have some weaknesses. Investment into safety was still low as profit margins and the construction economy were low. Barbour Homes (1999) commented that they had some clients asking them to comply with the JCOP but "in all honesty [they] don't price for it." Morse (1999) wondered if the "people who count the money would be happy with it." He continued and closed his explanations by the following comment: "because I don't think the money parties invest into safety will change."

The publication of the CDM regulation in 1994 brought a lot of change to the industry and the division of responsibilities between the parties, putting more duties and responsibilities on the designer. Building Authority (1999) viewed **the CDM** as **"a very prescriptive document"**, Morse (1999) thought the **CDM Regs were "too heavy"** and Barbour Homes (1999) saw in the **CDM publication a good exercise which made their organisation "sit down and think about the planning side and the brainstorm of how [they] were going to tackle the problem"**, but they still admitted **"CDM in its structure has got a lot of problems."**

The CDM focussed on health and safety standards with no reference to fire safety directly. The requirement of a health and safety plan suggested the initiation of a fire safety but not separately. It is nowadays a standard requirement in most of CAR/EAR insurance clauses to require compliance with JCOP. This insurers' rule initiated in 1992 following the two major UK construction site fires, enforced fire safety standard on sites. The practitioners were more concern about compliance with JCOP. Until 1998 and the new edition of JCTs Forms of Contract, the JCOP was not a requirement under the terms of the contract. But with the JCT98, it changed: amendment 17 was integrated in the new edition.

What needs to be done to improve safety? The JCOP publication and implementation were certainly a good step ahead and was supported by the industry, their insurers and re-insurers, the FPA, LPC, BEC, the Fire Brigade... So far we discovered that to be effective, the fire safety approach must be integrated in the organisational structure and belief ("its mission statement" like in Building Authority). An interesting comments was brought on by Morse (1999): "It's the same thing with most safety things. Disaster is waiting to happen, and then it happens, something will change." This reactive attitude seems to be a well known approach in the industry. Certainly the pattern of evolution of fire safety standards in the UK was following this path. As illustrated in Figure 7.2. The Safety Manager of Arlow (2000) agreed it was regrettable to have to suffer major accidents and disaster to react and improve the fire safety level[18]. The more disasters, the more the safety department advice and opinion was raised. Building Authority (1999) has been more concerned by the Dusseldorf fire in 1996,

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[18] "Il est clair que dans le domaine de la sécurité incendie, c'est malheureux à dire, mais c'est à chaque fois que l'on connait une catastrophe qu'on remet un tour de vis supplementaire. C'est valable

which killed 16 in an airport. The engineering elements which contributed to the catastrophic outcomes of the Dusseldorf fire raised a range of issues taken on board by major organisation dealing with the public and receiving large crowds in their facilities (airport authorities, shopping complexes, railway station…). Building Authority (1999) explained that "the Dusseldorf accident had more of an impact in terms of fire safety in the building design. It forced us to look very closely and re-examine our fire safety procedures and re-evaluate what they were." Radiant Property 1 (1999) argued that after Kings Cross fire a huge drive on fire safety improvement and requirements. For others, when asked if major incidents change their perception of fire safety, astonishing answer came across: "MCP: Are you aware of the two major fires in London which happened in 1990 and 1991? KELLY: Which ones are you talking about?" (Kelly, 2000). It might be due to the younger age of the interviewee compared to other participants.

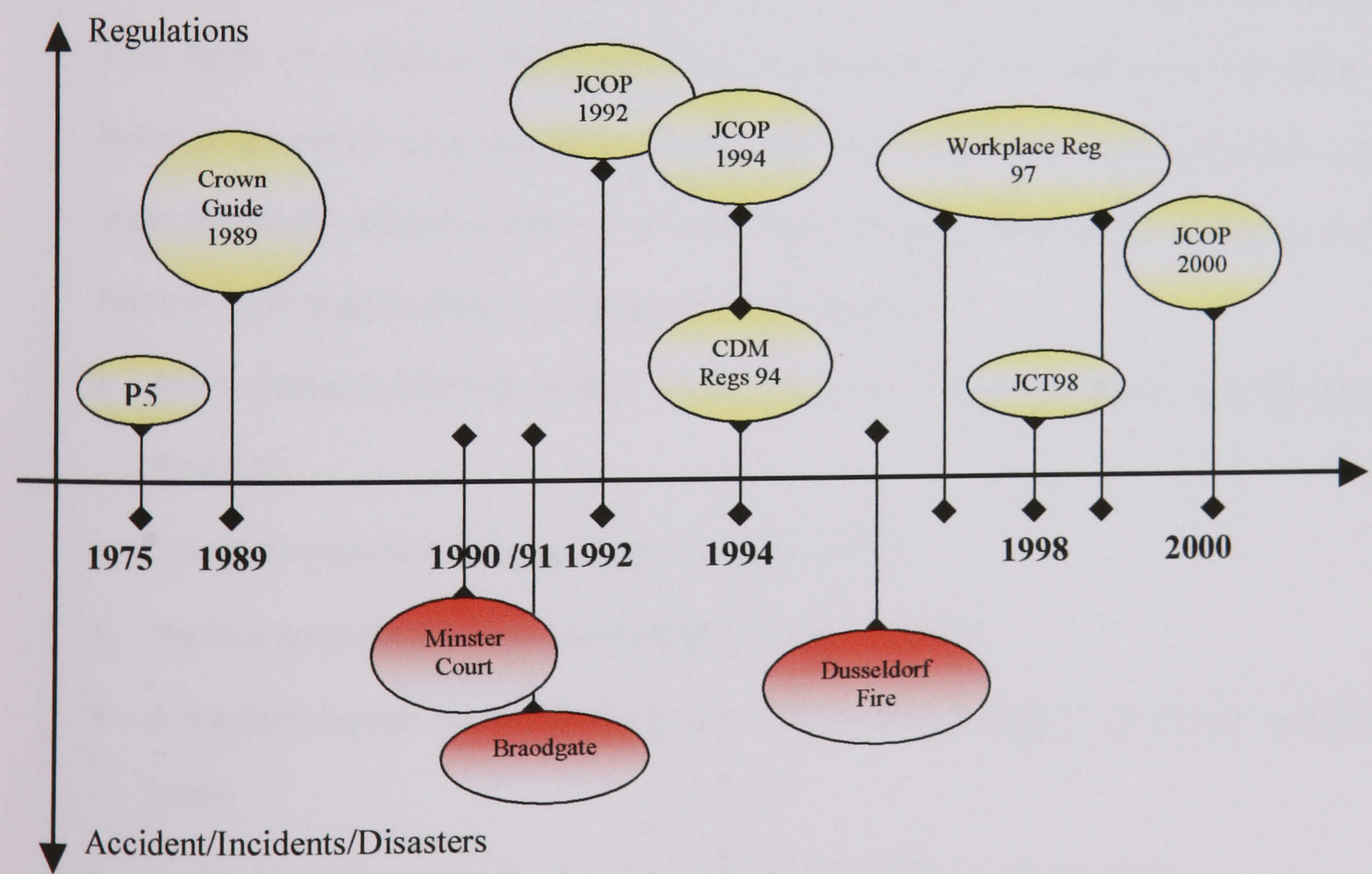

Figure 7.2: Reactive framework – Disasters vs. Regulations

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partout… plus il y a de pepins, plus il y a d'accident graves en sécurité incendie, plus on donne de moyens et plus le service de sécurité est écouté." (Arlow, 2000)

The discussion and exchange with practitioners on fire safety management and its regulatory requirements highlighted a number of strengths and weaknesses in the existing system. The series of measures taken throughout the last 15 years demonstrated the reactive behaviour of the government to implement stronger and better standards. The proactive actions of insurers in the 1990s to promote fire safety on construction sites and enforce compliance with a statutory guidance through the insurance covers was a success in raising awareness amongst practitioners and integrate a total fire safety management approach. As always it is profit driven, so far for the insurance industry, and contractors are now putting more pressure on their clients to invest into safety and raise the profile of safety in the industry.

7.2.1.4 Which fire safety strategy?

Since the publication in 1992 of the JCOP Code of Practice and its integration within the JCTs forms of contract in 1998, contractors and clients took the problem of fire safety on board. Major efforts were put into the development of an in-house fire safety procedure, often under the overall safety procedure. Fire safety was one section of the safety procedure. In the interviews, all organisations mentioned about their standard:

- Safety Schemes (Barbour Homes, 1999) with a set of standard issued nationally within the group.
- Standard compound drawings (Barbour Homes, 1999)
- National procedures and group standards (Radiant 2, 1999)
- A standard format for health and safety file: a Safety Handbook (Building Authority, 1999)
- Tool box talk to communicate to the workforce (Building Authority, 1999)
- Standard procedure across the organisation and specific fire plan (Kelly, 2000)
- A project board which is totally project specific (Building Authority, 1999).

The image of safety was important for these organisations. Some will see it as a selling point. Barbour Homes (1999) believed that "safety can assist [them] to sell houses and that is [their] aim." On the other hand Arlow (2000) sees it as an "image de marque" (business image) to sustain. **Their safety strategy differed and depended on their corporate objectives.**

However we observed some difference within the regional offices of one organisation as Kelly explained: "Generally, Kelly Scotland is using the same procedures but they are not quite as in-bread in the people, and the people are not as used to them as they are down south." (Kelly, 2000). Building Authority (1999) promoted a competitive approach: "the site safety awareness is a competitive thing because every contractor is getting a score every week so we have a league table essentially." The reward might be worse the game: "every week there is a contractor who wins and we draw a name out of a hat and he gets a gifts voucher." One drawback of this "successful" method was the overwhelming approach of certain contractor not to report incidents to get the gift. It is not anymore a working rule but a game. The author also came across the "worst contractor of the week" game, practised when the contractor knows he has no chance to win the first price. Barbour Homes (1999) encouraged a "two way information and feedback" between the workforce and the management and promoted "a fairly thorough hierarchy of safety communication... and the workforce could pass this message to the management." The health and safety manager for Barbour Homes believed "this is the way to communicate at all levels."

Primarily fire in historic buildings encountered very much a catch-22 situation in its prevention, this being the problems faced when considering methods of protection. In the case of an historic building there was a further dimension – the loss of property that forms part of a cultural resource which was finite, irreplaceable and whose architectural and historical integrity can be destroyed as easily by inappropriate fire precautions as by fire itself. When losses were a much onerous concern in terms of its value, like in historic facilities, major owners (private, crown owners, historic department, governments...) got together to find a better and more appropriate solution for the type of facilities they were dealing with. Within the Raphael Symposium major historic departments from the EU formed a working group on safety in historic buildings with one representative from each European country[19]. (Chastenet, 2000). Chastenet added that they had to fight for 5 years and put pressure on the contractors and sub-contractors to change their attitude towards safety. They had to fire site manager who didn't follow the procedure.[20] This initiative aimed to improve standard across historic facilities and to learn how each individual and the working group as a whole, can benefit from the other members experience and fire safety approach in their country. **A strong emphasis is put on the transfer of knowledge and promoting research and development in this field.** One objective was to collect, at a European level, records and data to produce adequate and accurate statistical data.

Insurers were also taking on similar initiative at a European level (Denney (FPA), 2000). The increase of the global market and growth of EU contracts demonstrated a dearth of research and common standard across the EU. European Directives were a good starting point but they didn't provide enough flexibility to allow a uniform adaptation of the fire safety requirements.

7.2.1.5 European Directives: pros and/or cons?

Minimal fire safety standard was complied with and most organisations which realise the potential benefits of developing their fire safety strategy started it after the publication of the JCOP for fire prevention on construction sites. One of the reasons why they were forced to sit down and think about it, was because the JCOP, as it was structured in 1992, didn't fit in any of the existing safety framework. At that time, minimum requirement was required, but there was no room for new initiatives. Insurers knew any client and contractor would have to comply with the JCOP soon or later and that it might take years to change the culture. Actually it nearly took 8 years (1990-1998). Figure 7.3 which illustrates the reactive approach

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[19] "On particpe dans le cadre du colloque Raphael a tout un groupe de travail sur la sécurité avec tous les responsables de monuments historiques de chaque pays d'Europe." (Chastenet, 2000).

[20] "Nous on s'est battu pendant 5 ans et il a fallu qu'on fasse pression sur des entreprises, que l'on fasse virer des agents sur des chantiers qui n'ont pas respecter cette procedure. (Chastenet, 2000).

of the British system, provides a good idea of the inter-relationship between disaster/incidents and the publication of new regulation.

The role of the EU in trying to harmonise the regulation across the members state required each country to implement the directives within a given period (usually 3 years, unless for an emergency). From 1992 to 1994, contractors and clients were faced with the implementation of the JCOP in their existing structure (under the UK law, compliance with JCOP is not required, the insurers required compliance through their contractual clause). In 1994 the government implemented the CDM Regulations 1994 and compliance with the document was required within 1 year (July 1995). The prescriptive requirements of the CDM disturbed the industry. The lack of knowledge of the regulation, the scope and purpose of the CDM put pressure on the construction parties to review their method and fire safety process. The CDM was a direct consequence of the EU Directive 92/57/EEC on the implementation of minimum safety and health requirements at temporary or mobile construction sites as discussed in Chapter 2. Building Authority (1999) indicated that "the construction industry has changed in the last 10 years and it is far more aware, far more safety conscious. The general safety awareness, individual safety awareness is so much better, people are far more better educated in good safety practice." But overall most organisation were forced to embrace the European standards ("Everything that Europe can throw at us" Building Authority, 1999). The general feeling was that **the EU directives are seen as negatives and over-regulating the existing structure**, when actually **it allows governments to deregulate to better regulate** (like the CDM Regs).

7.2.1.6 Business continuity and contingency planning: does it matters? "We are insured anyway..."

If we had a fire today, do we have contingency plan?: a simple question to explore the depth of the safety approach was asked to all interviewees. The continuity of a business was a priority for all organisations. Arlow (2000) admitted[21] that if a fire was to affect their business the consequences could be disastrous. Arlow didn't **have the infrastructure to cope with a major disaster** and they wouldn't have the capacity to transfer part of their business activity to another facility. This lack of flexibility of the design of facilities and the restraints on construction activities in a building in use were a major source of risk of fires during the construction process, refurbishment works and maintenance operations. When members of the public were involved or at threat, different measures must be taken. Building Authority (2000) draw a distinct line between the boundaries of the site and the facilities in use. The use of fire walls and partitions was now common and an increase use of temporary fire detection and warning systems was encouraged. We discussed in Chapter 3 the engineering characteristics of a site and how its evolutionary design and construction affected the development of a fire. **These elements of engineering were a very important parameter to understand the complexity of the problem**. However the scope of this research was not to develop an engineering approach, but a qualitative research. Nevertheless, as it was discussed, it is important to take it into account. Building Authority (1999) looked at the "building fire safety into design and how to have a compartment strategy and controls in compartmentation." But Building Authority (1999), like Arlow and Le Centre, was concerned about first "the safety of their occupants" and their public image, and second "the business economic impact of loosing a facility."

Barbour Homes (1999) who was dealing with a large number of small projects (houses) and some multi-storey facilities, was faced with a different set of risk. The type of construction played an important part in fires: timber structure tends to be prone to fire. Their approach was to maximise the implementation of a fire safety procedure on site to reduce the outbreak

[21] "Si on avait un incendie, est ce aujourd'hui on a un plan de gestion de la crise? Aujourd'hui si on perd un aerogare a cause d'un chantier on aurait un impacte sur l'exploitation qui serait trés important. On a pas des infrastructures qui nous permettraient de palier à cela. On a pas la capacité de transferer tout le traffic sur les autres aérogares. Il y aurait des perturbations sûrement trés importantes" (Arlow, 2000).

of fires and if one were to occur, to minimise the economical impact through their insurer: "we are self insured for £25,000... straight off our profits."

From the analysis of the data collected through interviews, **there was no evidence that contingency planning was a systematic exercise**. Certainly no evidence were here to demonstrate that the organisations interviewed have an operational continuity planning. The transfer of the risk of an interruption to the insurer seemed to be the easy escape to avoid a recognised problem. Often, interviewees were trying to avoid to answer the question by providing another answer, but no one of them stated: "yes, we have a contingency plan, and if today a fire broke out and destroyed our facility, this is what we would do." In contrary, because the risk of fire to destroy one of their facility was low or not worth considering, they decided not to develop a contingency procedure. The health and safety manager for Kelly (2000) had an interesting statement: "I imagine they (the fire brigade, his organisation...) will bring in the total emergency plan." Anyway, he never "came across considering the risk of spreading to adjacent offices and buildings."

Figure 7.3: PhD Schematic Structure: Interviews Findings / Model A

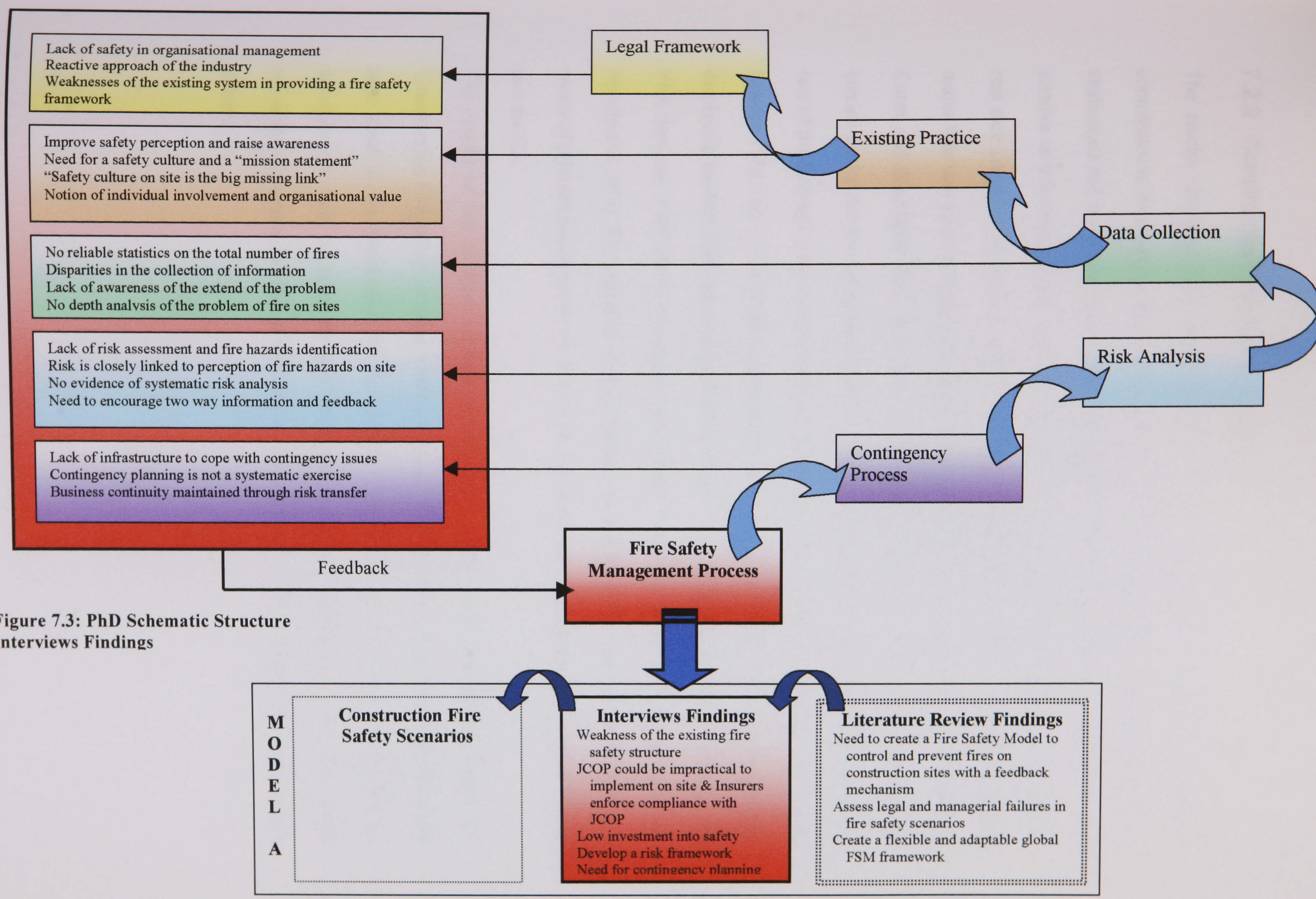


Figure 7.3: PhD Schematic Structure Interviews Findings

7.2.2 Construction Fire Safety Failures:

The results obtained from the interviews were not conclusive and did not completely contributed to demonstrate the research questions. The validity of the data collected could be challenged and the authenticity of the information provided could be discussed. However, a number of interesting issues were highlighted. It was now time to concentrate on a series of real case scenarios and analyse where really the problem was coming from. Access to data on major fires was again limited unless the government carried out a public enquiry. The Minster Court and Broadgate fires have been widely publicised and a detailed fire investigation carried out by the fire authorities. However, how were these major fires representative of the rest of the iceberg? They were major fires (£35mand £110m losses), some office facilities in London (The City = The Media), presented a complex design (atrium, multi-storey building, displaying modern materials and innovative design...)... Out of the 50 fires recorded by the FPA between 1985-1998, Broadgate and Minster Court are at the top of the pyramidal distribution (4%). The objective of this chapter was to present the result of the analysis of a series of relevant construction site fires in the UK and France, and some in the rest of Europe and the US.

The results of the analysis of these failure fire scenarios were presented in Table 7.3: Construction Fire safety Failures Matrix. Lessons learnt from these fires were also listed and later used in the preparation of the FSMM. Observations on the origin of the fire, its development and containment and extinguishment were highlighted. The fire safety management system, in place at the time of the fire, was also analysed and criticised to assess failures.

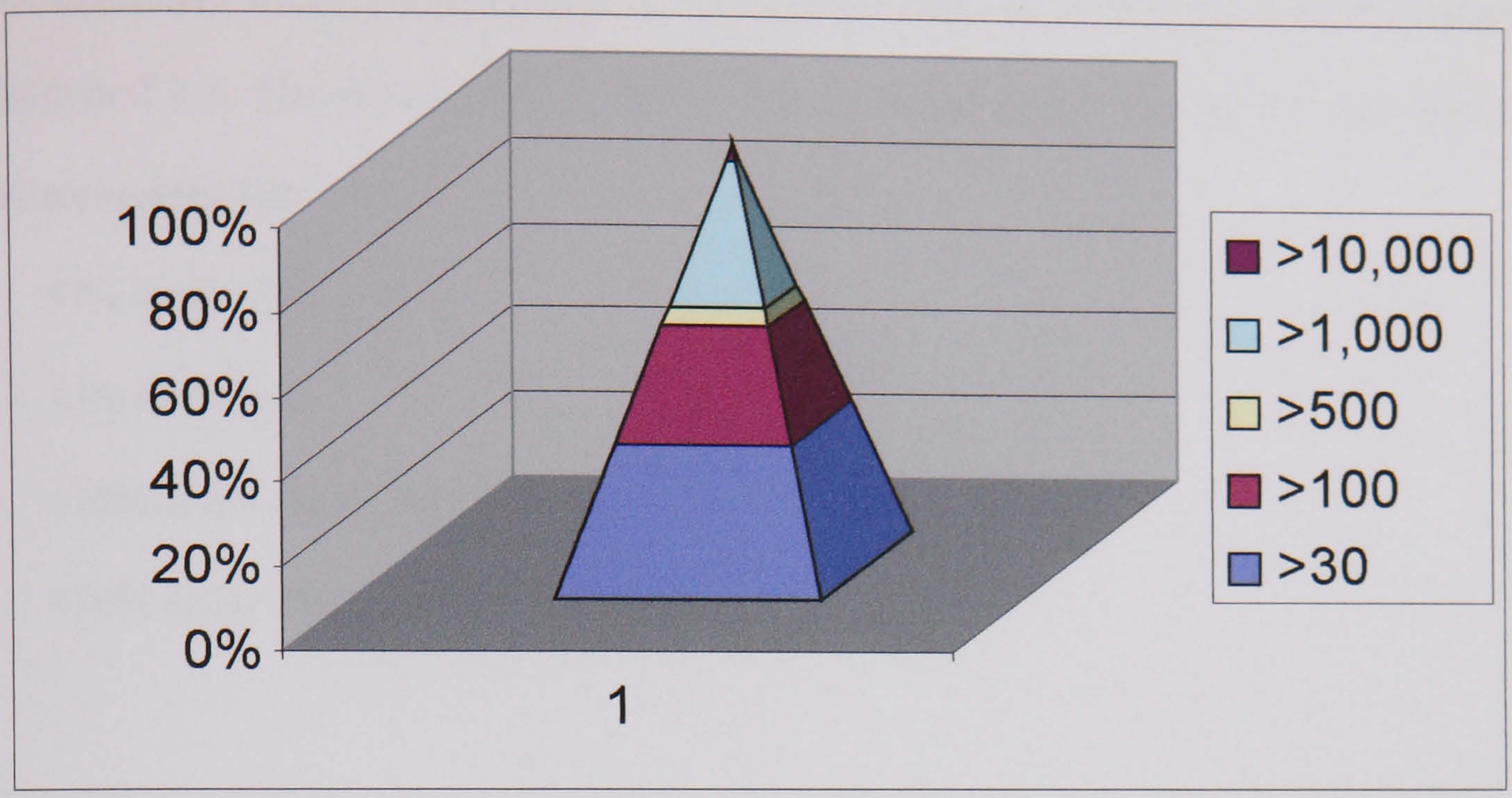
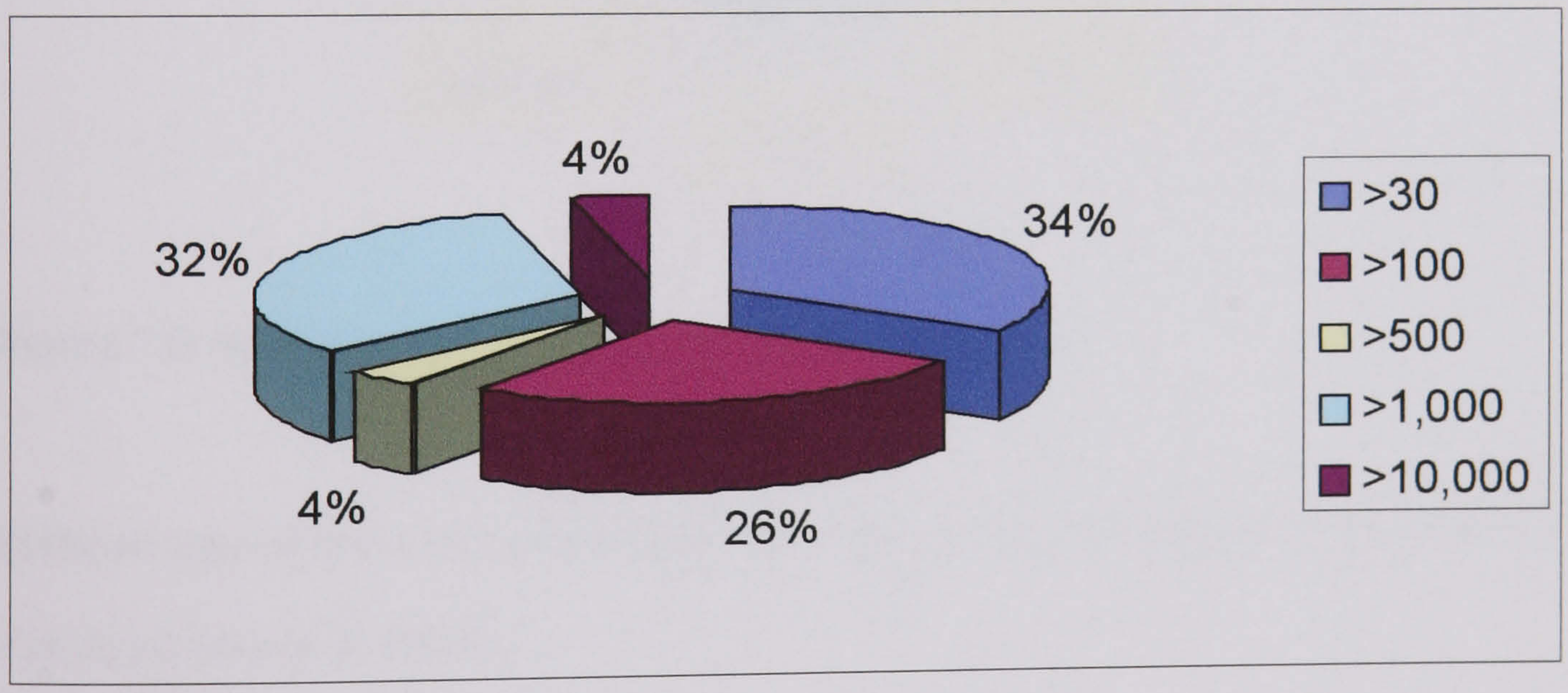


Figure 7.4 (a&b):Distribution of fire losses in % by category of losses (£,000) from 1985 to 1998



7.2.2.1 The Construction Fire Safety Failure Scenarios:

The qualitative study of construction site fire safety scenarios looked at 21 different cases as listed in 7.2.2. The distribution of fires primarily concentrated on the EU and especially France and the UK:

- 47% in the UK
- 33% in France
- <10% in the rest of the EU
- <10% in the US

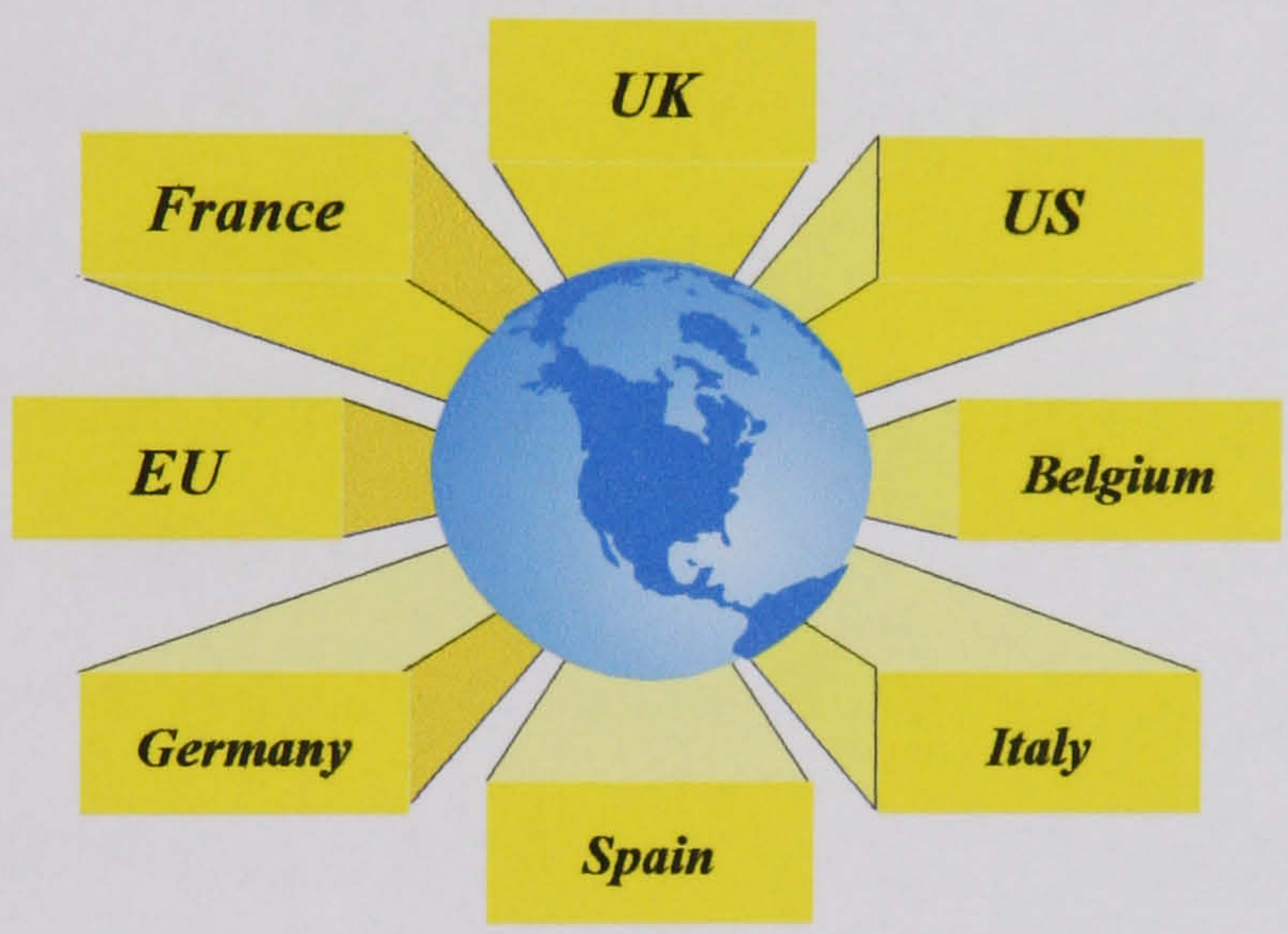


Figure 7.5: Selection of case studies and fire scenarios

Different type of site were selected and with comparative cases between France and the UK. The distribution is as follow:

- >28% of New Construction sites
- >57% of refurbishment works
- >14% of maintenance sites.

It was not a hazard that the majority of the cases studied for this research (57%) were refurbishment sites as the risk of fire in these construction activities is often very high.

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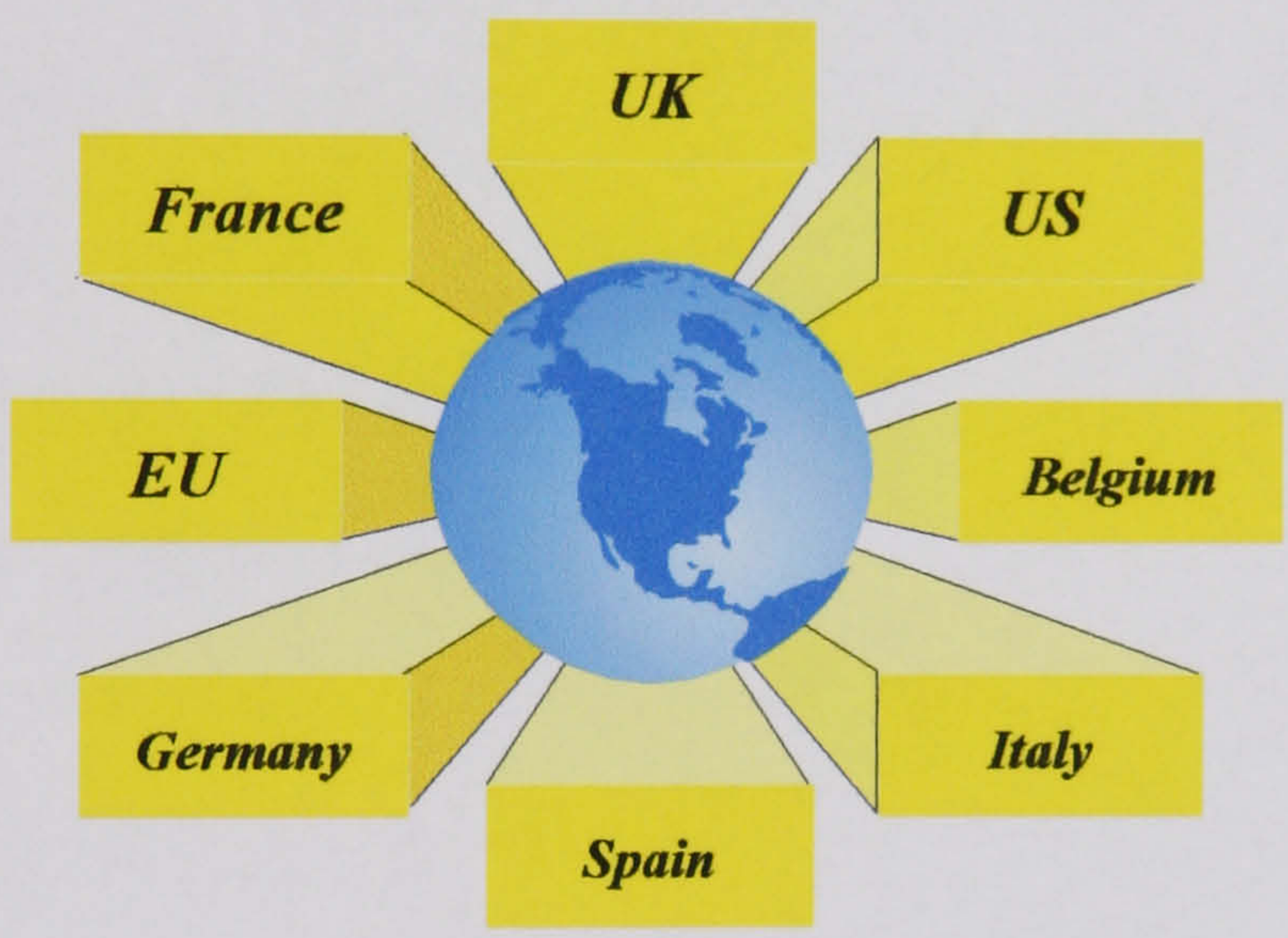

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To ease the analysis of the fire safety failure scenarios and extract valuable information on the safety system failure, the author concentrated on the thorough analysis of five types of facilities:

- Retail Units and Shopping Centres: UK Retail Store I (2000) and II (2000); FR Retail Store Sama (2000).
- Factory Units and Processing Industry: UK Processing Factory (1998), FR Frigécrème (1996), FR Factory (1994), FR Factory (1996)
- Offices: UK Broadgate (1990), UK Minster Court (1991), UK Bank (1999), FR Residential and Offices Facilities (2000), FR Bank (2000)
- Public Facilities / Entertainment: UK Hospital (2000), US Sight & Sound Theatre (1997)
- Historic Buildings: UK Hampton Court (1986), B Palais des Malines (1995), US Harrisson Building (1985).

The author aimed to compare and contrast fire failure scenarios between France and the UK and for this reason, similar case studies were identified on both sides. Unfortunately the information collected in the claim files and reports by the insurance companies, is not the same from both sides. The UK system seemed to be more thorough and detailed, thanks to the work of Loss Adjusters on behalf of the insurers. The detailed analysis of the circumstances of the fire and its development were not as well detailed in the French claim files.

The table 7.3 below provided a matrix of construction site fire safety failure for each fire scenarios analysed in this chapter. Conclusions were extracted after the analysis and at the end of this chapter. Confidentiality on most of the fires, their location and companies involved has been retained and each scenario is identified as a code: Country / Type of Site / Date of Fire.

Country: France-FR, United Kingdom-UK, Germany-D, Belgium-B, United State-US for example, FR Retail I (1999): France, Construction of a Retail Unit in 1999.

INPUTS | **DESIGN AND ENGINEERING**

INPUTS	Inadequate Building Layout	Inadequate Design	Failure of Passive Design	Inadequate fire protection measures	Failure Fire Protection Measures	No Active Fire precaution Measures	No Passive Fire Precautions Measures	Rapid Fire Spread	Slow fire spread	High fire load	Low fire load	Inadequate compartmentation	No compartmentation	Technical Failure	Structural Failure
RETAIL UNITS															
UK Retail I (2000)		v	v	v	v	v		v			v	v			v
UK Retail II (2000)		v				v		v			v	v			
FR Retail Sama (2000)					v	v		v		v		v			
FACTORY UNITS															
UK Factory (1998)				v		v		v		v					
FR Factory I (1994)						v			v	v					
FR Factory II (1996)		v						v		v					
FR Frigecreme (1996)								v		v					v
OFFICES															
UK Broadgate (1990)		v	v			v		v		v		v			v
UK Minster Court (1991)		v						v		v		v			
FR Bank (2000)		v	v	v	v			v			v		v		
UK Bank (1999)								v			v				
FR Office (2000)				v		v		v			v				
US Harrisson Bldg (1985)						v	v	v		v					v
PUBLIC															
UK Hospital (2000)	v	v		v				v			v	v			
US Sight & Sound (1997)		v			v			v		v		v			v
D Dusseldorf (1996)	v			v		v		v	v	v			v		
HISTORIC BUILDINGS															
UK Hampton Court (1986)			v	v		v		v		v					
B Palais Malines (1995)		v	v		v				v	v					

MANAGERIAL STRATEGY

INPUTS	Failure to comply with FS Requirements	Inadequate fire safety strategy	Failure of fire safety management strategy	Evidence of compliance with JCOP or equivalent guide	No evidence of compliance with JCOP or equivalent guide	Poor managerial control	No storage facilities	Poor storage facilities	Poor site management	Inadequate risk management	No risk management	Human error / failure	Lack of awareness	Communication failure	Inadeuate staff training	Inadequate waste management	Negligence	Inadequate security management
RETAIL UNITS																		
UK Retail I (2000)	v			v		v			v	v						v		v
UK Retail II (2000)				v		v			v	v								v
FR Retail Sama (2000)					v												v	
FACTORY UNITS																		
UK Factory (1998)		v		v		v			v	v								
FR Factory I (1994)		v			v					v								
FR Factory II (1996)	v	v			v	v	v		v	v							v	
FR Frigecreme (1996)					v													
OFFICES																		
UK Broadgate (1990)		v			v	v	v		v	v						v		
UK Minster Court (1991)		v			v	v			v							v		
FR Bank (2000)	v	v			v	v	v		v				v		v	v		
UK Bank (1999)	v		v		v	v	v				v		v			v		
FR Office (2000)		v	v		v			v								v		
US Harrisson Bldg (1985)					v											v		
PUBLIC																		
UK Hospital (2000)					v	v			v	v							v	
US Sight & Sound (1997)					v			v		v				v	v			
D Dusseldorf (1996)		v			v								v	v				
HISTORIC BUILDINGS																		
UK Hampton Court (1986)		v			v	v			v				v		v			
B Palais Malines (1995)		v			v												v	

CONTINGENCY PROCESS

INPUTS	Failure Emergency procedure	Inadequate emergency procedure	No emergency procedure	No evidence of contingency plan	Inadequate contingency plan / DRP	No evidence of Business continuity plan	Inadequate BCP	Effective Fire Brigade Action	Inadequate Fire Brigade action	No salvage plan	Inadequate salvage plan	Difficult acess to fire zone
RETAIL UNITS												
UK Retail I (2000)				v		v						
UK Retail II (2000)		v		v		v						
FR Retail Sama (2000)		v		v		v						
FACTORY UNITS												
UK Factory (1998)			v	v		v			v			
FR Factory I (1994)				v		v				v		v
FR Factory II (1996)				v		v						v
FR Frigecreme (1996)								v				
OFFICES												
UK Broadgate (1990)												
UK Minster Court (1991)		v		v		v			v			v
FR Bank (2000)		v		v		v						
UK Bank (1999)			v	v		v						
FR Office (2000)												
US Harrisson Bldg (1985)								v				
PUBLIC												
UK Hospital (2000)				v		v						
US Sight & Sound (1997)				v	v	v			v	v		
D Dusseldorf (1996)	v	v										
HISTORIC BUILDINGS												
UK Hampton Court (1986)						v		v				
B Palais Malines (1995)				v		v			v	v		v

Table 7.3: Construction Fire Safety Failure Matrix

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7.2.2.1.1 Retails Units and Shopping Centres:

- UK Retail Store I (2000) and II (2000); FR Retail Store Sama (2000).

The importance of the design and compartmentation in a facility was one key factor of the control of the spread of fire. Retail units and shopping centres have a very specific design which aims to allow the circulation and move of occupants in a commercial environment. The facilities were not only constructed top protect the occupants through the provision of adequate fire safety measures (detection systems, warning, extinguishment, means of escape) but also to get the public to buy the products on display. The consequences were a design usually very modern and using a range of flashy modern materials (metal, decorations and ornaments, display units...) and presented in large open spaces. This design approach was not only found in the UK but worldwide.

The case studies the author analysed presented similar characteristics. The two retail units in the UK were owned by the same retailer and the French case study concerned a typical renovation project in a shopping centre widely known and used by the public. Renovation works were taking place and a large quantity of product was stored in the facility during the works. In retail Unit I and II, the facilities were closed for business but due to reopen soon after the fire incident. For the FR Retail Store Sama the renovation took place in the 1926 multi-storey facility for one unit retailer.

The **UK Retail Unit I** was undergoing refurbishment and was being refitted by a main contractor and sub-contractors at the time of the fire. The Security Guard was employed 24 hours a day and 7 days a week. A temporary security fence has been erected around the northern end of the building, prior to the fire, to restrict access to all of the entrances on this side of the premises. The building was fitted with temporary lighting which was left switched on overnight as a security measure. The contract commenced on site in March and was due to completion at the beginning of May. The contract value was in the region of £700,000.

The loss premises are part of an industrial estate a short distance from the town centres (in the UK). A company of builders and a number of sub-contractors were refitting the Retail Unit at the time of the fire. The prospective tenants of the facility were supposed to occupy the building after its refurbishment.

- Show room: 23,630 sq.ft
- Warehouse: 15,854sq.ft

The Retail Unit I (UK) comprised a steel portal frame building clad with profiled metal sheet. The loss premises adjoined a similar structure from which the occupier was actively trading. The internal layout is similar to many modern retail units. The warehouse was partitioned off by jumbo stud partitioning and it is an entirely self-contained unit. The showroom has the usual open plan display. The premises were not sprinkled and a normal intruder alarm protection was fitted. There is no perimeter security.

Planned System	Operational and Active Systems	Recovery and Continuity System
Design failure: fire stopping, structural integrity, fire resistance. No evidence of proper fire safety management on site Failure to secure site insurance	Fire origin: Arson attack by unknown intruder 2 seats of fire Inadequate fire precautions measures Fire and Intruder alarm not operational No sprinklers system Improper fire doors fitting No waste disposal Failed fire curtains operational Lack of compartmentation No evidence of proper fire safety management on site	No evidence of Recovery and continuity planning. Large Loss Advice by Insurer following the fire.

Table 7.3: UK Retail Store I (2000)

A number of evidence were collected and explained the circumstances of loss:

- Evidence of arson or deliberate acts. The most likely explanation was that the fire was started by intruders.
- There were two seats of fire, one in the showroom and one located in the warehouse.
- There is evidence of a forced entry to the building and also that the building was not secure.
- A fire door located on the southern side of the building was insecure at the time of the forensic examination. Despite numerous attempts this door could not be made to lock and so could be opened from outside the building even when it was closed.
- The possibility that the security guards showed a lack of care cannot be ruled out.

- The building was insecure at the time of the fire and possibly for some time prior to the fire.
- A degree of vandalism has occurred in the building.

The **Retail Store II** was situated in a Retail Park in the UK in a modern out-of-town retail development. Constructed 7 years ago and owned by a single landlord. The occupier retail unit was 20,000 sq.ft facility and was one of seven similar units in a terraced multi-tenure retail block[22]. The contract value was approximately £500,000 and a contract period of 2 months to reach completion has been agreed.

The Premises[23] was of steel portal frame construction with in-situ concrete foundations/ground floor with insulated composite roof and wall cladding. The individual letting units were sub-divided by 'Jumbo stud' partition walls. The proposed internal layout was typical of modern stores, consisting of a large open plan display/sales area.

The premises comprised a modern, west facing, mid-terrace retail unit with the front and rear walls clad with profiled sheet steel. The roof of the retail unit was clad with profiled sheet steel and contained plastic rooflights.

The premises were not sprinkled. Although the new intruder alarm, fire alarm and CCTV installations were in place, none had been commissioned or operational at the time of the loss[24].

The retail unit[25] was undergoing refurbishment which had commenced approximately 6 weeks prior to the fire and was due to completion two weeks after the fire occurred.

The main contractors for the refurbishment were experienced and working with sub-contractors. There was a strict 'no smoking' policy in place in the retail area.

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[22] Loss Adjuster Report (2000) UK Retail Unit II
[23] Fire and Forensic Report (2000) and Loss Adjuster Report (2000) UK Retail Unit II
[24] Loss Adjusters Report (2000) UK Retail Unit II

Circumstances of loss[26]:

- Suspect arson in a new store being fitted out. 90% completed.
- Existing temporary portable display unit being retained during the reinstatement of the facility.
- Site patrolled by a third party Security Company, frequently employed by the Occupier.
- Facility was not insured by the same insurer as the Principal Contractor.

The direct fire damage[27] was limited to the unit occupied by the facility occupier although there was reportedly minor smoke damage to adjacent units. There was extensive high level smoke and heat damage throughout the showroom and smoke had vented from the eaves at the rear of the building. Within the central floor area of the showroom there was very little heat damage below the suspended ceiling. The direct fire damage was isolated to the kitchen display aisle involving four kitchen displays. It was evident that the gypsum wallboard on the occupier side of the wall had been breached by the heat of the fire although the other side of the wall was still intact. Therefore only minimal smoke was able to spread into the neighbouring units via this route.

Planned System	Operational and Active Systems	Recovery and Continuity System
Inadequate design and passive fire measures. No fire protection system in place during the construction works.	Fire origin: deliberate ignition Rapid unrestricted vertical fire spread Security company failed to maintain tight security on site No automatic detection and warning system No sprinklers system Improper intruder alarm: Access to building not controlled and detected Open space and No compartmentation Important smoke release	No evidence of Recovery and continuity planning. Large Loss Advice by Insurer following the fire.

Table 7.4: UK Retail Store II (2000)

The Retail Store Sama (2000) was under refurbishment at the time of the fire. A sub-contractor was working on one of the flat roof at the 7th floor and cutting some of the central heating pipes with a naked flame. Prior to renovate the facility, the main contractor was

[25] Fire and Forensic Report (2000) UK Retail Unit II
[26] Large Loss Advice (2000) UK Retail Unit II
[27] Loss Adjuster Report (2000) UK Retail Unit II

required to demolish part of the facility and sub-contracted the work. The main contractor recognised his sub-contractor caused the fire with a naked flame[28].

The loss premises were located in a city centre within enclosed buildings. The multi-storey shopping centre was let to several separate retailers. The lack of information on the type of building structure of the facility does not allow a clear identification of the contribution of the materials to the growth and spread of the fire. However, the building was constructed in 1926 and we can assume the structure was built out of new product which would have a better fire resistance. Damages to the structure and lower floors were severe and required the installation of a temporary roof structure to protect the rest of the facility. Material damages were estimated to be 3.5mFF. A three-month delay was expected before opening. A CAR insurance have been contracted for this project and unfortunately it did not have any special clause for fire on construction sites[29].

Planned System	Operational and Active Systems	Recovery and Continuity System
No evidence of fire detection and warning measures	Fire origin: cutting work on heating system pipes Rapid fire spread to above floor Manual fire fighting	Evacuation of building and adjoining facilities by the police No clear evacuation procedures and plan
No sprinklers system operative at the time of fire	Negligence by SC No evidence of fire detection and warning measures	No BCP by employer
Inadequate fire compartmentation in roof structure	No sprinklers system operative at the time of fire Inadequate fire compartmentation in roof structure	

Table 7.5: FR Retail Store Sama

Design & Engineering:

Across the three case studies of retail facilities, we can observe the design contributed to the growth and spread of fire. Failure to compartment the large open spaces meant the fire was free to develop and damage the existing stock and displays. Arson attacks on commercial properties was a common cause of fires. In the UK for 1999, the Home Office (2000) reported

[28] Assurance (2000) Avis de sinistre Important, FR Retail Store Sama, 2000.
[29] Quad (2000) Note d'expertise n.1, FR Retail Store Sama, 2000.

that 39% of fires in retail and distribution were malicious fires[30]. The lack of adequate fire protection measures was also a major factor contributing to the spread of fire. In the case of the FR Retail Sama, a fire on a flat roof was difficult to detect if on one was around to raise the alarm. However the two retail units in the UK were not new construction but existing premises under refurbishment. At the time of the fire, the fire detection system was not operative and no sprinkler system was installed in the premises. The spread of the fire in the open unit was straightforward. The UK Retail Store II (2000) suffered from a rapid unrestricted vertical spread up to the face of the jumbo stud internal partition wall. In the UK Retail Store I (2000) the fire curtains installed as part of the re-fit failed to prevent the fire from spreading. The design fire stopping was not such that ceiling tiles formed an integral part of the structure. The Structure could be said to be incomplete and not offering its designed resistance to fire spread. As a way of example in Tesco Stores Ltd. V The Norman Hitchcox Partnership Ltd. (ORB; 8 October 1997) lack of compartment and fire resistance were also to blame for the rapid spread of fire: "The plaintiffs accepted that there were defects in the building, for which it was responsible and which led to the spread of fire throughout the building. The defendant had neglected its duty to inspect the shopping centre before and after construction and during and after fitting out of the interior so as to detect any defects in design and construction related to the need to contain the spread of fire." The fire devastated the Grove Green shopping centre in Maidstone in 1993. The fire started by youths who deliberately set fire to some waste behind the centre.

Managerial strategy:

Failure to secure an insurance cover in respect with the contract also appeared to be a common "mistake" in the fire scenarios observed for this research. In the UK Retail Store I (2000) the main contractor failed to secure the CAR cover and did not comply with the JCOP for fire prevention. The Fire Safety Plan, as required under the JCOP, and often closely linked

[30] In 1999 there 43,600 fires recorded in buildings other than dwellings. 13% occurred in retail

to the Health & Safety Plan, under the CDM Regs 1994, required the implementation of limited managerial measures on site. In the FR Retail Store Sama (2000) inadequate measures to raise the alarm and fight the fire at an early stage proved to contribute to the damaging effect of fire and smoke. In the case of the UK Retail Store II (2000) because the incident happen at night and after a supposed arson attack, the circumstances were different. Nevertheless failure from the security company to maintain tight security on site, combined with a defective security doors to the facilities allowed the intruder to enter and leave the facility without being detected.

The combination of managerial failure, equipment failure and inadequate design was disastrous. Poor inspection of the shell work and poor workmanship could explain the chain of effect. In Tesco Stores Ltd. V The Norman Hitchcox Partnership Ltd. (ORB; 8 October 1997) the architects were found in breach of duty by failing to "observe and/or take further action in respect of various aspect of poor construction and workmanship."

Contingency process:

The evaluation of fire risks prior to the start of the construction operations should be reinforced and systematically required. In commercial properties, arson attack were well known problem and in the light of the characteristics of the site (on retail parks, in confined city centre) security measures should be taken to prevent any arson attack on the facilities. The maintain of a fire protection systems should be essential whenever possible. Both UK Retail Units I and II had either an inadequate fire protection system or no automatic detection and warning system. Both did not have a sprinkler system.

Fires as observed in earlier cases, has a devastating impact on the business. It was rare to find organisation with an adequate contingency planning to respond to emergency situations and incidents. The FR Retail Store Sama (2000) lost three months of business over the Christmas and Sales period (December/January/February). In some circumstances it was possible to transfer the business activity and maintain a strong public image on the market. The UK

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distribution (5,600 fires) and causing 52 non-fatal casualties.

Retail Store I (2000) could transfer its business activity to new premises and a local retail unit. A reinstatement could take long enough to destroy a business.

7.2.2.1.2 Factory Units and the Processing Industry:

- UK Processing Factory (1998), FR Frigécrème (1996), FR Factory (1994), FR Factory (1996)

Factories shell and engineering were very specific. The design of a factory (steel frame structure, shell, open space, no partition, low insulation, lightweight materials) contributed to the fast growth of fire. The series of fire in clod stores built off sandwich panels cost the life of dozen of fireman (special reference to the Sun Valley Poultry Ltd, 1993). The low fire resistance of certain materials used in the construction of factories combined with a high fire load (Manufacturing and storage: 1180MJ/m2 (BSI, 1997)) created fast growing fires and low fire resisting structure. In 1997 the Fire Research and Development Group of the Home Office agreed to consider as a matter of urgency the fire safety of sandwich panels. The Fire Research Station (FRS, 1997) had the mission to determine the extent of the problem and what could be done about it. The safety of fire-fighters in buildings containing sandwich panels was the main concern although building occupants may also be at risk. Other factors were the possibility of large property losses and environmental pollution (FRS, 1997). Sandwich panels were made of two metal skins and fillings made of either expanded polystyrene (40MJ/kg), or polyurethane (23MJ/kg) or mineral fibre (around 3MJ/kg). These filling materials could be highly flammable compared to other material like paper (17MJ/kg) or bitumen (42MJ/kg). This calorific value of the dry material contributed to calculate the fire load density.

Factories and manufacturing environment presented multiple risks. The construction of these facilities was usually simple and with lightweight material. The construction itself, did not present some major risks of fire. However, the maintenance or refurbishment process could be more critical in this working environment. The **UK Processing Factory (1998)** was under refurbishment and comprised the construction of an extension to the existing factory. The high economical pressures on this type of business often means that no interruption of the processing activity was possible. Sub-contractors employed to repair the electricity and maintain the existing electrical installation are often required to work in enclosed spaces, in roof voids and on high technological equipment. In the UK Processing factory (1998) fire, the factory owner who bought the premises in 1996 an invested £11m in a refurbishment program starting in January 1998 and due to have been completed in 1998[31]. The management of the Factory appointed a food technology consultant to advise on how the plant should be extended and to manage the extension program. The Factory directly employed the electrical contractors to provide supplies to new electrical panels located in a switch room in the slaughter house. One sub-contractor dropped a bold in a "live" breakout box and provoked an electrical short circuit which produced an explosion. Incentive material ejected and ignited the roof insulation. At the time of the fire "the quality of the buildings ranged from basic traditional brick-block sheds with slate or asbestos roofing; 50s style column and truss framed buildings with single skin metal sheeting, asbestos roofing, and part granolithic, part proprietary seamless industrial flooring, with the balance far more modern and comprising purpose built reinforced concrete/portal steel structures, with plastisol coated double skin insulated profiled metal sheeting panels to walling and roofing, fully laid with seamless industrial flooring, generally to modern food processing standards.[32]" The outer walls were constructed from a sandwich of profiled metal sheeting, thermal insulation and profiled metal sheeting[33].

The fire spread rapidly, activated by the large quantity of combustible materials in the roof void, the sandwich panels which had de-laminated and exposed polyurethane foam which had burned away. An analysis of the fire scenario determined that the fire spread to all the roof void within 2 minutes and flashover occurred 47 minutes after the explosion. The enclosed

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[31] Anon (1998) Fire and Forensic Report, UK Processing Factory 1998.
[32] Anon (2000) Final report on fire claim, UK Processing Factory 1998.
[33] Anon (1998) Fire and Forensic Report, UK Processing Factory 1998.

location and difficult access to the site of the fire enabled the fire brigade to accurately estimate the extend of the fire when they arrived on site. There was dense black smoke and firefighters could not see the extent of the fire[34].

Planned System	Operational and Active Systems	Recovery and Continuity System
Inadequate Fire safety measures	Fire origin: electrical short circuit in roof void. Igniting roof insulation	No emergency procedures operative
	Explosion	Action of fire brigade increased damages
	Rapid fire spread	
Poor contractual administration	No emergency procedures operative	
	Use of portable fire extinguishers as first aid fire fighting	No BCP
	No automatic detection and warning systems	
	Poor site management	

Table 7.6: UK Processing Factory (1998)

Nothing could be done to control the spread of the fire in the facilities. The damages sustained both direct and indirect through the loss of the business, its activity, market shares, reputation, contracts, etc., reaches more then £40m. In the Insurance Property Survey Report (1996) mentioned that "the principle building on site is the Factory which freely communicates throughout to form a single fire risk[35]." The report concludes that the Estimated Maximum Loss[36] for the Building is 70%, Plant: 50% and Stock 80%.

Anticipating maximum losses and planning for emergencies and disasters was not a systematic approach for an organisation owning and managing property. The risk of insuring works in progress remained with the contractor until handing over, practical completion or partial possession. However, during maintenance operations, the responsibility of the facility is under the owner. **In France**, legislation was slightly different from the UK, but the principles are the same: **Ownership defined responsibilities for the facility**. When no contract was signed and the responsibility for the facility was not transferred to the contractor (through possession of the site), the owner was responsible. The case of the **FR Frigecreme**

[34] Anon (1998) Fire and Forensic Report, UK Processing Factory 1998.
[35] Insurance (1996) Property Survey Report, UK Processing Factory 1998.
[36] Estimated in accordance with the ABI recommended definition: "an estimation of the maximum loss which could reasonnably be sustained from the contingencies under consideration, as a result of a single incident considered to be within the realms of probability taking into account all factors likely to

Factory (1998) was one of the only fire in this research which had positive outcomes. The management should be commanded for their contingency actions and strategy on the day of the fire. Unless the UK Processing Factory (1998), Frigecreme managed to save its stock and limit the damages to its facilities. This ice-cream factory in an industrial area along the Nantes-Saint-Nazaire city bypass, in June 1998, was subject to a major firebreak out. Hot works carried out by some welders working on the highly insulated sandwich panels caused the origin of the fire, i.e. negligence as quoted in the report *"l'origine de l'incendie résulterait d'une imprudence"* (CNPP, 1998). A hot work permit has been issued and the work was nearly completed without any incidents. The fire spread very quickly while the construction workers tried to extinguish the fire before raising the alarm (CNPP, 1998). An hour later, 3,000m2 of the factory are completely destroyed. The factory evacuated 250 employees and managed to save all its stock of ice cream through the careful implementation of a Disaster Recovery Plan (CNPP, 1998).

Planned System	Operational and Active Systems	Recovery and Continuity System
Structural failure: sandwich panels. Use of compartmentation to stop spread, by zoning Adequate fire safety measures in place.	Fire origin: welding operations (Negligence) Rapid spread of fire Employees and public at risk Use of compartmentation to stop spread, by zoning	Fire Emergency plan operational and successful Business interrupted + 100 employees off work. 500m security perimeter to protect public Complete evacuation of factory plus another neighbouring building. One hospital at risk (smoke and fumes pollution) Evidence of a Recovery Plan.

Table 7.7: FR Frigécrème (1998)

Unfortunately, this type of contingency actions was not always possible and loosing a stock and archives could have a devastating impact in a business. The major fire outbreak in a French **Processing Factory (1996)** was a typical example of the benefits a Contingency Plan could have on the day of a disaster. Hot works above a storage room caused a major fire

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increase or lessen the extent of the loss, but excluding such coincidences and catastrophes which may be possible but remain unlikely."

outbreak and destroyed 15 years of archives of a fabric and textile factory[37]. Fortunately, the fire didn't have the chance to spread beyond the boundaries of the storage room thanks to the use of a large number of extinguishers by the employees. The loss adjuster estimated that the direct damages (repair of the building) to be of £5,000 and indirect damages to replace the value of the archives and historical value around £750,000 (settled at £435,000)[38].

Circumstances leading to the fire could have increased the damaging effect of the incident. A hot work permit was issued[39] and the workforce was working close to two fire extinguishers[40]. It is also suggested that the chain of events leading to the fire could have increase the damaging effects of the fire, especially due to the difficult access to the fire zone, and later in the investigations, of the unknown value of the stock in the storage area. The investigators discussed the interest to replace to the total lost stock as the use of the archives was interrupted from 1972. The high value of the destroyed stock did not justify the lack of precautions in the storage room. The Factory argued the "active live and precious value of the stock. And that the use of the stock was the memory of the Factory and the content of the stock contributed to the manufacturing of fabrics for the last 30 years[41]."

Planned System	Operational and Active Systems	Recovery and Continuity System
Hot work permit No FSP or fire prevention measures No automatic detection and suppression system Inadequate FSM approach in the factory No pressure from insurer to promote a better FSM approach Difficult access to the fire zone	Fire origin: hot work and falling burning material in storage room below the area of work. Fire contained in storage room. Manual fire fighting using a large number of fire extinguishers No automatic detection and suppression system	Inadequate FSM approach in the factory Loss of valuable archives used to sustain business activity (1972-2000) No evidence of a BCP No evidence of safe storage of copies of the destroyed document (back-up / hot site) Unique site of the factory

Table 7.8: FR Factory (1994)

[37] Tribunal de Commerce (1994) Audience de Référés: Conlusions, FR Factory 1994.
[38] Expert (1995) Troisieme Rapport d'Expertise, FR Factory 1994.
[39] Expert prés des Sociétés d'Assurance (1994) Rapport n. 1: rapport de reconnaissance, FR Factory 1994.
[40] Avocat à la Cour (1994) Audience de Référés: Conclusions, FR Factory 1994.
[41] Tribunal de Commerce (1994) Audience de Référés: Conlusions, FR Factory 1994.

Hot work was the source of many fires on construction sites. The use and issue of a hot work permit was not the single and only protection against fire of this nature. There was a natural belief that because a hot work permit is issued then the contractor was protected. The author already argued **the need to implement a fire safety strategy** to prevent fires during construction operations. **This implementation required a change of culture within the organisation and the support of the management to implement and sustain the strategy** (training, policy writing, control and monitoring, incentives, rewards and penalties…). In the **FR Factory Fire (1994),** the classical scenario was often repeated and often in the same organisation. A waterproofing contractor was engaged on the construction of the extension of pharmaceutical factory. The construction works comprised different activities presenting different risks. However, the hot work activities on a flat roof were at high risk and required the implementation of a strict procedure to prevent fire. The use of ignition sources, combined with flammable substances (gas/LPG) was the perfect mixture for disasters. The site was nearly complete at the time of the fire[42]: Substructure/Superstructure (100%), Partitioning and Insulation (80%), Electricity and cabling (80%), Waterproofing (80%). The Expert Report suggested that a blowtorch was left unattended on the flat roof and a leak of the gas cylinders provoked an explosion. The fire destroyed[43] 300m2 of the flat roof and the five consecutive explosions damaged the building under construction and projected the LPG cylinders up to 500m away from the site. The structural Expert[44] estimated the extend of the damages and suggested remedial works on the structure: partial destruction of the floor, distortion of the steel frame structure, damages to the façade and internal damages to the partitions due to the explosion. The impact of the explosion on existing building was minimised but disruption to the business activities was assessed. The pharmaceutical factory manufacturing high tech equipment comprised special room to under dust and moisture control. The explosion

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[42] Experts Construction (1996) Rapport d'Expertsie n. 1, FR Factory 1996
[43] Experts Construction (1996) Rapport d'Expertsie n. 1, FR Factory 1996
[44] Bureau de Controle (1996) Avis Technique, FR Factory 1996

damaged the existing equipment and services. Total damages for this facility were estimated at £65,000[45].

Planned System	Operational and Active Systems	Recovery and Continuity System
Inadequate Design and choice of materials.	Fire origin: hot work on flat roof Fire ignition and smoke release followed by an explosion of gas cylinders	Major structural damages to the building and adjoining facilities (500m away)
Inadequate access to roof area: no permanent ladder	Fire spread to the entire roof area: insulation material combustible. Fire damages restricted to the flat roof	No salvage plan No back up and copies of archives.
No evidence of proper HSP or FSP or hot work permit	Inadequate precautions to stock gas cylinder Negligence from the SC: security measures to ensure safety of the work after completion	No evidence of Recovery and continuity planning.
No evidence of proper risk assessment	Inadequate supervision of the works Inadequate project management	Delay to completion: 3.5 months

Table 7.9: FR Processing factory (1996)

Design and Engineering:

A fire safety engineering method is possible to anticipate the worse case scenario and assess the damaging effect of a fire. However an uncompleted building presents a lower fire load density and on the other hand could the unfinished characteristics of the structure could also contribute to the growth of the fire on site (reservations, unfinished partitions and walls...). Across the four case studies discussed above, once again the design of the facilities played a major role into the development of the fire. The rapid spread of fire seemed to be common feature. Also the lack of active protection measures delayed the discovery of the fire. The author already discussed the characteristics of the materials used in the construction of factories and manufacturing units. The combination of a large number of combustible materials (sandwich panels, insulation materials, flammable material like LPG, storage areas) with ignition sources in confined areas (roof spaces, storage room) or large open spaces (flat roof) contributed to the damages of the fire. Lack of compartmentation in the facility, especially in the case of the UK Processing factory (1998) was a key issue in this type of facility.

[45] Experts Construction (1996) Rapport d'Expertise Definitif, FR Factory 1996

Managerial strategy:

Moving away from an engineering approach which required expert knowledge, an initial Property Survey Reports usually conducted by the Insurers focuses on highlighting the risk in the premises, the fire protection measures in place, the occupation, housekeeping and waste management policy. Aspects of arson and security in the case of factories were a major concern. Commercial threats and attacks were often the cause of malicious fires. The issue of business continuity was also highlighted and a calculation of the Estimated Maximum Loss carried out in anticipation of any losses.

Failure to administrate the contract properly tended to be a common practice on short and easy project, ignoring the vulnerability of the facility and relying of the easy task to complete the job without any problem. This lack of awareness and inadequate project management was the source of problem in case of emergency. The analysis of claim files revealed the deep extends of the problem and underlying administrative problems. This endemic problem went on over the fire investigations by sometimes hiding information and not collaborating with the experts.

Construction activities required the supervision of the work operation by a competent professional: architect, planning supervisor, project manager, facilities manager for examples. Across the four case studies of factory's fires analysed in this chapter common managerial mistakes were highlighted. The lack of supervision and awareness of the risk of fire, inadequate fire safety strategy, inadequate risk management, poor managerial control of the construction activities contributed to the chain effect.

Contingency process:

The success of the salvage plan of the FR Frigecreme (1996) factory demonstrated the **effectiveness of a contingency strategy**. Not only the stock was saved, but a transfer of the activities to another facility could be envisaged at a later stage. It was common to seek help of competition or other factories to face an emergency situation. Thoughts into emergency actions and business continuity were less rare in the 21st century, but there were still organisations betting on luck to sustain their business activities. The case of the fire in the fabric factory (FR Factory, 1994) was a typical example of the lack of concern from the management for the valuable historical archives of their organisation. No preventative action were taken to anticipate the disaster and no fire precautions measures were installed in the storage room to accelerate the control of the fire (smoke detectors, sprinklers system or gaseous system, CCTV...).

However, sometimes the size of the disaster was not comparable to the extend of the losses. In the FR Factory 1994, the fire was contained in the storage room (5mx5mx3.5m = 87.5m3) and losses estimated at £450,000. The average losses per m3 are rounded at £5,143. Compared to the UK Processing Factory (1998), the total loss of the facilities (120mx80mx5m = 48,000m3) and losses estimated at £42m. The average per m3 is £875.

When business activities depended on the survival of the facilities, like in manufacturing premises, more concern should be put on a proper risk assessment and the implementation of a fire safety strategy to safeguard the occupants, the property and the business activity. The hard lessons learnt from disasters should encourage organisation involved with high risk activities like hot work, electrical operations, welding activities, use and storage of flammable material etc., **to consider the impact of these activities on the normal running of the premises and business, and the after disaster impact** (business recovery).

7.2.2.1.3 Offices / Workplace

- UK Broadgate (1990), UK Minster Court (1991), UK Bank (1999), FR Offices/Residential Facilities (1992), FR Bank (2000), US Harrisson Building (1985).

The two major construction site fires in the UK (**Broadgate UK**, 1990 and **Minster Court UK**, 1991) have already been widely discussed in early chapters. The impact of these fires on the construction industry was important and gave rise to several research and investigations in the problem of fires on construction sites as discussed in chapter 3.

In the **UK Broadgate (1990)** the Steel Construction Institute (1991) argued the fire began in a large contractor's hut on the first floor and smoke spread unchecked throughout the building. The fire lasted for 4 ½ hours with excess temperature of 1000 degree Celsius for 2 hours. The chain of events leading to the fire demonstrates many managerial failures which contributed to the development, growth and spread of fire in the facility. More information on the review and analysis of this fire is presented in chapter 2, section 2.2.2.

Planned System	Operational and Active Systems	Recovery and Continuity System
Improper design approach Structural Failure: sandwich panel / lightweight panel, deformation of the structure Temporary site accommodation prevented effective fire fighting Inadequate fire precautions measures	Fire origin: discarded material / Unknown / Site Hut Inadequate Fire Plan and Fire Fighting Equipment Rapid Fire spread Explosions Failure of fire-fighting activities Significant smoke damages throughout the entire building Lack of fire precautions No automatic fire detection and fire alarm / not installed Sprinklers not installed at the time of the fire Improper design approach Lack of compartmentation No proper fire escape routes	Significant risk to loss of life and financial loss. No evidence of Recovery and continuity planning. Further to this fire, Bovis developed a R&D programme to improve the level of safety on all their sites.

Table 7.10: UK Broadgate (1990)

In the **UK Minster Court (1991)** the total losses for this fire were reported by the FPA (1996) to be £105million. The source of ignition has not been clear identified by the Fire Brigade (North Area Fire Brigade, 1991), but from the available evidence it is likely that an introduced ignition source in the form of a naked flame was the most likely source. The full review and analysis of this fire is presented in chapter 3, section 3.2.3. The summary of the fire safety failure was presented below.

Planned System	Operational and Active Systems	Recovery and Continuity System
Inadequate Design Inadequate Fire Safety Emergency procedures No waste management	Fire origin: Naked Flame / Rubbish wastes Fire development: Sterling board and timber scaffold planks Fire detection and alarm operative Attempt fire fighting by workforce Rapid fire spread Improper fire escape routes High amount of dried rubbish Lack of compartmentation.	No evidence of Recovery and continuity planning. Second fire on site a month later!! Bovis was the main contractor on site. R&D initiative under development and progress.

Table 7.11: UK Minster Court (1991)

The management of buildings in the event of fire may be critical to survival of users and structures. Prevention was key. Understanding of the behaviour has developed greatly over recent years and technology moves on apace. The purpose of the building determined the type of occupancy. In a situation of fire, people will behave differently, depending on a large range of factors: their *physical conditions* (visual disability, patient in a hospital, old people, a kid...), there *awareness/non-awareness* to the problem of fire (training, knowledge, experience...), the *environment* they are in (a known/unknown facility), the *system in place* to support their action (warning system, protection system, the management of the situation of crisis, action from external services such as the fire brigade...), the *dependency* of the individual (wheelchair user, blind/deaf person, prisoner in a cell...) and many other factors. Fire safety in the workplace was under the responsibility of the building owner or occupier, i.e. the employer.

The Health and Safety at Work etc. Act 1974 set out the general duties which employers have towards their employees and members of the public. Employers have to ensure, so far as is reasonably practicable, the health, safety and welfare both of their employees and of any other people who may use, or have access to the workplace.

Compliance under the following regulations was required by the employer:

- The Management of Health and Safety at Work Regulations 1999 (HSWA): employers requirement to manage health and safety.
- The Workplace (Health, safety and Welfare) Regulations 1992: made under the HSWA and regulate basic workplace health, safety and welfare.
- The Fire Precautions (Workplace) Regulation 1997, with 1999 Amendment: the provisions relate to fire precautions in the workplace. It covers aspects of fire fighting and fire detection, emergency routes and exits and maintenance.

Recently, fire safety regulation was reinforced by the publication of the Fire Precautions (Workplace) Regulation 1997, amended in 1999, The draft BSI (1997) Fire Safety Engineering in Buildings: Part1. Guide to the application of fire safety engineering principles, the Loss Prevention Council Code of Practices which may be applicable to satisfy higher and different/additional standard of construction. The Fire Precautions (Workplace) (Amendment) Regulations came into force in December 1999 - the main effect being to impose substantive requirements directly on those employers who have control of workplaces[46] previously exempted.

The main trends of the UK new fire safety approach was to give more power at a local level, i.e. to decentralised the control of fire safety in buildings through the increasing involvement of Fire Authorities to ensure satisfactory arrangements for inspections. This new regime enforced the duty of Fire Authorities at a local level and community level. Another important **feature of the new regulations was that they were goal-based rather than prescriptive.** This fire safety engineering oriented approach was clearly considered under §15 "...if employers wish to achieve compliance by other means, it is open to them to do so". Four main streams have been identified throughout the new proposal:

- Duties on the "responsible person", i.e. owner or occupier.
- Obligation to attend Fire Precautions.
- Requirement to maintain adequate Fire Precautions, i.e. to review and to maintain in satisfactory order.
- Freedom to chose the adequate fire safety solutions.

All categories of premises would be covered unless exempted, i.e. single dwellings.

The Management of Health and Safety at Work Regulations 1999 (MHSWR) generally makes more explicit what employers were required to do to manage health and safety under HSWA. These Regulations, as amended by the Fire Precautions (Workplaces) Regulations

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[46] **"workplace"** means any premises or part of premises, not being domestic premises, used for the purposes of an employer's undertaking and which are made available to an employee of the employer as a place of work and includes:
(a) any place within the premises to which such employee has access while at work; and
(b) any room, lobby, corridor, staircase, road or other place -
(i) used as a means of access to or egress from that place of work; or
(ii) where facilities are provided for use in connection with that place of work, other than a public road;

1997 , FP (W)R, required employers to formally assess the risk of fire to their employees at work and in their premises[47] as part of the general risk assessment required by the Regulations. However, responsibility for enforcing these MHSWR requirements lied with fire authorities and not HSE.

Employers have ultimate responsibility for the safety of their employees in the case of fire, even where others have obligations to ensure that the requirements of the Regulations are complied with. Construction site fires in office type of building occurred at different stages of the life of the facility:

- Under construction:
- During maintenance operations, and
- During refurbishment works, where one part of the facility might be occupied.

The first type of fire scenario encountered in the construction of offices, was a site in the busy Canary Wharf in London. **The UK Bank (1999)** fire involved some hot work on one of the tower cranes. The method statement for this site specifies that the operation would take approximately two full night shifts, possibly running into a third night. The circumstances leading to the fire showed the lack of care and negligence from the subcontractors in carrying out some dangerous work on site. The stringent location of the site and the possible devastating impact of a fire in this area of the town has been once again carelessly ignored even if the Broadgate and Minster Court fires showed the seriousness of construction site fires in city centres and enclosed sites.

The work was duly scheduled to be carried out on Tuesday and Wednesday. The permit of access for the second night's work was issued prior to the work by the site owner and a hot work permit was also issued for the period of the work and the day. The standard precaution prescribed in the Hot Work Permit included that "when working… on staging… openings to

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[47] "**premises**" includes any place and, in particular, includes -
(a) any vehicle, vessel, aircraft or hovercraft;
(b) any installation on land (including the foreshore and other land intermittently covered by water), any offshore installation, and any other installation (whether floating, or resting on the seabed or the

other levels covered with a blanket or other non-combustible materials.[48]" The Construction Manager signed the permit, confirming as the construction supervisor, that the specified precautions would be complied with and that the persons carrying out the work would be fully briefed on the safe method of work.

The welding operatives fixing lugs on mast of the tower crane started their work around 22.00 and by 02.00 the CCTV of an adjacent building (no tight security measures on site) recorded unequivocal evidence of molten globules of metal falling from the work platform (work areas was not kept tidy and free from combustible materials as required under the Hot Work Permit precautions to be taken). The globules of metal ignited acoustic foam insulation of the diesel generator set which was gutted by fire[49]. Within 5 to 10 minutes, the fire developed and appearance of flames were detected by the CCTV at 02.15. A fire patrol was in charge of the control on site and an incident occurring at 22.00 should have raised his awareness on the high risk of fire in the area of work. The individual fire patrol observed "that a small quantity of waste that was present at the base of the crane had become ignited. He descended one level and found two powder extinguishers which he operated to extinguish the fire. He explained that a second outbreak of fire occurred at around midnight." No preventative actions were taken by the fire patrol to raise awareness of the high number of fire outbreaks to the welders and no further intensive fire watch was put in place to detect future possible fires later in the night. This poor site management from the fire patrol could be due to a lack of awareness of the evident possible dangers and/or negligence from his part. By 02.00 a third fire broke out and this time the fire patrol was unable to control it.

Managerial failures could be observed from both the site owner and the subcontractors. The investigations by the Consulting Scientists and Engineers (1999) confirmed that "the cause of

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subsoil thereof, or resting on other land covered with water or the subsoil thereof), and (c) any tent or movable structure;

[48] Contractor (1999) Bank Project: Hot Work Permit, UK Bank 1999.

[49] Consulting scientists and engineers (1999) Report concerning the fire that occurred at the Bank Construction, UK Bank 1999.

the fire can be attributed to deficiencies in the method of working adopted by the staff of the welder contractor:

- "inadequate precautions had been taken in the immediate vicinity of the working area." The Method Statement[50] clearly indicates under the risk assessment section: "high risk of fire when welding or burning. Action: use of blankets inside the work platform to prevent the majority of sparks from falling from the work place. Provide a Marshall to patrol the area below the ground. Provide 2 no, fire extinguishers – one for the welder, one for the ground Marshall."
- "it is self evident that no attempt was made to remove loose waste material from the base of the crane and/or to protect exposed combustible material from ignition of falling molten globules."
- failure to adhered to "precautionary measure of ensuring suitable fire extinguishers were to hand during the carrying out of hot work."
- The fire patrol was "sufficiently diligent in his role to identify and respond promptly to any ignition.

Planned System	Operational and Active Systems	Recovery and Continuity System
Inadequate fire safety measures Hot work permit No waste disposal and management Failed to implement proper fire safety management strategy	Fire origin: Ignited acoustic foam insulation Fire spread rapidly No detection and warning system No fire extinguishers close to hand for first aid fire fighting Late warning by Security Guard CTTV system in operation on nearly building but not on site Failed to implement proper fire safety management strategy	No evidence of Recovery and continuity planning.

Table 7.12: UK Bank (1999)

Managerial control and preventative measures on site were central to the prevention of fires on construction sites. The author already observed that the role design and engineering was playing in the development of a fire is major. The next fire scenarios analysed for this research look also at the bank facility, however this time under refurbishment. **The FR Bank (1997)** fire had a major impact on the business activity of a bank and a toy store in the vicinity of the working area and site. The refurbishment works concerned the renovation of a flat roof above a toy store. The source of ignition was once again linked to the use of a blow torch for the bitumen waterproofing of the flat roof[51]. As highlighted below a large number of failures were observed. Circumstances leading to the fire and the non-compliance of the facility with design requirement under the French law proved to be a major factor in the development and spread of the fire. The lack of compartmentation between the bank and toy store and the absence of fire wall in the suspending ceiling left the fire free to develop in the open and confined space[52]. A spark ignited some combustible materials stored in the toy shop was at the origin of the fire. An attempt to fight the fire with a fire extinguisher from above and through the gutter was unsuccessful and forced the workforce to leave the fire scene and contact the fire brigade. It seems that the delay to detect the fire could have been avoided by the improvement of fire precautionary measures during the construction activities. The appointment of a fire watch below the working area was a common practice.

The facilities were completely destroyed by the fire and large damages to the structure and its integrity required the partial demolition of the building and complete refurbishment of the bank. The stock stored in the toy shop was destroyed and had to be replaced. Loss of income from the business was also assessed for at least one year.

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[50] Welding Subcontractor (1999) Tower Crane Build Operations Method Statement, UK Bank 1999.
[51] Experts Prés la Cour d'Appel (1997) Rapport d'expertise, FR Bank 1997.
[52] Société d'Avocats (2000) Conclusions récapitulatives, Audience Mars 2000, FR Bank 1997.

Planned System	Operational and Active Systems	Recovery and Continuity System
Hot work equipment not tested and checked before the works No waste disposal of removed insulation material Storage area not protected on site Void / openings between main roof cladding and roof structure. Void / Opening between adjoining buildings Work SC to another SC unknown to the MC Inadequate method statement and program of works Lack of experience and qualifications of second sub-SC. Inadequate fire precautions measures Sub-SC did not have a contract with SC Inadequate knowledge of regulation Inadequate design of the facilities at the conception phase Unclarity of the contractual documents of SC Lack of training for fire safety on site Non respect of the contractual agreement and terms	Fire origin: Hot work in roof structure. Ignition of insulation material in suspended ceiling below work area by a spark or naked flame Rapid fire development and spread to entire roof structure and adjoining facilities No compartmentation and fire stopping in suspended ceiling Void / openings Inadequate fire precautions measures on site Attempt to fight fire before raising the alarm at the earliest stage Late fire detection and warning Failure to supervise and manage the SC works by architect No evidence of adequate fire safety plan and emergency procedure	No evidence of adequate fire safety plan and emergency procedure No evidence of Recovery and continuity planning.

Table 7.13: FR Bank (2000)

Amazingly, the design failure which aggravated the fire and managerial failures were not the only failures on this site. The sub-contractor declared that they were not aware of the existence of a regulation regarding building and technology (DTU[53] 43.3). The examination of the contractual documents also revealed the unclarity of the terms and wording and suspicious form[54]. Failure to comply with the regulation was clearly stipulated in the evidence submitted by the expert. The responsibility of the architect, as a work supervisor, has been rejected as his contract stipulated the subcontractor was under the obligation to ensure respect with the law and regulation[55].

[53] DTU: Document Technique Unifié equivalent to the British Standard.

[54] Experts Prés la Cour d'Appel (1997) Rapport d'expertise, FR Bank 1997: "l'examen de ce contrat de sous-traitance, tant dans sa forme que dans son fond, suscite un sentiment de malaise. L'Expert n'a jamais vu au cours de sa vie professionnelle de contrats de sous-traitance qui soient à la fois aussi bien faits et aussi mal faits, aussi précis sur sertains points et flous sur d'autres."

[55] Société d'Avocats (1999) Conclusions devant le tribunal de grande instance, FR Bank 1997: "Ledit contrat précisait: 'il est expressément convenu que, compte tenu de la mission partielle de l'architecte, l'entreprise soumissionnaire assurera, sous sa propre responsabilité, le respect des règlements loi décret, règlement de police, etc… en vigueur à la date de réalisation de ces ouvarges."

The impact of the fire for the toy store and the bank were very high as the activities of the businesses was greatly affected. The total evaluation of losses according to the experts were superior to £600,000 for the demolition works (£163,000), rent for shop and bank (£23,000), refurbishment and recovery of the bank facilities (internal equipment and consumables: £23,000; internal layout and decoration: £147,000; IT equipment: £52,000; financial losses: £50,000; business continuity losses: £60,000), for the shop (stock: £50,000; business continuity losses: £35,000). The total losses were later revised and agreed at £476,000.

The bank also had to cope with the loss of part of their archives. Even if the impact of this fire and the loss of archives are not as damaging as in the case of the fire in the FR Factory (1994), the manufacturer of fabric, it is still a major prejudice for an organisation.

Like in the FR Factory (1996) fire involving the explosion of gas cylinders, **the FR Office/Residential (1992)** fire involved an explosion. The unsafe use and storage of flammable material like gas cylinders has been a major worry in health and safety on site. In the UK, under the Health and safety at Work Act 1974, the storage and use of flammable material is a real matter of concern. Regulations on the storage of equipment and safe use of gas have been developed and are nowadays widely comply with. Effort to control the application of the law by the HSE and HSC improved safety on site. Earlier in this research, the author identified that certain industries, such as the off shore and chemical industry, has very strict rules on the use of flammable material, their storage and safe handling. A managerial approach of zero accident was always developing as a single mistake or misuse of this equipment could lead to a major disaster.

The origin of the FR Office/Residential (1992) fire concerned some cutting work on a flat roof. The planning permission specifies[56] the construction of a multi-storey facility comprising a series of flats at the upper floors, and shops and offices at the ground floor. A subcontractor was engaged by the client to carry out the waterproofing of two flat roofs and 15 days prior to the fire, the workforce left behind on the flat roof, their melting pot and 6 gas

[56] Expertises (1992) Rapport d'informations sur sinistres, FR Office/Residential 1992.

cylinders with 2 fire extinguishers. The equipment was left unprotected for 15 days until the day of the fire where another subcontractor sent one of his men on the flat roof to cut some the HVAC pipes. The worker saw some flames close surrounding the gas cylinder and immediately left the flat roof to raise the alarm to the site manager. By the time they came back to the flat roof, they heard two consecutive explosions. The cylinders were projected 100m away from the site and 200m2 of the flat roof were completely destroyed.

Many managerial mistakes were observed in these incidents as highlighted in the table below. First poor management and control seems to be at the origin of the incident. The solicitor[57] concludes that the worker involved in cutting the HVAC pipes must have manipulated the gas cylinders to carry out his work.

Planned System	Operational and Active Systems	Recovery and Continuity System
Inadequate method statement No evidence of proper risk assessment Failure to organise a proper health and safety management and Coordination on site Improper waste management / Tidiness of the site Lack of awareness of the scope of the contract	Fire origin: cutting work on a flat roof Explosions (2) of gas cylinders Inadequate storage facilities (for 15 days!) Failure to stock the gas cylinders vertically Negligence into the storage of gas cylinders Evidence of fire extinguishers Inadequate project management Non respect of the FSP Damages to adjoining facilities by explosion Failure to comply with the obligations by H&S Coordinator under the terms of his contract	No evidence of Recovery and continuity planning.

Table 7.14: FR Office/Residential (1992)

The report continued to highlight mismanagement: untidiness of site, the inadequate supervision of the work by the planning supervisor, lack of risk assessment and management, poor project management, etc. The expertise[58] highlights the incompetence of the planning supervisor in assessing the major risks of fire and explosion on the flat roof and the improper storage of flammable material on site.

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[57] Avocats Associés (1992) Conclusions aux fins de Rétablissement, FR Office/Residential 1992: "une manipulation injustifiée et malencontreuse d'une bouteille de gaz, par l'ouvrier de la société de ventilation."

The conclusion of the expertise was significant in assessing the extend of the problem of project management. Responsibilities for the fire were shared amongst several parties: the client, the contractors (HVAC and waterproofs), the planning supervisor, the technical control bureau and the project manager.

The century year old six storey **Harrisson Building (1984)** in the US was undergoing extensive renovation to provide an estimated 240,000 sq. ft. of office space and shops. The investigation report (Rule, 1985) analysed the fire development and spread in the facility and comments: "the building was approaching full fire involvement within ten minutes after fire department notification and was severely exposing numerous other structures on all sides, including an occupied shopping mall across the street that contained an estimated 25,000 people." The following failures were extracted from the analysis of the evidence submitted in the fire investigation report:

Planned System	Operational and Active Systems	Recovery and Continuity System
Fire protection system removed during renovation operations Active and passive fire protection measures removed (firewalls, elevators, sprinkler and standpipe systems, stairways) Large open spaces of 40,000 sq. ft of undivided floor area.	Fire origin: sparks from cutting operations ignited combustible debris. Rapid fire spread: building was approaching full fire involvement within ten minutes after incident notification. Portion of the building started to collapse after 20 minutes of the arrival of FB.	An estimated 25,000 people at risk. Effective management of the fire by the FB. Abundant water supply in the area to enhance fire-fighting operations Use of fixed fire suppression systems in adjacent buildings exposed to fire Cooperation between fire, police and private securities forces in evacuating a large number of civilians exposed to fire propagation. No Salvage Plan No evidence of Recovery and Continuity planning.

Table 7.15: US Harrisson Building (1985)

The renovation works affected the integrity and fire resistance of the facility, as some partitions old pipes and wiring had to be removed from the site. The Fire Department determined that sparks caused the fire from cutting operations which ignited combustible debris. Demolition and renovation works could bring new dangers on a construction site.

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[58] Cour d'Appel (1992) Rapport d'Expertise, FR Office/Residential 1992.

Design and Engineering:

A **rapid spread of the fire combined with inadequate design of the facilities** was a common combination in construction site fires. The fire scenarios the author analysed in this section on offices and places of work, demonstrated the importance of the implementation of a fire safety strategy to prevent construction site fires.

The spread of fires through opening, holes, reservations was observed in the fire scenarios just analysed in this section. The **lack of control measures** to support a free fire environment needs to be developed and adapted to the site environment. In the case of the FR Bank/Shop fire, the uncontrolled spread of the fire from a storage area below the working area to the bank facility could have been avoided. First through an early detection of the fire and a better design and compartmentation of the facilities. Containment was not possible and the devastating effect of the fire was a matter of concern.

In explosions, the integrity of the facility and its structural stability could be affected and major repair and recovery works have to be done to restore the facility. The threat of an explosion in a facility was a major concern but it doesn't seem that it was in the scenarios the author analysed. It seems that the "site" situation lesser the perception of explosion as a major concern and risk.

Managerial Process:

Across the fire scenarios analysed in this section, the author could observe a large number of managerial failures. From a **failure to comply with fire safety requirements to poor management and control**, all contributed to the fire occurrence and its spread. The case of the UK Bank fire in 1999, demonstrates the **lack of awareness** of the danger of welding work on site. Most surprisingly, the earlier breakout of fires on site in the 4 hours prior to the major incident did not serve as a lesson for the fire patrol. No recording, any action was taken to prevent further outbreaks. This was an inexcusable attitude from the fire patrol. The combination of the action of several parties is clearly demonstrated in the FR

Office/Residential fire, where **the chain of effects** which could be observed at least over 15 days is unbelievable. Lack of care, failure to comply with the terms of the contract, failure to take appropriate actions, non compliance with the regulation, negligence, communication failure on site... are an unequivocal proof of the depth of the problem.

Contingency Process:

Many events could affect your business, the core business of your company as well as the supply chain. Recent articles demonstrated that Outsourcing activities was one solution adopted by businesses to transfer risk to another entity. Pilkington glass maker recently decided to outsource its store management in order to add value and they concluded that "running and managing stores is not of [their] core business." Such a strategic decision was not unique nowadays. Companies were getting more and more conscious of **the importance of their core business** and are willing to protect it in the best way they can. However not all businesses can outsource and transfer risk.

In the workplace, Employers should be concerned with several issues that would affect the safety, health and welfare of their employees:

- Building fabric and Fire Engineering aspects: Fire Protection and Design against Fire, Passive Fire Protection
- Means of escape and emergency procedure
- Active systems and equipment
- Special hazards: flammable substances...
- Construction and Maintenance of the facility
- Coping with Arson, Terrorist Attack and Threats
- Other general fire precautions.

The promiscuity of facilities and working areas or sites could drag on business losses. In the case of the FR Bank/Shop scenario, the impact of the fire on the continuity of the business activities was very important (one year). The author also observed the lack of precautions in the bank facility and their protection of archives. Modern technology now improves the storage of data and information. The computerisation of data management and the use of back up process are common practice.

7.2.2.1.4 Public Facilities and Assembly:

- UK Hospital (2000), US Sight & Sound Theatre (1997), D Dusseldorf Airport (1996)

Large death tolls were often encountered in fire involving facilities occupied by the general public. The often unknown environment, in which the occupants were moving, did not facilitate the evacuation process. 'Public' facilities were here defined as any assemblies[59], and facilities of mercantile occupancies[60] like shopping mall, and shops, and any facility receiving members of the public. In France, special regulations exist for every facility receiving members of the public, and including as such hospital, high rise construction open to the public use, schools, libraries, airports... For the purpose of this research, this chapter will look at the analysis of several fires in public facilities and try to establish relationship between these incidents.

In the UK one fire disaster involving the public was a major concern for the safety of people. The King Cross fire in 1987 was a rare fire of major proportion within an underground station. Thirty members of the public and one fireman were killed in this fire. Engleman (1997) commented on the station fire hazards including poor housekeeping and the ignition of an electrical fire in the escalator machine room and in the vicinity of a confined space where paint products and other materials were temporary stored. Following the fire and the investigations into the cause and development of the fire in the station, major recommendations (164) were formulated to improve the safety of the passengers in underground stations. All the recommendations are now applied.

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[59] Sharry, J. (1997) Assembly occupancies, Section 9/Chapter 3, SFHE Fire Protection Handbook, Published by the NFPA: 2Assemblies occupancies can be defined as structures in which groups of people gather for purposes such as deliberation, worship or entertainment."

[60] Schultz, Ed. (1997) Mercantile occupancies, Section 9/Chapter 4, SFHE Fire Protection Handbook, Published by the NFPA: "Mercantile occupancies are facilities in which a wide variety of goods and services are displayed and sold."

However the King Cross fire was not construction related even if at the time of the fire, refurbishment works were taking place in the underground station and some of the construction materials were stored under the escalator (origin of the fire). Recently, a fire which had a major impact on the way our industry look at the fire safety in places receiving members of the public, is **the Dusseldorf airport fire in 1996** in Germany. This disaster which cost the lives of 16 persons, has already been discussed in earlier chapter and recommendations addressed in the discussion (Section 5.2.2) and summarised below.

Planned System	Operational and Active Systems	Recovery and Continuity System
Inadequate fire safety measures. Lack of awareness of employees	Fire origin: welding operation (Negligence) Slow fire growth: delayed discovery of fire Lack of awareness of building layout No detection system Rapid spread of fire in airport premises No compartmentation Lack of awareness of employees	No Fire Action Plan Slow fire growth: delayed discovery of fire Transmission of erroneous information Inadequate emergency procedures Lack of awareness of building layout Lack of adequate communications capabilities Lack of awareness of employees

Table 7.16: D Dusseldorf Airport (1996)

When construction work take place in an existing facility open to the public, special precautions should be taken to ensure the safety of the users if a fire was to break out within the site boundaries. Construction sites could also affect members of the public in adjacent buildings and neighbouring facilities. But major concerns were raised when common work operations take place in the occupied facility for maintenance purpose. Often, the public building would not be close for the time of the work (like in Dusseldorf) and the movement of the public within the facility would not be restricted. **The interface between the normal activity of the public, the employees and the construction activities** was often not managed adequately and gives rise to multiple problems which could lead to a fire outbreak.

The fire scenarios observed and analysed in this section took place in facilities open to the public or within a public environment. In the **UK Hospital (2000)** fire, we were dealing with a very specific environment. In the UK the NHS has a very strict regulation for fire safety in its facilities and also a strict code of practice for maintenance or refurbishment works. The UK Hospital was founded in 1921 as a nursing home that provided care to the local community. Following a major expansion it was designated as an 'acute' hospital in 1983 and at the time of the fire was a 66-bed private hospital that treated more than 5,000 patients per year. The wing where the fire took place was designed in 1982 and the building's design and construction should have been guided by the 1976 Building Regulations and any applicable amendments[61]. The refurbishment and conversion work were isolated from the rest of the facility and not occupied by the employees at the time of the fire. The work comprised the complete refurbishment of the wing into an HDU and the incorporation of some fire stopping into building's design. The fire occurred whilst contractors were joining together sections of medical gas copper pipe in the roof void with an oxy-acetylene torch. The contractor inadvertently set fire to combustible components of roof. The fire rapidly spread throughout the wing at rafter level before it could be detected by smoke detectors in the roof void. The intense fire allowed the fire to break through the slate covering and vent to atmosphere. Seconds after the spread in a south direction, the fire spread north above two other rooms[62]. The roof void partially compartmentalised and the presence of openings in the walls contributed to allow the fire to spread throughout the wing. The table below summarises the site safety failures.

Planned System	Operational and Active Systems	Recovery and Continuity System
Defective design and no attempt to remedy it. Provisions for fire protection systems. Hot work permit delivered.	Fire origin: welding works in roof void Rapid fire spread throughout the roof wing Inadequate fire compartmentation and fire doors in roof void Operational fire detection and warning system in roof void No sprinkler system Attempt manual fire fighting with Hospital equipment Poor fire precautions Lack of care by main contractor Hot work permit provided Maintenance technician failed to supervise the work adequately	No evidence of Recovery and continuity planning.

Table 7.17: UK Hospital (2000)

[61] Expert Scientist and Engineer (2000) Fire Report, UK Hospital 2000.
[62] Insurance (2000) Preliminary Report on fire claims, UK Hospital 2000.

It was understood that many mistakes occurred. The circumstances leading to the fire put in evidence the failure of the management, human error and negligence from the contractor. The initial breach of the building regulations by the designers (acting on behalf of the owner) has been confirmed through the fire investigations[63]. Adequate fire check door "should have prevented the passage of fire for a minimum of 30 minutes and it should have also been fitted with a self-closing device." Unfortunately at the time of the fire "the absence of fire stopping, absence of an intumescent strip along all the closing edges of the door and absence of self closing device means that the relevant Building Regulations were breached."

The circumstances leading to the fire occurred throughout the project life cycle: design phase in 1982 with the non-compliance with the regulations, pre-construction stage when the risk assessment was not conducted and adequate fire safety measures put in place to prevent fires, during the construction phase by adopting improper working methods and note safely ensure the continuity of compartmentation in the roof void. Finally the choice of materials and components combined with poor workmanship lead the contractor to breach some regulations.

The damages were very important considering the size and type of fire. The roof required to be completely replaced (660m2), as well as "the entire timber frame roof, synthetic slate covering and all insulation the entire services contained within, including electrical wiring and plumbing required complete renewal due to the widespread heat damage.[64]" The recovery works might have required the partial replacement of the ceiling. One of the room was completely destroyed and required full replacement, including furniture and equipment. Other rooms will require minor works.

The business interruption for the hospital has been traumatic, first for the patients and the then the staff. The hospital employs 220 staff and the facilities are exclusively utilised by self-employed consultants (99) and physicians (30). Patients had to be evacuated and relocated in the nearby hospital. 24 beds out of 54 were loss for several months and the business

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[63] Expert Scientist and Engineer (2000) Fire Report, UK Hospital 2000.

interruption could have a major impact on the hospital's business relationship with the consultants. The hospital feared[65] "that the turning away of potential patient bookings due to unavailability of rooms in the short term may lead to Consultants taking their patients to competitor hospitals in the longer term." The possibility of hiring a temporary ward block was discussed with the hospital and the indications are that the acquisition of a 12 bed unit will be economic. Also the temporary conversion of a limited number of consulting rooms into day patient accommodation was considered.

Transfer of the activity or business was not always possible. Special type of building cannot be replaced and the impact of the fire on the business continuity could be disastrous. There are a large variety of buildings receiving members of the public. Assemblies and places of entertainment are one of them. In the **US Sight & Sound Theatre (1997)** fire, the author could again observe many managerial failures summarised in the table below:

Planned System	Operational and Active Systems	Recovery and Continuity System
Inadequate Design	Fire origin: welding operation (Negligence) Rapid spread of fire.	200 Employees at risk at the time of fire Inadequate staff training
Structural failure	Employees delayed report of fire Alarm system failure	No pre fire planning No evidence of Recovery and continuity
Inadequate staff training	Sprinkler system waived No water supply	planning.
No pre fire planning	Lack of compartmentation Lack of exterior fire stream access Failure of fire brigade tactical operations Failure to comply with fire code Inadequate staff training	

Table 7.18: US Sight & Sound Theatre (1997)

The author already discussed the characteristics of this fire and its development (Section 5.2.2): "The storage area was undergoing renovation and the theatre was closed to the public. However 200 construction staff and employees were in the building at the time the fire started. The fire was caused by a construction worker welding steel plates on the stage floor decking directly above the point of origin. During the removal of the floor covering, screw holes were exposed which allowed sparks and/or a molten arc-welding rod to fall onto

[64] Insurance (2000) Preliminary Report on fire claims, UK Hospital 2000.

combustible props stored below. Two theatre employees who went to the storage area for equipment and saw a stored stage prop on fire at three points discovered the fire. At approximately the same time, "the welder smelled smoke but disregarded it, thinking it was the welding and the hot steel burning the soles of his boots" (FEMA, 1997). The fire caused the collapse of the state-of-the-art, seven-year-old theatre and resulted in structural damage to most of the connecting buildings. The total loss was valued at over $15m, and clearly the business continuity issues were immense." Sharry (1997) restated on the risk of fire in theatrical stages and remember the 1903 Iroquois Theatre fire in Chicago. Traditional stages present specific characteristics and the potential of a fire can be great with the combination of fuel from the stage and scenery and the sides of the stage; and potential ignition sources from the electrical equipment and lighting. Following the Iriquois Theatre fire, fire protection measures were required: automatic sprinklers, ventilation over the stage and fire curtains (Sharry, 1997). The lessons of the Sight and Sound fire are not new. Other similar fires in history contributed to assess potential failures in assemblies with a large occupancy: the 1967 Chicago Ill fire in the exhibition hall destroyed the facility. The hall was non-sprinkled and failure of the fire resistive protected steel constructed building contributed to the steel failure and total collapse. The maintenance crews tried unsuccessfully to control the fire and the notification to the fire dispatched was delayed (FEMA, 1997).

The US Sight & Sound Theatre was a fast burning, with a high rate of heat production and caused complete collapse of the building. Structural failure and inadequate compartmentation contributed to the collapse and large damages to the facility. The failure of the alarm system delayed the dispatch of the fire brigade on the scene. The shortage of supply of water restrained the fire brigade action to control the spread of the fire.

Fire protection measures in the facility were inadequate and the owner breached the State regulation which requires public assembly buildings to an automatic sprinkler system with buildings of a capacity greater than 500 people and a storage room of over 100 sq.ft. "The

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[65] Insurance (2000) Preliminary report on business interruption, UK Hospital 2000.

owner requested that the State waive the sprinkler requirement because of the financial hardship caused by providing a water supply for the sprinkler system" (FEMA, 1997). The owner intended to rely on a centrally monitored smoke detection in the stage area, but following a series of false alarm, heat detectors replaced the smoke detectors. "The investigation by the Police revealed that the theatre management routinely shut off the alarm system during stage performances to prevent interference from false alarm. Instead, a fire watch was maintained using trained theatre staff."

The FEMA (1997) technical report highlighted all the failures and extracted lessons learnt and recommendations. Their analysis reveals that "the fire is notable for the breakdown of the systems originally intended to provide basic fire safety in the Theatre." From the concept of the design during renovation of the original stage and auditorium in 1990, through the management of fire safety during the use of the facilities and repeated decisions to turn off the system at certain time, through the major renovation project in 1997 and the mismanagement, lack of awareness, negligence of the owner in appreciating the high risk of fire. 10 major recommendations were issued and addressed the major failure analysed in this fire.

Design and Engineering:

In facilities receiving members of the public, safety was a priority. The life safety concept and strategy to enable a safe evacuation of the occupant in case of emergency was essential. However, in the case of construction site related fires, the safety of the public was of prime importance when construction activities are linked to the mobility of the public. For construction and refurbishment works, the site would be clearly limited and access to the public forbidden or restricted. However, when maintenance operations take place, like in Dusseldorf Airport the public was directly linked to the working area and there were no clear boundaries of the site. The connection between the site of the fire and the public areas was evident. In the Sight & Sound Theatre fire, the building was being used and occupied by 200 staff at the time of the fire and the fire had a major impact on the business continuity of the theatre as it was completely destroyed.

Design and engineering in these situations played a key role in the development of the fire. Refurbishment works often require demolition or change of the internal layout and these modifications would affect the structural fire resistance of the building. Also compartmentation and containment can be temporarily interrupted. Maintaining an integral fire resistance as early as possible is essential to ensure the fire could be contained and controlled within the facility. The high fire load of some facilities combined with an inadequate design contributed to a rapid spread of fire.

Managerial strategy:

Managerial decisions taken prior to the construction works could also have a major impact on fire safety during construction activities. In the cases observed and analysed, decision on design and alterations in prior construction works contributed to increase fire damages: Reducing the level of fire protection in the facility due to economical pressures, non-compliance with the building regulations and fire codes, poor management and control of high fire risk activities during the construction operations, no systematic risk assessment, failure to communicate information between employees and the fire brigade, employees and the workforce, the workforce and the site manager…

Contingency process:

It appeared again unacceptable that major organisation receiving members of the public in their facilities (either customers, patients, passengers…) did not have a proper contingency strategy to face a disaster. The low churn rate of the facilities might explain the poor flexibility and ability to transfer some of the activities to other sites, but the poor emergency response and planning was not encouraging and reveals a dearth of knowledge on this aspect of the business threats from the owner.

7.2.2.1.5 Historic Buildings:

- UK Hampton Court (1986), B Palais des Malines (1995).

Historic buildings included almost every building type, from crofts to palaces, warehouses to libraries, lighthouses to railways stations, chapels to cathedrals. It is with such a difference in buildings that the scale, complexity and construction of each vary. It was primarily the elements of construction which brought individual difference. Wall, roof, and floor construction require consideration in each case as to establish the best method of fire protection suited.

Fire protection in historic buildings was far from the more clear cut outlook of a newly constructed building. In the case of an historic building there was a further dimension – the loss of property that forms part of a cultural resource which is finite, irreplaceable and whose architectural and historical integrity could be destroyed as easily by inappropriate fire precautions as by fire itself. It was considered that the loss of authentic historic fabric was a tragedy in itself, and it is upon this reasoning that fire protection must be present within historic buildings. But in analysis, the provision of a sufficient level of fire protection could be a problematic aspect of fire management. In providing adequate fire protection minimal intervention in conservation terms may be breached. The dilemma being in short firstly, the need to protect the building from fire itself and secondly, as to how an adequate level of protection was acquired without excessive intervention with the existing fabric. It is under this predicament that the issue of management becomes the amicable solution. Much can and should be done to minimise the likelihood of fire by the early elimination of major risks and by the management and control of those risks that cannot be eliminated.

The fire scenarios the author looked at in her investigations revealed a large number of failures in the system. Because of the way historic building have been built and unmodified over the centuries, smouldering fires are not rare. However in the **UK Hampton Court (1986)** fire a rapid spread of the fire contributed to greater the damages. The investigations report (DOE, 1986) supposed that a naked flame was at the origin of the fire. The slow and smouldering fire grown between the bed and the window of the main bedroom and break out at a later stage. Cold smoke spread along the roof void and the spaces behind the panelling followed by a "fierceness and rapid spread of the fire."

The unsatisfactory design feature combined with a series of technical and equipment systems failures would explain the devastating impact. Fortunately the rapid actions of the salvage squad permitted to save a large part of the art pieces while the fire spread in the facility. The lack of managerial control and improper management arrangements raised a lot of concern on the safety level in all historic buildings around the UK. The failures were summarised in the table below:

Planned System	Operational and Active Systems	Recovery and Continuity System
Unsatisfactory design feature of the fire detection system Less than inadequate commissioning process of the fire safety systems Lack of training of staff Low record of fire drills No operating manual for automatic fire detection system Lack of proper log Improper Management arrangements: line of responsibility and decision making	Fire origin: supposed naked flame, smouldering fire between the bed and the window of the main bedroom Fire development: considerable spread of cold smoke and fierceness and rapid spread of the fire Evidence of an automatic fire detection system which failed to operate properly. Inadequate response by the custody staff Delay in the operation of fire alarm Inadvertent rendering inoperative automatic fire detection system System failures: complete system failure / alarm zones switched off / system switched off / inadequate response to fire alarm	Safe evacuation of occupants but one casualty. Salvage squad in operation: successful salvage operation No evidence of business continuity plan

Table 7.19: UK Hampton Court (1986)

The Belgium fire of the **Palais de Justice de Malines (1995)** was another example of the successful actions of a salvage team in emergency situation. This XVIth Century building house the local court of justice in Malines. The unsafe use of naked flame and blow torch for repair works were at the origin of the fire. The internal construction was made out of timber as well as the roof structure (ANPI, 1995).

In 1982 renovation works were carried out on the facility and comprised the work on the stability of the structure, its thermal insulation and fire safety protection. The ceilings were replaced to enforce the fire protection level and avoid the propagation of a fire from the ground floor to the upper levels and the roof. Even if proper thoughts were put into the improvement of the passive fire protection features, inadequate design was carried out. Some fire walls were improved but did not provide a continuous fire resistance up to the roof structure. The table below summarises the fire safety failures for this fire:

Planned System	Operational and Active Systems	Recovery and Continuity System
No evidence of a hot work permit. Major renovation works in 1982 to consolidate the structure, improve thermal insulation and fire protection measures. Improvement of compartmentation. Inadequate design of firewalls in roof space Provision for extinguishers in the facility, but difficult access to fire zone.	Fire origin: maintenance work on gutters with a naked flame. Smouldering fire for several hours. Negligence from the workers. Fire spread in a confine space. Inability to use fire extinguishers to control the spread of fire. Late automatic fire detection: smouldering fire undetected in roof structure.	Extensive water damages. Damages to archives by water and smoke and heat. No salvage plan in place. No evidence of Recovery and continuity planning.

Table 7.20: B Palais des Malines (1995)

Following some repair on the drainage system outside the roof structure and using a blowtorch, a slow smouldering fire developed for several hours (from 15.00 to 22.00). The fire broke out at 22.08 and rapidly developed in the roof structure and outside.

The rapid spread of the fire in the roof structure and around the outside of the roof, explained the late detection of the fire. The difficult location of the fire did not allow a safe fire fighting action and the presence of portable fire extinguishers was unnecessary in this situation. The action of the fire brigade in trying to control the fire contributed to major water damages to the archives and internal furniture and equipment. The attic contained a collection of law book from the 19th century and of a great value. The collection has been seriously damaged by the smoke, the aches and especially the water. The salvage and adequate emergency and evacuation plan was proved to be extremely successful in the recovery of the facility.

Design and Engineering:

It is commonly found that older buildings have been constructed with provision for very different methods of transferring air, heat and light around the structure, often in the form of ducts and shafts, these as stressed prove very problematic. It is also worthy of mention that with the introduction of more modern day building services, the original structure may well have been built over or adapted, creating further voids, again having obvious implication when thought is given to potential fire and smoke spread. These highlighted areas alone justified the benefits of a thorough investigation and survey of a building and its history prior to any works commencing and also the need to keep accurate records of works undertaken that can be consulted at a later date. The fires at Hampton Court Palace and Windsor Castle where such ducts, voids and shafts were evident, and contributed heavily to the fire spread throughout the building, are tragic examples of the potential dangers.

Managerial Strategy:

As one would expect there was a limitation as to the extent when the application of passive and active measures may be merited. With greater degrees of fire protection technology and processes there was a requirement for unacceptable levels of intervention, it was at this point effective management was required. Bodies such as Historic Scotland and the FPA advised that when fire precautions involve alterations, careful and sympathetic design was needed to minimise the effect which these have on the architectural and historic character of the building. Management therefore is fundamental in any approach. The best form of protection was to stop the fire from occurring in the first place, and it was upon this principle that the merits of training, management and the removal of risk are warranted. Many practical common sense fire precaution measures could be implemented at no significant cost, the approach to recommend best practice will be examined further.

Contingency Process:

The criticality of the implementation of a salvage plan and a salvage team to save part of the invaluable treasures of a historic facility was widely demonstrated in the Hampton Court (1986) fire and the more recent Windsor Castle fire which was not construction related.

7.2.2.1.6 Conclusion of the analysis:

The selection of case studies was significantly representative of the problem of fire on construction sites, with a wide spread of cases and situations, but also comparative elements across all the fire scenarios (see Figure 7.2).

To ease the analysis and comparative study, the sites were divided in 5 groups: retail, factory/manufacturing, offices, facilities receiving the general public and historic buildings.

General findings were raised for each group under three heading: Design and engineering, Managerial strategy and Contingency process. The results of these findings are summarised in Table 7.22: Outcomes of the Construction Fire safety Failure Analysis.

The **common characteristics across all the fire scenarios** were found under the three heading. The first element which was noticeable was the rapid growth of fire on construction site. Several elements could contribute to the a rapid fire growth, like the high fire load, the storage of flammable materials, the accumulation of waste, the storage of construction material on site and confine spaces, etc. However the analysis revealed that fire scenarios analysed in this research, became very quickly uncontrollable and the presence of manual fire fighting equipment appeared unnecessary at the time of the fire. This might also explain the large losses and damages sustained by the facility.

The **inadequate design of the facility** in most of the case also contributed to the spread of the fire throughout the site and sometime beyond its boundaries, affecting existing and occupied facilities. Lack of compartmentation restrained the containment of the fire and allowed the fire to spread rapidly. However the fire was most of the time controlled before it could affect the structural stability of the building. The design of certain types of facilities, like factory and manufacturing units, or retail shops, could be major effect on the development of the fire. Large open spaces left the fire free to spread and the smoke to affect the all facility. Because there were no obligations to provide an active fire protection system to detect fires at an earlier stage and raise the alarm, delay in discovering the fire would delay the fire fighting action. In certain circumstances, refurbishment and maintenance operations, where the active system could be maintain operational throughout the work operation, the case studies revealed that the system was often temporary turned off to avoid false alarm.

From a **managerial point of view**, many criticisms could be listed under this chapter. However, baring in mind the difficult environment in which contractors sometimes have to operate and **the lack of regulatory enforcement to sustain the implementation of an integrated strategy on site**, some mistakes are unavoidable. However, simple precautionary measures would eliminate most of the risk of fire. Safe working practices combined with a proper management and supervision of the construction activities were essential to provide a fire free environment on sites. There was no evidence of a systematic risk assessment where fire risk would be clearly outlined and the development of risk management strategy implemented to control fire outbreaks. An inadequate fire safety strategy is always linked to a series of managerial failures like poor managerial control, poor site management, lack of awareness, etc. Across the cases studies only two sites in the UK provided evidence of a link and application of the 'Joint Code of Practice for fire prevention on construction sites' (JCOP) or similar guidance apply by other countries. The author already widely debated the scope and use of the JCOP and its recognition by the industry as a viable guidance for preventing fires on construction sites. The JCT forms of contracts required compliance with the JCOP and most of the major insurance companies would also require full compliance under the insurance contractual terms.

The **contingency process was a concept not yet fully accepted by the industry** and the author guess it took at least five years before it is recognised a sound concept. Across all the case studies analysed in this chapter, there was no evidence of the implementation of a complete contingency process. Some organisations have evidence of a short term recovery plan and in a crisis situation, salvage plans are ready to operate. However it was not a common practice and it appeared they chose to transfer this risk to the insurer. On large and repeated fire losses with the same contractor, insurers would develop a risk programme and issue a large loss advice for their clients. Even if a business continuity insurance was issued and a contingency plan is required, it was difficult to control its implementation and effectiveness on the day of the disaster. The way out of this problem was to limit the losses to a maximum sum, agreed prior to sign the insurance contract. On large projects, some insurers would decide to transfer the risk of fire to a reinsurer for an agreed premium.

The observations and findings of the construction fire safety failure scenarios revealed a large number of common characteristics. The summary of these findings was presented in Table 7.21: Outcomes of the Construction Fire Safety Failure Analysis. From this analysis a generic failure scenario was designed using a fault tree technique. The results of this fault tree were presented in the next section of this chapter.

Table 7.21: Outcomes of the Construction Fire Safety Failure Analysis

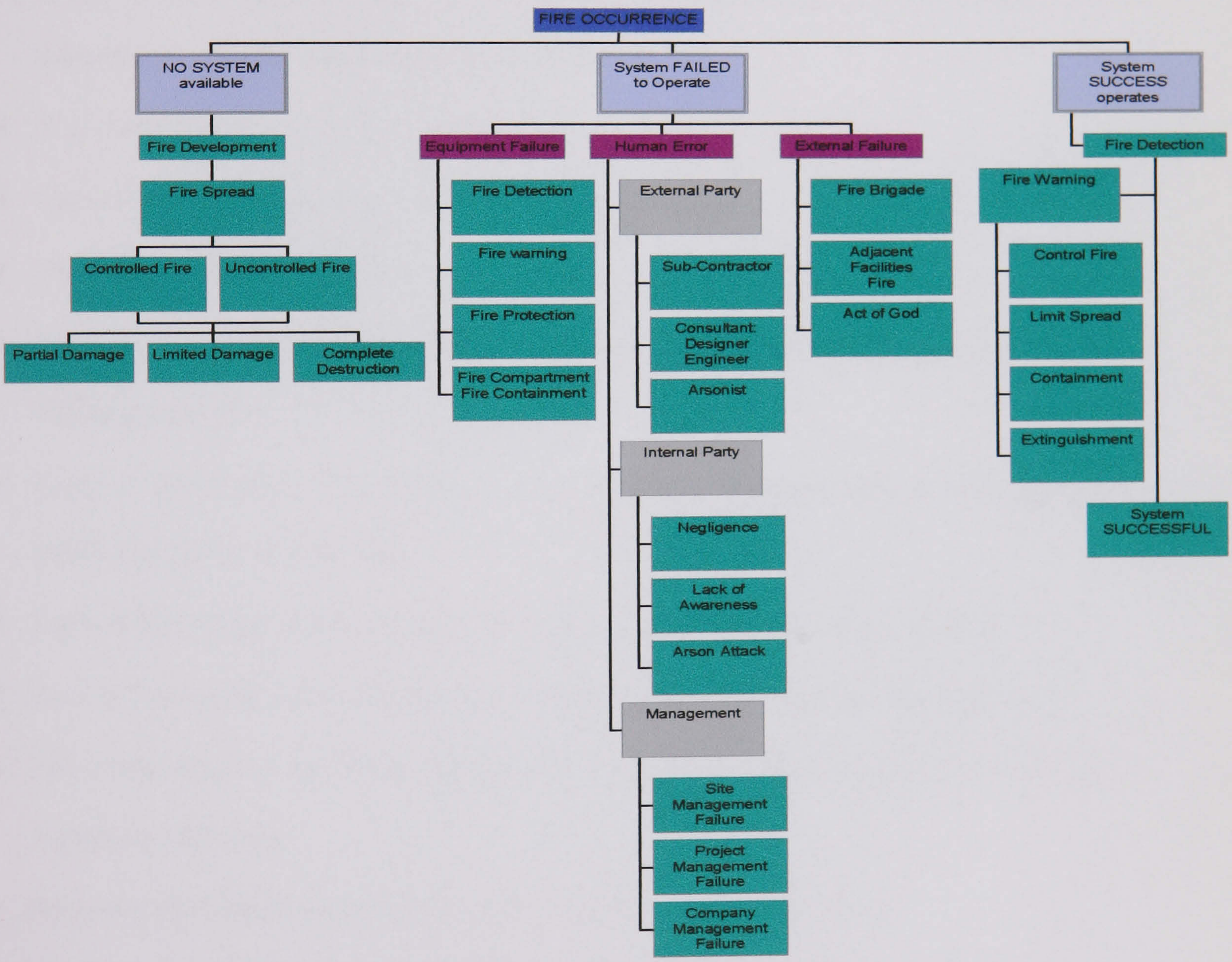
OUTPUTS	DESIGN AND ENGINEERING	MANAGERIAL STRATEGY	CONTINGENCY PROCESS
RETAIL UNITS UK Retail I (2000) UK Retail II (2000) FR Retail Sama (2000)	Adequate design of the units and enforced use of compartmentation to contain fire spread. Choice of low combustible materials	Security control essential to prevent arson attacks Adequate Fire Safety Strategy in the facility Reinforced control and management on site Systematic risk assessment and risk management programme	Preparation of a contingency planning to response emergency situations and maintain business activities.
FACTORY UNITS UK Factory (1998) FR Factory I (1994) FR Factory II (1996) FR Frigecreme (1996)	Control of ignition sources and fire load in the facility Implementation of operational fire protection measures Control of compartmentation and containment	Systematic risk assessment and risk management programme Adequate Fire Safety Strategy in the facility Reinforced control and management on site	Preparation of a contingency planning to response emergency situations and maintain business activities.
OFFICES UK Broadgate (1990) UK Minster Court (1991) FR Bank (2000) UK Bank (1999) FR Office (2000) US Harrisson Bldg (1985)	Improve passive design and compartmentation as soon as possible throughout the construction operations Adequate fire protection and detection system Containement... Containment... Containment	Adequate Fire Safety Strategy in the facility Reinforced control and management on site On large sites, the use of CCTV system is recommended Reinforced security in tight sites and sensitive areas (town centres...) Systematic risk assessment and risk management programme	Preparation of a contingency planning to response emergency situations and maintain business activities.
PUBLIC UK Hospital (2000) US Sight & Sound (1997) D Dusseldorf (1996)	When safety of public is at risk, isolate site from the public areas and improve compartmentation Adequate passive measures to contain fire spread	Adequate Fire Safety Strategy in the facility Reinforced control and management on site Systematic risk assessment and risk management programme	Preparation of a contingency planning to response emergency situations and maintain business activities.
HISTORIC BUILDINGS UK Hampton Court (1986) B Palais Malines (1995)	Maintain integrity of the structure and improve passive protection Reinforced fire protection and detection system	Adequate Fire Safety Strategy in the facility Reinforced control and management on site Systematic risk assessment and risk management programme	Preparation of a contingency planning to response emergency situations and maintain business activities.
	Inadequate Building Layout Inadequate Design Failure of Passive Design Inadequate fire protection measures Failure Fire Protection Measures No Active Fire precaution Measures No Passive Fire Precautions Measures Rapid Fire Spread Slow fire spread High fire load Low fire load Inadequate compartmentation No compartmentation Technical Failure Structural Failure	Failure to comply with FS Requirements Inadequate fire safety strategy Failure of fire safety management strategy Poor managerial control No storage facilities Poor storage facilities Poor site management Inadequate risk management No risk management Human error / failure Lack of awareness Communication failure Inadeuate staff training Inadequate waste management Negligence Inadequate security management	Failure Emergency procedure Inadequate emergency procedure No emergency procedure No evidence of contingency plan Inadequate contingency plan / DRP No evidence of Business continuity plan Inadequate BCP Effective Fire Brigade Action Inadequate Fire Brigade action No salvage plan Inadequate salvage plan Difficult acess to fire zone

Table 7.21: Outcomes of the Construction Fire Safety Failure Analysis

7.2.3 Generic Failure Scenario:

Primary investigations into the causes and consequences of fires on construction sites contributed to the assessment of a failure scenario. This event tree illustrateed three different events following the fire occurrence: there was no system available to control the fire, the system failed to operate due to an equipment failure, Human error or an external failure. Finally the system was operational and succeed to control the fire.

Model Event Tree Fire on Construction Sites



The analysis across a large sample of fires draw the conclusion that in most cases the system in place at the time of the fire occurrence failed to operate due to a Human Error either from an internal or external party, or from the management directly.

7.2.4 Lessons Learnt from failures scenarios

- Need for a detailed assessment of the risks and hazards before and during the construction stage.
- Implementation of an operational emergency plan and test it.
- System of control and monitoring of FSP during the construction stage.
- Develop training and awareness among employees and the workforce about the danger of fire, its consequences and line of conduct in case of fire.
- Improve communication and liaison between the Contracting company and the FM: compatibility of the project safety information
- Liase with local fire services and fire brigade
- Improve fire safety by design (fire engineering approach)
- Pre-construction meeting necessary
- Improve Structural fire resistance and compartmentation to limit the spread of fire in the building premises
- Lack of knowledge of the legislative and regulatory requirements and obligations in health and safety, and fire safety.
- Lack of knowledge of the contractual obligations under the terms of the contract.
- Lack of knowledge and understanding of the insurance policy and its scope and limits.
- No appreciation of the likely impact of a fire for the organisation, its recovery and continuity after a fire.
- Recovery Plan often ignored and risk transferred to Insurance Company.
- Need for the implementation of business continuity planning for all organisations. No systematic fire risk assessment
- No systematic risk assessment
- Need for a Partnership between Client / Insurer, Client / Contractor, Contractor / Sub-Contractor, Site Management / Emergency Services.
- Need to consider the implementation of Recovery and Continuity Plan.

- Effective communication between fire, police and emergency services to control the fire zone and adjacent facilities and evacuate civilians and control traffic.
- Adequate water supplies to site.
- Successful fire ground operations.
- Salvage Plan for facilities of an outstanding and historical value: historic monuments, archives, museums, and libraries...

7.2.5 Research Findings:

The **contractual agreement** was often unclear to the parties and its content unknown or not well assimilated. Most of UK contractor will chose a traditional and standard form of contract and the rest will tend to develop a bespoke form of contract or no contract is signed for the project.

The knowledge of contractors on their **Insurance policy** was limited and often they were unaware of the form of policy they subscribe to.

An **Annual or Specific insurance** was always subscribed but there was still great confusion on the distribution of responsibilities between the parties and their duties and responsibilities to subscribe a **CAR or Joint Names Policy**.

The **Joint Code of Practice (JCOP)** did not address the full extent of the problem of fire on construction sites and concentrate solely on the construction stage. The limited spread of the JCOP is major weakness of the existing strategy.

Compliance with the JCOP was very difficult to prove and require extensive monitoring and control of the contractor activities on site.

Partnership was an essential ingredient of the proper collaboration between the insurance company, their support organisations (Loss Adjuster / Fire and Forensic / Reinsurers / Underwriters) and the inured.

In a fire situation, often the **FSP** developed prior to the commencement of the works was not operational or the workforce involved has not been trained to react to the fire in proper manner. The consequences of late action and improper strategy to control a fire situation, lead to disastrous consequences, loss and damages.

The **CDM regulations and other health and safety regulations** relevant to the construction industry, forced parties to look at health and safety issues at the design stage and throughout the full construction process, but does no address specifically fire safety issues on sites.

Active fire precaution measures were not encouraged during the construction process and are most of the time implemented at a very stage of the project. For refurbishment and maintenance works, this approach has been encouraged but was not common practice amongst the construction industry.

The **Fire Precautions (Workplace) Regulations 1997** with 1999 amendments excluded a construction site as a place of work. The protection of construction employees against fire during their normal schedule of work was not addressed and their level of safety was not improved.

Systematic **risk assessment** was not carried out at an early stage of the development of the project and limited partnership is maintained between the insurer and the insured. Such an approach would encourage insurers to provide support to their insured on establishing a risk programme to assess, control, monitor and prevent major fire risks on construction sites.

The full consideration of a **Disaster Recovery Plan** was not promoted and the insurer sustains losses and damages dues to fire. The extent of the consequences of a major fire during the construction process was not well understood by the contractor and the client, as well as the impact of such a disaster for their business.

Business Continuity Planning (BCP) was the systematic forethought to allow response during and immediately after an event to be based on pre-planned and optimised solutions which minimise the consequences for the business.

Business Continuity Planning was not a systematic exercise for an organisation and insurers do not have the power to enforce this approach. The development of a Company BCP would limit the consequences and impact of a fire for a business. The organisation would possess an operational BCP to support the early recovery of their business, assess the core and non-core activities of their organisation, and define an adequate strategy to limit losses and maximise profit.

The **BCP was a Live Document or a Live Plan** and it involved securing the continuity of the business activities and the real estate or facilities. It was also related to the relatively intangible issues affecting business capital.

Figure 7.6 illustrated how the research findings of the post analysis contributed to develop the fire safety management model.

Figure 7.6: PhD Schematic Structure
Construction Fire Safety Failures Post Analysis

7.3 Interim conclusions to support the development of a fire safety management model

The attempt to extract major recommendations at this stage of the research was not definitive, as the Expert Reviews will participate to dress conclusions, which are relevant to the industry. However the qualitative analysis and design of the FSMM contributed to identify significant findings and based on this primary but not definitive analysis, to generate recommendations and conclusions for this report.

The second problem related to the statistics arisen because a large number of fires appeared to be unreported, usually because they are without any major or immediate financial and human consequences. This invisible element of the problem will leave the lessons from the near misses fires where any processes or procedures lead to successful control, also unreported.

The risk of a fire occurrence was generally recognised as being extremely high during the construction, refurbishment, or maintenance of buildings - because of the combination of large quantities of combustibles were combined with numerous potential ignition sources in a rapidly-changing environment. In partially occupied or occupied buildings undergoing such works the consequences in terms of direct loss of property and/ or occupant safety are potentially profound, even where the fire which causes these problems may be relatively minor.

The significance of this issue for business appeared to still require drawing-out, perhaps via the Facilities Management field. The direct consequences for the core and non-core business from fire events in critical core or support business premises (and/ or to people) were potentially very damaging to business continuity. However the issues appeared to remain under-stated.

The need to address globally the problem of fire safety on construction sites was significantly demonstrate in this report, and within prior publications on this issue. Overall it seemed that significant work has been carried out by the insurance industry to consider this problem and limit losses on fire incidents on construction sites. Certainly the publication and continuous review of the LPC Code was a firm proof of the interest into the problem. It was also apparent that other EU countries, and especially France which was widely considered in this research, was well behind in terms of preventing fires on construction sites. The slow progress in research and development on this subject could be explained by the lack of major fire incidents in other EU countries to the UK (Broadgate and Minster Court in the 90s). The attempt to explain and review this problem and address the findings in a Managerial Model has been proposed in this thesis and aimed to demonstrate the validity of this Model through two expert reviews. A number of conclusions, which will contribute to knowledge in the field of fire safety on construction sites, were addressed below.

A **large scale study** of fires on construction sites and a **centralised system to gather data** on the number, cause and consequences of fires: the qualitative analysis proposed in this research contributed to identify the strengths and weaknesses in the existing system for the prevention of fires on construction sites. However the unavailability of quantitative data to support this research was a significant barrier to demonstrate the validity of the research hypothesis. The existing system to collect information on fires on construction sites failed to gather accurate data which could be exploited. This research has identified several points to consider:

- **Recording information** on the fires: the fire report (Format and information required not precise, depth of information required), treatment of information by the statistical bureau (FPA, Home Office, Fire Brigade, HSE), the analysis of these data not completed, access to data often difficult and reliability of the information publicly available.

- **Incompatibility of the data** between statistical offices: reasons for such differences was often not explained but an in-depth analysis of the collection process highlighted the following problems: definition of a construction site unclear, classification and categorisation of facilities (site / site huts / site accommodations and offices / building merchants / building storage / construction company (could be a manufacturing line for manufactured elements) / open site / civil engineering works), the estimation of losses (>£50,000, direct / indirect losses), reported / unreported fires with injuries (HSE), with losses (Fire Brigade and FPA and Insurance Companies), with intervention of the Fire Brigade but losses < to £50,000.

- The **lack of research** on the subject: Insurance companies were in the best position to analyse their claims files and due to a lack of time and investment in research and development many opportunities to develop valuable analysis on major incidents were often denied, forgotten and not a priority for the business. The impact of a large scale investigation on fires on construction sites could be significant and affect the general health and safety provisions. Already pressures from the EU to develop new directives transformed our legislative framework and improved it. The Fire Brigades which significantly contributed to increase damages on site due to the use of a large amount of water, are protected their interests.

A **collaboration** between the contractor, the client, the insurer: the CDM regulations aimed at encouraging collaboration between the construction participants on health, safety and welfare matters, at a earliest stage of the project. Pressure on the designers to "Think Safety First" and promote a "Safe Working Environment" through their design was a significant step ahead. However, as this research identified it, fire safety matters are not directly addressed in the CDM Regs. On the other hand, the publication and wide use of the LPC Joint Code of Practice (JCOP) for Fire Prevention on Construction Sites and Building Undergoing Renovation, promoted the importance of implementing fire safety measures during the construction / refurbishment process and obliged parties to the contract to coordinate their approach towards fire safety. This role of coordination being assumed by the Health & Safety Coordinator appointed under the CDM Regs has now been widely recognised and accepted by the industry as a whole. However to need to consider specifically fire safety as a single and distinctive aspects of health, safety and welfare was to date not yet completely assumed. Pressure by the Insurers to comply with the JCOP contributed to **change the safety culture of the industry and the fire safety approach on sites**. Maintaining a long term collaboration between first Insurers and Contractors, Insurers and Clients and Clients and Contractors was essential to systematically adopt a fire safety approach on every site.

A **Partnership** between the insurer and the insured: all construction works contain elements of risk. The fire risk is common to all construction works and also cause financial losses which were sustained by the Insurers through a transfer of this risk with the subscription of an Insurance Policy (CAR / Specific Perils) by the Contractor and/or Client (Joint Names). The **implementation of a System of prevention** combined with the development of a **Partnering approach** between Insurer and Insured (Contractor or Client) would promote an active preventative approach, develop the communication channels between the parties, enforce the implementation of a Risk approach and culture in the organisation. However there were some barrier to the implementation of this concept: the delay to implement the strategy, the investment to develop the concept, the opposite effect of prevention without a Partnering approach.

Risk Management: a better analysis of the risks at the earlier stage of the project would undoubtedly provide the contractor/client and insurer a better perception of the risks involved and appropriate information (and maybe data) to implement a suitable strategy or procedure to control and monitor risks throughout the complete project cycle. The FSMM addressed risks issues at a very early stage with the development of a FSP and HSP and also looking at a long term strategy, with consideration for a Recovery procedure and Business Continuity

Plan, first for the organisation and also project specific. **This management of the risk was an integral concept** and depends on a change of the safety culture of the organisation.

A **Global Approach** and an **Integral Concept**: The scope of the prospective FSMM highlighted the need to consider a Global approach towards fire safety, rather than a project specific approach. In fact, considerations for the complete project cycle and its relationship to the organisational and managerial strategy were essential to built up an appropriate concept and implement a procedure. As such consideration for the integration of the Recovery and Continuity Systems was essential to appropriately manage the risks of fire during construction works.

Figure 7.7: PhD Schematic Structure
Summary of Findings / Model A

8 DEVELOPING A MANAGERIAL MODEL

8.1 Introduction and Research Concept

The full PhD schematic structure of this research and its outcomes and findings were available in each chapter. These schematic structures demonstrated the integration of the research findings in the development of the fire safety management model.

- The proposed FSMM addressed the managerial approach and presents a framework of implementation from inception towards hand over. The FSMM also took into account three different types of construction works: new built, maintenance and refurbishment. It offered enough flexibility to permit changes but sustain a high level of control of the risk over the activities on site.
- A set of requirements has been assessed throughout each phase of the development of the project (Inception, feasibility, design, substructure, superstructure, fit-out / hand-over, maintenance, refurbishment) and its life cycle. It also integrated five safety systems: planned, operational, active, recovery and continuity systems. The link and overlaps between those systems were presented in a separate model.

The constructive analysis was developed throughout this thesis and a thorough research analysis has been required to consider a number of issues and checked them against a hypothetical scenario. In a first instance, this chapter reviewed the strengths and weaknesses of existing safety models and systems. The second part of this chapter introduced the concept of the fire safety management model developed by the author and based on the research findings. Three different models are then presented and the second and third version offered for review to two Expert Panels in France and the UK. The results of the Expert review were presented and discussed in the next chapter.

8.2 Background to the research:

The use of safety models or systems to assist professionals to understand the process of fire safety has been widely used and is nowadays recognised as a reliable assessment method. A summary of the papers reviewed in this section is available in Table 8.1. Watts (1997) defined a system as "a set of components that work together for an overall objective... the objective of which is to provide an acceptable level of fire safety in building."
Watts proposed an alternative method he defined system analysis "as simply the methodical study of an entity as a whole."

Fitzgerald (1985) proposed an engineering method for building Firesafety Analysis and recognised eight major parts that can be grouped into three categories to complete the engineering methods: performance criteria, the analysis of the facility and an engineering design. Molkov (1999) modelled explosions in buildings through an interpretation of real accidents. He argued that based on an engineering and scientific approach "the design procedures for avoiding the development of excessive overpressures during deflagrations could be improved." Wade & Whiting (1997) described a method of fire risk assessment known as Building Fire safety Engineering Method (BFSEM) which main components included the evaluation of probability of the fire self-terminating, probability of automatic suppression and the probability of manual suppression by the fire service. Probabilistic approaches were again develop to evaluate fire risk as detailed in a paper by Ramachadran (1988) where he reviewed techniques using fire statistics. Beard (1999) applied the concepts of systems to the creation of a fire safety management system for offshore facilities. These researches had something in common: they relied on a detailed set of data, they were based on a probabilistic approach and involve engineering techniques. The problem of fire safety on construction should be approached through a different angle, as no statistical data were available in this field of the construction industry. A bare list of major fires was usually published, but there was no evidence to support an engineering and probabilistic approach to create a Fire Safety Management Model (FSMM). Lo (1999) proposed a fuzzy fire safety assessment approach based on fire risk ranking techniques that may form part of the safety evaluation tool for existing buildings. His approach evolved from insufficient fire data to carry out statistical inference tests, making statistical and probabilistic studies.

The concept of the use of a model in safety and risk management was not new. A review of current and past model developed in managerial research revealed that they have been used in research for the last decade. The form and design of these models varied a lot and it seemed there wasn't a clear definition of it. Models combined with the use of systems were identified but did not provide an adequate strategy to design them. Smallman (1994) proposed a safety management systems for the offshore industry. In his review of past and current safety management systems for offshore installations, Smallman highlighted the strengths and weaknesses of the safety management approach. His research and investigations highlighted a number of interesting issues, common to the construction industry:

i. Need to integrate a systematic safety management approach
ii. Lack of perception of the problem of safety by offshore organisations
iii. Poor communication of safety culture
iv. Problem to analyse failures and learnt from failure scenarios
v. Broadening safety culture

The offshore industry which suffered a series of major explosions and fires (Flixborough (1975), 28 killed; Piper Alpha (1990), 167 killed), the later gave rise to the Cullen Report (1990). Prior to the Piper Alpha disaster, nothing in the legislation required explosions to be considered at all and the fire protection systems were unsuitable for the types and severity of the fires. Crawley and Dalzell (1997) recognised that most people in the industry did not recognise explosions as a threat. Cullen identified three major concern: the need for a safety management system, a risk and hazards identification to protect personnel and the need for temporary refuge on the installation. This concept helped Beard and Santos-Reyes (1999) to develop a fire safety management system. This FSMS was constructed in four steps:

i. Prototypical FSMS by using the viable system model

ii. Test FSMS by applying Failure Paradigm Method

iii. Synthesis

iv. Further testing of the FSMS

The FSMS model aimed to maintain an acceptable level of fire risk in offshore installation operations. It was a systematic set of six inter-related subsystems: fire safety implementation, fire safety co-ordination, fire safety audit, fire safety functional, fire safety development, fire safety policy. This Safety System was developed from a detailed set of quantitative data and a strong engineering approach. The design of the model was very sophisticated and detailed but its principles were commonly understood.

Moving away from the offshore industry which presented very specific characteristics, not always comparable to the construction industry, Models were also develop in risk management. Tummala & Leung (1996) proposed a risk management model to assess safety and reliability risks and to evaluate several alternatives response plans to reduce and control identified risks. The model was based on risk management process with a clear identification of the risks and the development of action plans with risk evaluation and risk control and monitoring.

Waring (1996) developed a Model of a safety management system. In his approach Waring seek to outline the requirements for successful health and safety management and how this may be addressed systematically through strategy and safety management system. He proposed a clear procedure and model based on a sound managerial approach, as well as a detailed hierarchy of business and safety objectives.

Eric Marchant who has been researching on fire safety since the mid 70s, started writing papers on fire safety in buildings and construction site. Recently Marchant (2000) developed a new approach to fire safety systems. His paper looked at the technological functions of fire safety systems in buildings and how they interact with other systems. Marchant took into account the aspects of the whole building performance and fire safety design. It was a good approach for construction works where facilities are in-use and occupied during operations. Other authors like McKie (1997), Chazot (1997) from Eurotunnel, Crawley & Dalzell (1997) from WS Atkins and BP Exploration, explored safety management for different type of incidents and accidents in various industry. Common ground such as the implementation of an integrated strategy were discussed and the formulation of managerial approach is argued and put forward.

McKie (1997) argued that "a complete operational safety system should encompass all aspects of technology, systems and culture." Therefore the system interacted with its environment: technological environment, cultural environment... Watts (1997) explored the characteristics of a systems and define them as having a boundary, an input and an output, some variables and a structure.

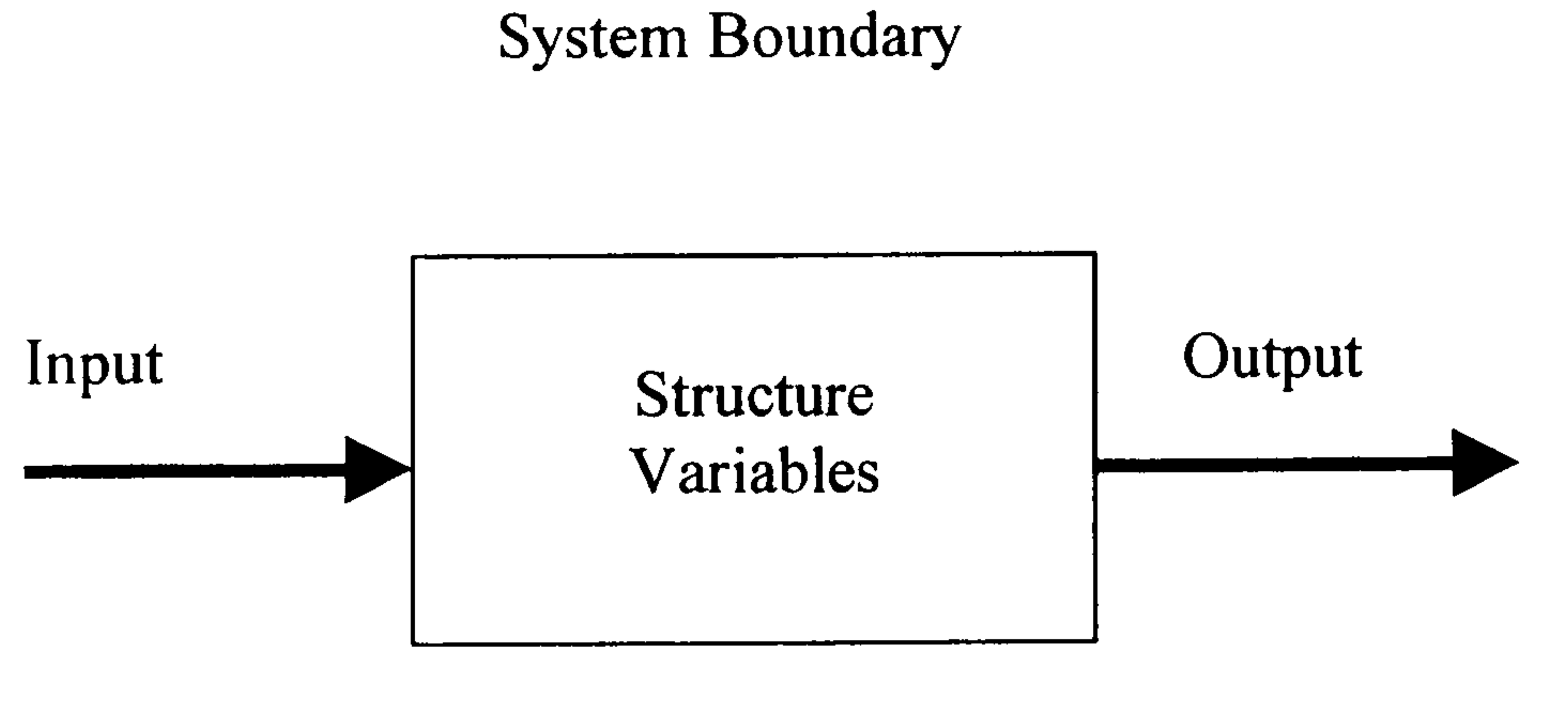


Figure 8.1: Characteristics of Systems *(Source: Watts, J. (1997) Systems concepts for building fire safety).*

However Watts (1997) argued that "the system may interact with its environment, but outside events do not themselves govern the behaviour of the system, i.e. there is no feedback mechanism between the system and external elements." **This is the major weakness of the Watts' approach. The researcher believed that to achieve an integrated approach of the fire safety system, the Model proposed in this research must interact with its environment (cultural and technological) and through a feedback mechanism evolve into time and change according to the modified parameters.** The Model presented in this research was a live strategy and unique to every site. Like MacKie (1997), the author believed that the implementation of a fire safety management model cannot be detached from a cultural change within the organisation and through the management. MacKie (1997) restated that "a much better management process will recognise the need for rules, regulations, etc., but will provide a working environment, or culture, where each and every employee understands the need to work safely and ensures that they do so." He later argued in his paper the need to develop a total safety culture.

The Fire Safety Management Model proposed in this report is based on a detailed analysis of data collected through interviews and an extensive analytical review and analysis of major fires on construction sites. The FSMM addressed issues raised by professional interviewed and the findings extract from the analysis of real failure scenarios.

The objectives of this review by two Expert Panels were to critic the hypothetical FSMM and highlight significant areas of improvements to develop a final Model.

8.3 Model A: Prospective Fire Safety Management Model (FSMM) for the Prevention of Fire on Construction Sites

Through the analysis of relevant cases of fires originating on construction sites, a comparison was made between recognised good and bad practices, and a proposed Managerial Model to meet the requirements for Fire Safety was presented for review.

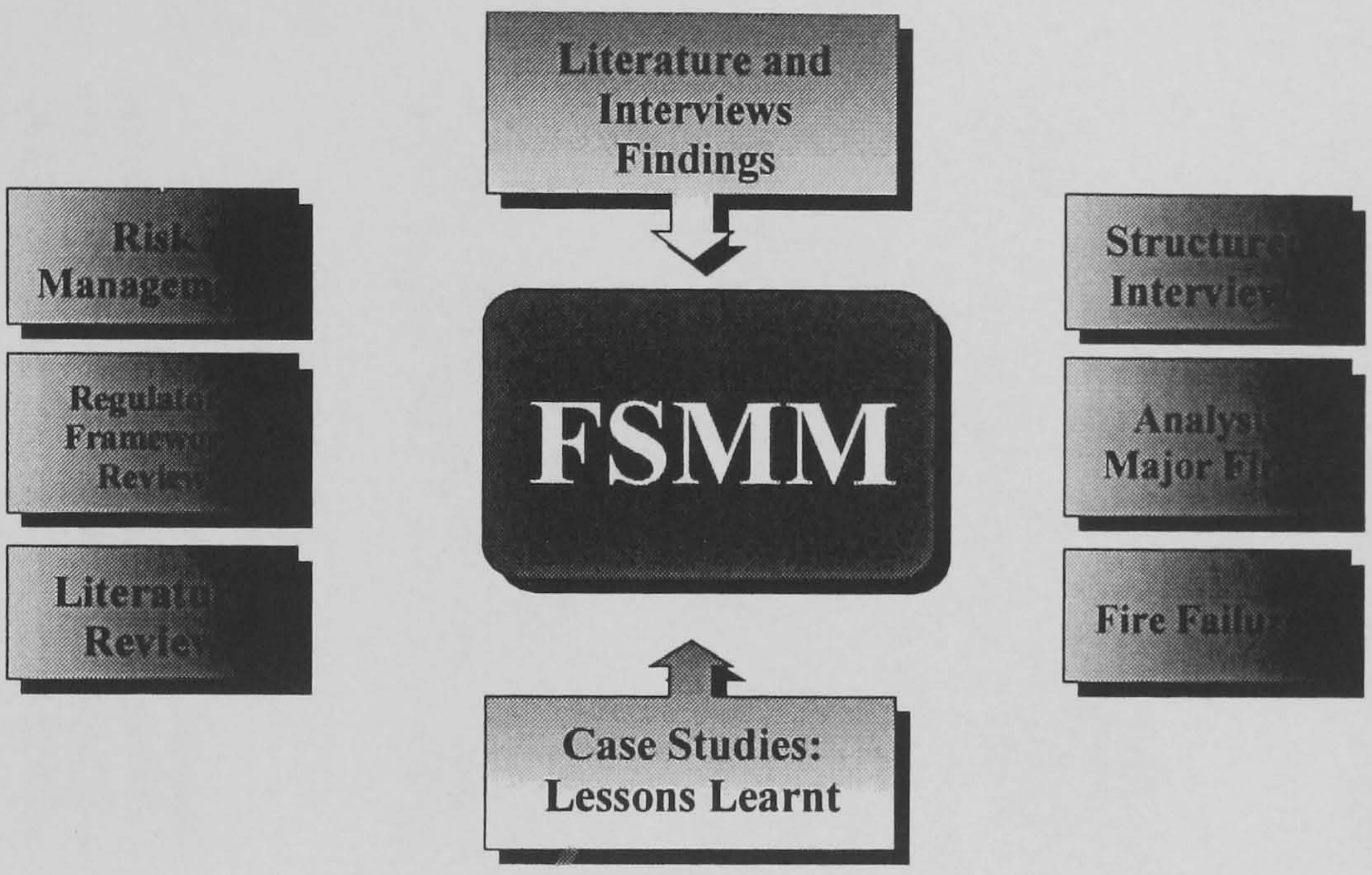


Figure 8.2: FSMM: Process of building the concept

In Chapter 5, the author detailed the research concept and process of building theory (Figure 8.3 below). At this stage, the author planned to develop several Fire Safety Management Models and to revise them periodically through the presentation of the Models to two Expert Panel. The success of the approach was based on a sound review and critical analysis of the strengths and weaknesses of each model and to demonstrate their validity and applicability in organisation. The author already argued the scope and limit of the research, and concluded that the testing of the model in organisation was not possible in this research. However enough evidence have been collected in the Expert Reviews to justify the validity of the Model and how it contributed to raise awareness and provide a sound framework to develop an integrated fire safety management concept and process in organisations.

Table 8.1: Review of managerial models and systems concept in the literature.

Author, Date	Title	Model	Overview	Strengths and weaknesses
Smallman (1994)	Offshore safety management systems: current practice and a prescription for change.	Safety Management Systems	A review of past and current safety management systems for offshore installations, highlighting the strengths and weaknesses of the safety management approach.	✓ Need to integrate a systematic safety management approach ✓ Lack of perception of the problem of safety by offshore organisations ✓ Poor communication of safety culture ✓ Problem to analyse failures and learnt from failure scenarios ✓ Broadening safety culture
Tummala & Leung (1996)	A risk management model to assess safety and reliability risks	Risk Management Model	The paper propose a risk management model to assess safety and reliability risks and to evaluate several alternatives response plans to reduce and control identified risks.	✓ Model on risk management process with a clear identification of the risks. ✓ Development of action plans with risk evaluation and risk control and monitoring.
Waring (1996)	Corporate health and safety strategy	Model of a safety management system	The approach seeks to outline the requirements for successful health and safety management and how this may be addressed systematically through strategy and safety management system.	✓ Clear procedure and model and based on a sound managerial approach ✓ Detailed hierarchy of business and safety objectives
Watts (1997)	Systems concept for building fire safety	Concepts of systems and systems thinking	The paper introduces the concepts of systems and systems thinking. It then briefly describes principles of, and a generalised procedure for systems analysis.	✓ Clear definition of a system and its characteristics ✓ Provide background on system analysis and scientific method. ✓ Systems approaches are applied to the fire problem and using the fire safety concepts tree developed by the NFPA. ✓
MacKie (1997)	The development of an operational safety culture	An integrated improvement model	"The author expands on the concept that, in industry, more attention is given to the technical and system aspects and too little attention is given to the people cultures necessary to ensure success.."	✓ Clear definition of safety culture in industry and its inclusive management system. ✓ Develop concept of total safety process and its benefits.

Lo (1999)	A fire safety assessment system for existing buildings	Fire Risk Ranking System	The article proposes a fuzzy fire safety assessment approach based on fire risk ranking techniques that may form part of the safety evaluation tool for existing buildings.	✓ Interesting research methodology based on Expert reviews and seminars to collect quantitative data for risk ranking. ✓ Reliability of data collected could be questioned.
Beard & Santos-Reyes (1999)	Creating a fire safety management system for offshore facilities	Fire Safety Management System	The FSMS is constructed in four steps: ✓ Prototypical FSMS by using the viable system model ✓ Test FSMS by applying Failure Paradigm Method ✓ Synthesis ✓ Further testing of the FSMS The FSMS model aims to maintain an acceptable level of fire risk in offshore installation operations. It is a systematic set of five inter-related subsystems: fire safety implementation, fire safety co-ordination, fire safety audit, fire safety functional, fire safety development, fire safety policy.	✓ Model developed from a detailed set of quantitative data and a strong engineering approach ✓ The design of the model is very sophisticated and detailed but principles are commonly understood.
Molkov (2000)	Explosions in Buildings: modeling and interpretation of real accidents	Fire Safety Engineering	The paper explores real explosions in domestic structures and industrial plants. Molkov argues hat the design procedures for avoiding the development of excessive overpressures during deflagrations can be improved.	✓ Description of explosion conditions ✓ Explosion dynamic modeling
Marchant (2000)	Fire safety systems: interaction and integration	Fire Safety Systems	The paper looks at the technological functions of fire safety systems in buildings and how they interact with other systems.	✓ Take into account the aspects of the whole building performance and fire safety design. ✓ Good approach for construction works where facilities is in-use and occupied during construction works.

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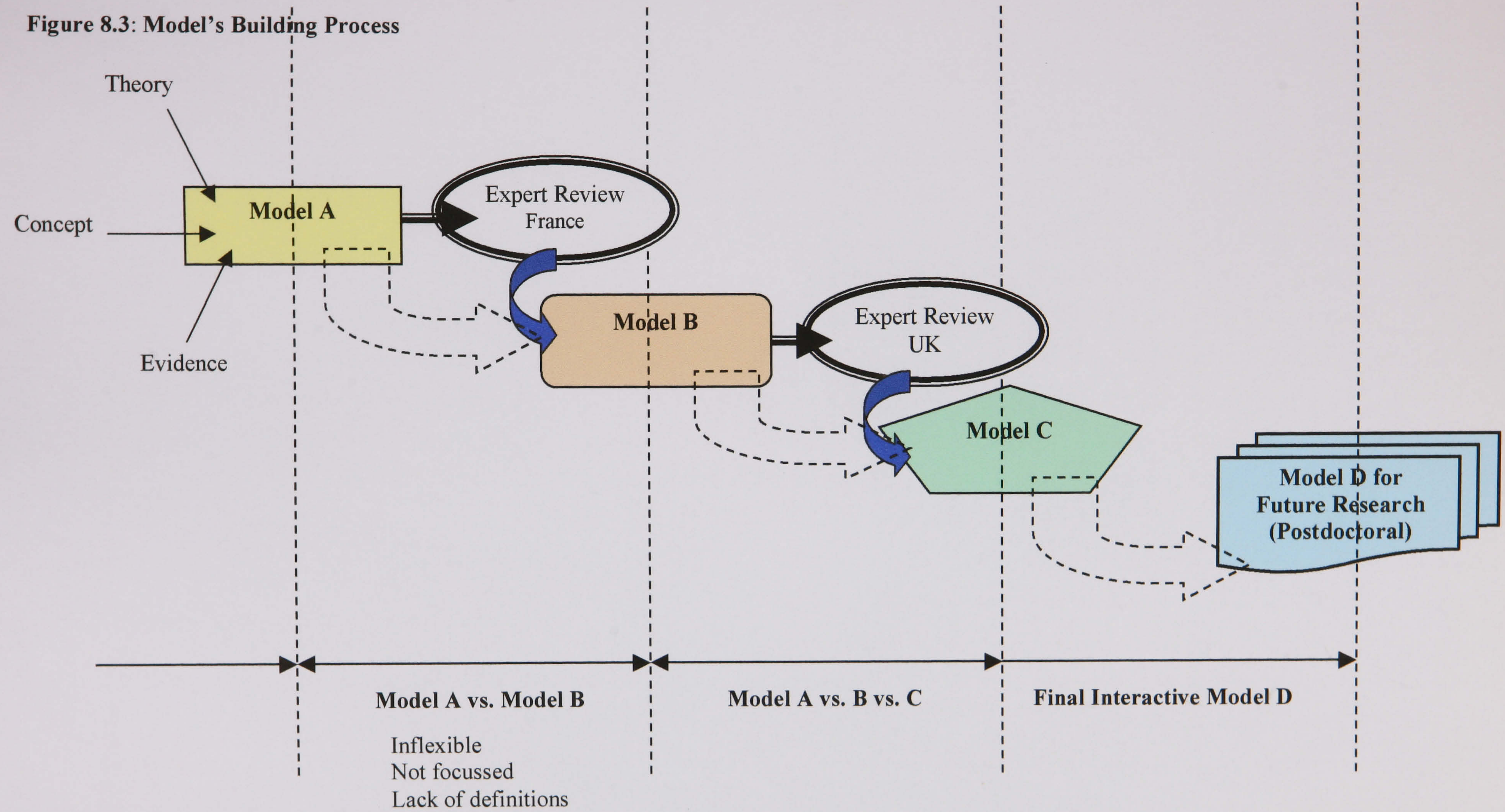
Figure 8.3: **Model's Building Process**



8.3.1 The Prospective Fire safety Management Model (FSMM): Model A

The next pages present the prospective **Fire Safety Management Model (Model A)** for review and analysis by the French Expert Panel.

Further explanations on the how to use this model and the interaction between the systems will be discussed on the day of the review. To enhance the analysis, a case study was put together in Appendix B and will form the basis for the analysis of the FSMM.

The Model indicated the relationships between the stages of the process and was indicative of the flexibility of the overall framework. The use of colours for each different system aimed to ease the understanding of the Model and the importance of considering the phases of the project from Conception, through Execution / Construction and Exploitation of the facility (Maintenance / Refurbishment).

Figure 8.4: PhD Schematic Structure
Model A / Interpretations of the Findings

The research findings highlighted the need to consider five different systems in the prospective FSMM:

1. **Planned System**: this system looked at the pre-construction phases to consider to develop the project and what specific areas need to be consider to put together the project. Health and safety requirements played a major part in this system as legally the parties have obligations under the contractual agreements, the law and regulations applying to the industry, the insurance policy.

2. **Operational System**: This was the system in place during the construction / refurbishment / maintenance phases which will look at the implementation of the Fire Safety Plan, its control, monitoring and updating throughout the all construction phase. Compliance with the JCOP is compulsory and is supervised by the Insurance Company.

3. **Active System**: The combination of a set of passive measures (determined at a design stage and in the FSP) with active measures was a key issue into the control and prevention of fires on construction sites. This system was particularly relevant to the refurbishment and maintenance sites where a high control of fire breakout was essential. Active and passive measures were slowly installed in the project either using temporary equipment or the permanent one.

4. The implementation of Disaster Recovery Plan was not always a systematic exercise for facilities owners and contractors. The participation of the Insurance company in building up their insured files should draw to their attention the benefits of implementing a Disaster Recovery Plan to limit the loss and damages to their business (facility, activity, assets, capital, public image, shares…) following a fire. The Survey Report completed by the Insurance should highlight potential risks to help the

Insured to develop a Risk Programme, if required and necessary, and manage the risks throughout the construction phase.

5. **Continuity System**: Most organisations did not have a BCP. The benefits of preparing a BCP and anticipating a potential interruption of the business were an essential element of a good managerial approach in any given business. The BCP process comprised six phases: initiation of the BCP and Risk Assessment; business impact analysis; the analysis of the critical processes; the creation of the BCP; testing of the Plan and finally the updating of the BCP creating a feedback loop. This continuous cycle of the BCP, its development, implementation, improvement, made the BCP constantly up-to-date with the evaluative business environment, a clear and recognised risk management approach throughout the life cycle of the facility (construction / maintenance / refurbishment) and its interaction with the business objectives.

All these systems of course interact with their environment and consider the legal system in place as well as the organisation. Figure 9.2 expresses these interrelationships.

Each system was spread across the three main stages of the project cycle: Pre-Construction; Construction; and Post-Construction / Life Cycle / Sustainability of the facility.

The author's definition of a construction site addressed these phases: *any facilities where there is new construction taking place, where modifications are being made to the existing facilities, and/or there are maintenance works being undertaken in part or all of the premises.*

Project Matrix

Project Specifics:

Fire Safety Management Model

System	Plan	Item	Inception	Feasability	Design	Substructure	Superstructure	Fittings/Hand-Over	Maintenance	Refurbishment	Item	Plan	System
			Pre-Construction			*Construction*			*Post-Construction / Life Cycle / Sustainability*				
						Risk Ass: 1 2 3	*Risk Ass: 1 2 3*	*Risk Ass: 1 2 3*	*Risk Ass: 1 2 3*	*Risk Ass: 1 2 3*			
PLANNED System	*Conception Plan*											*Conception Plan*	**PLANNED System**
		Company Safety Policy	Written Policy						Written Policy	Written Policy	*Company Safety Policy*		
		Contractual Agreement	Standard / bespoke	Draft Agreement	Sign Agreement				Standard / SLA	Standard / Bespoke	*Contractual Agreement*		
		Insurance Policy	Annual / Specific	Contact Insurer	CAR/Joint Names				Owner B+C/BI or CAR/Joint	CAR / Joint Names	*Insurance Policy*		
	Health & Safety Plan											*Health & Safety Plan*	
		Tender stage		Draft HSP	CDM Regs	HSP Operational	HSP Operational	HSP Operational	CDM Regs Compliance	CDM Regs Compliance	*Tender stage*		
		Pre-Construction stage		Tender HSP	CDM Regs Compliance	HSP Check/Updated	HSP Check/Updated	HSP Check/Updated	HSP Operational	HSP Operational	*Pre-Construction stage*		
OPERATIONAL System	*Fire Safety Plan*											*Fire Safety Plan*	**OPERATIONAL System**
		Review/Control FSP			Draft FSP with JCOP	FSP Operational	FSP Operational	FSP Operational	Work Permit	FSP with JCOP	*Review/Control FSP*		
		Inspection/Log Book				JCOP Compliance	JCOP Compliance	JCOP Compliance	Compliance WP/JCOP	Compliance JCOP	*Inspection/Log Book*		
ACTIVE System	*Fire Protection Plan*											*Fire Protection Plan*	**ACTIVE System**
		Passive Measures (PM)			Design approach	Temporary PM	Temporary PM	Permanent PM	Permanent PM	Permanent PM	*Passive Measures (PM)*		
		Active Measures (AM)			Engineering approach	Temporary AM	Temporary AM	Permanent AM	Permanent AM	Permanent AM	*Active Measures (AM)*		
RECOVERY System	*Disaster Recovery Plan*											*Disaster Recovery Plan*	**RECOVERY System**
		Emergency Plan	Existing Emergency Plan?	Draft Emergency Plan	Operational Emergency Plan	Operational Emergency Plan	Operational Emergency Plan	Operational Emergency Plan	Operational Emergency Plan	Operational Emergency Plan	*Emergency Plan*		
		Audit / Risk Management	History?	Survey Report	Risk Programme	Risk Management	Risk Management	Risk Management	Audit / Risk Programme	Audit / Risk Programme	*Audit / Risk Management*		
CONTINUITY System	*Business Continuity Plan*											*Business Continuity Plan*	**CONTINUITY System**
		Company/Annual BCP	Existing BCP?	Draft BCP	Agree BCP	BCP Operational	BCP Operational	BCP Operational	BCP Operational	BCP Operational	*Company/Annual BCP*		
		Project specific BCP		Consider Project BCP	Draft Project BCP	Project BCP Operat.	Project BCP Operat.	Project BCP Operat.	Project BCP Operat.	Project BCP Operat.	*Project specific BCP*		
		Project Observations:	*Check List 1*	*Check List 2*	*Check List 3*	*Check List 4*	*Check List 5*	*Check List 6*	*Check List 7*	*Check List 8*	*Project Observations:*		

Figure 8.5: Prospective FSMM - Model A.

The role of the organisation to implement the fire safety management strategy was fundamental to the success of the Model. The project management was core to the development of the procedure or processes and its documentation, but interaction with the environment (cultural and technological), the organisational needs and objectives (both of the contractors and clients), the legal framework and its requirements were determining the overall framework of implementation of the FSMM. Figure 8.6 illustrated this interaction between the systems. There wasn't one single solution for all sites, but one solution of each different site.

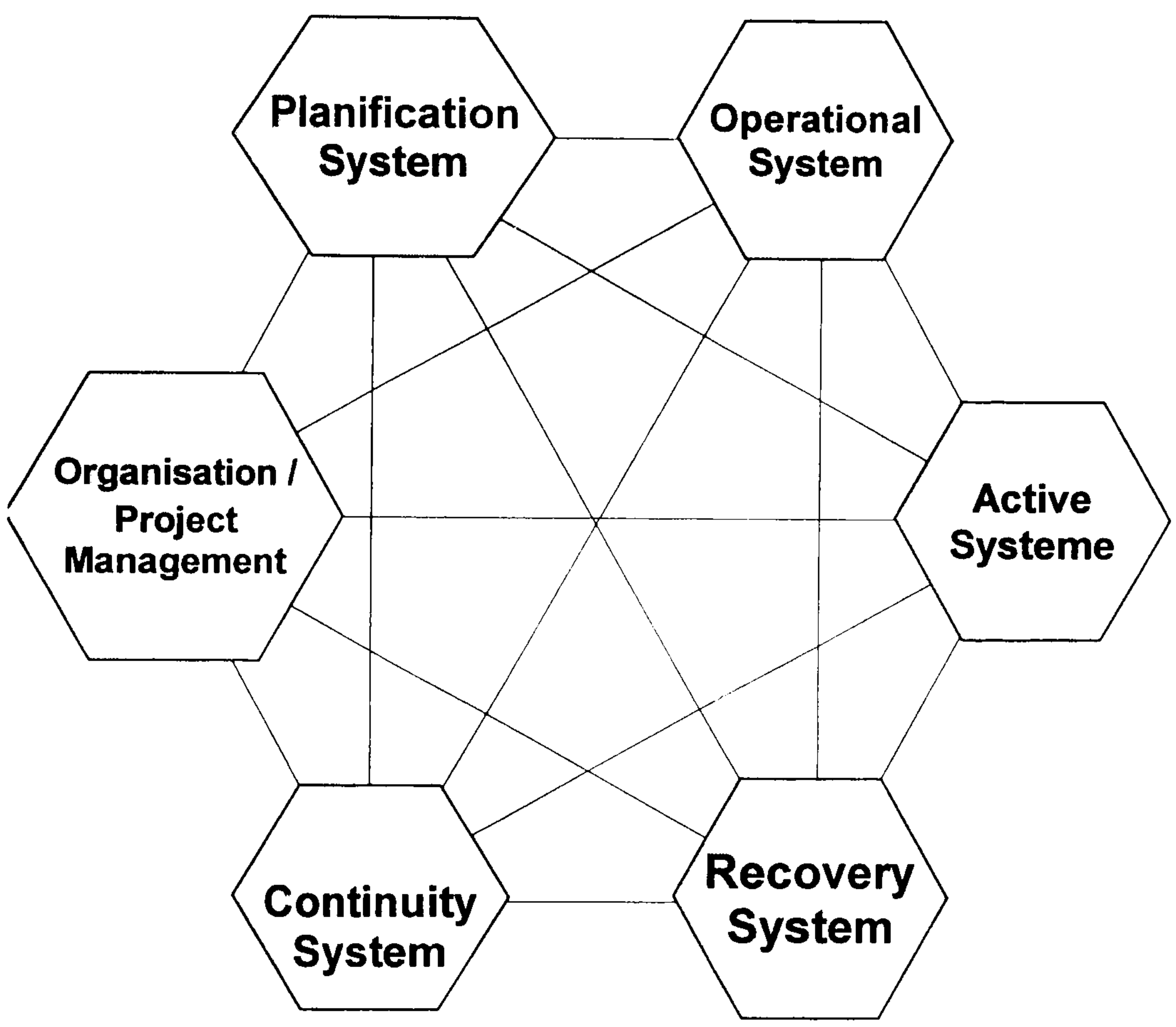


Figure 8.6: Systems Interrelationships

The FSMM aimed to offer this flexibility and allow for changes: managerial changes, organisational, cultural, legal, environmental... The success of the Model was based on the full understanding of the need to consider each system independently and develop a set of procedures or plans around the systems, but also to consider its overlap and interaction with other systems either already in place, or under implementation. The FSMM also aimed to achieve corporate objectives or initiatives within the company. These needs and requirements must also be taken into account when developing and implementing the FSMM.

The Project Matrix below represented, in two dimensions, the essential components of the FSMM. Earlier in this chapter, the author defined each system and discussed the interaction of these systems with each other's.

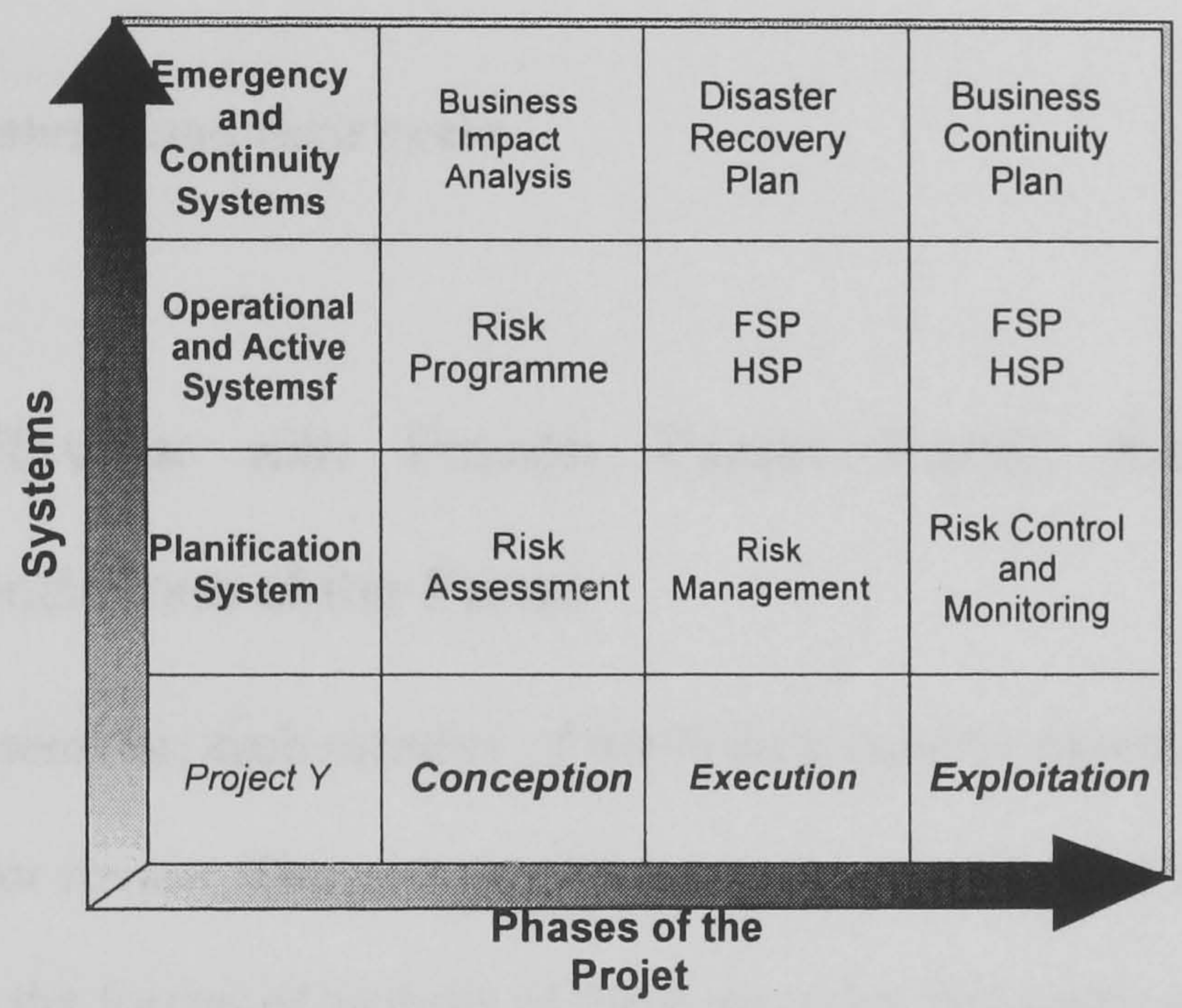


Figure 8.7: Project Matrix

Interaction and overlapping of the systems was one flexibility of the Model. However the strategy for implementation considers a clear order in the FSMM. Preventative actions are the main focus of the Model and it also considers a cycle as illustrated in Figure 8.8 below.

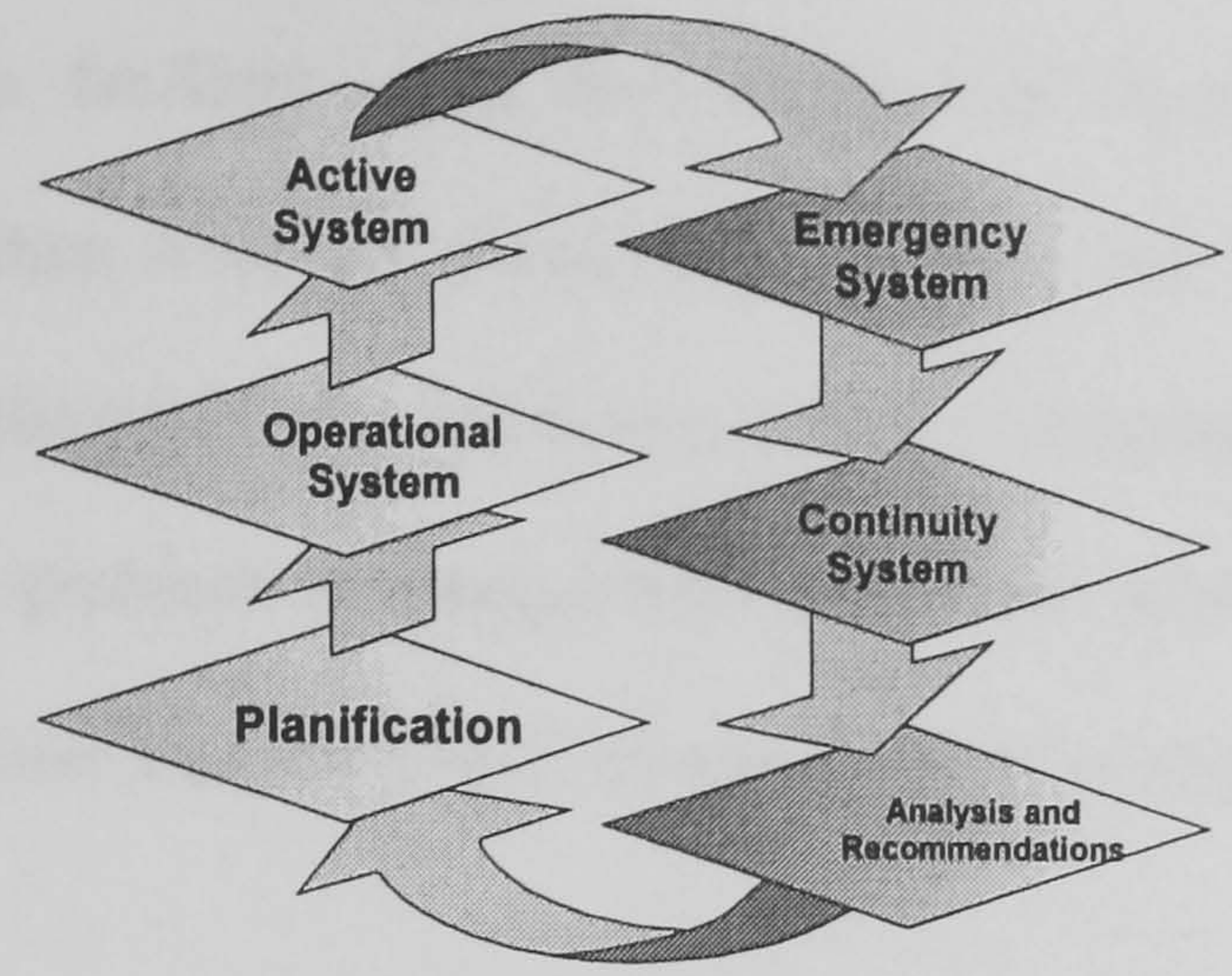


Figure 8.8: The systems and their cycle

8.3.2 Expert Review with French Expert Panel: the outcomes and recommendations of the Panel.

Prior to the expert seminar, each member of the French expert committee was sent a copy of the interim report for review. The content of this report was discussed in chapter 6: Research Concept, as well as the format of analysis of the prospective fire safety management model.

In the following section, the author analysed the results and outcomes of the expert review and synthesis the major recommendations of the expert panel.

The first element of discussion focussed on **the problem of definition of a site**. In chapter 2 of this thesis, the author discussed the current definition of a site and argued for a broader assessment of the scope of a site and a clearer definition. The author defined construction site as *any facilities where there is new construction taking place, where modifications are being made to the existing facilities, and/or there are maintenance works being undertaken in part or all of the premises.* It was also important to define what did we meant by a construction activity: *A construction activity is a work operation outside the normal use of the facility: new constructions, alterations, refurbishment, change-in-use, maintenance and/or demolition.* Members of the French expert panel supported this approach and the need to wider the scope of the definition to take into account the full life cycle of the facility: Execution, Exploitation, Refurbishment and Demolition. One particularity of the French legislation is an overlap of the legislation between facilities under construction and in phase of exploitation. However maintenance activities were not categorised as sites, but the intervention of an external organisation in existing facilities and in use, is under a separate decree.

Following on this problem of **categorisation of sites and fire incidents** in construction activities, a discussion was developed around the aspects of statistical data. Four issues were raised:

- Lack of quantitative data: like in the UK, access to reliable statistical data was difficult. First due to the problem of definition of a site. Statistics are collected by the Fire Brigade, the Association of Insurers (APSAD/FFSA) and the Government. The most comprehensive data are collected by the Fire Brigade which recognises different categories:
    - Nature / Origin of the fire: construction industry, temporary constructions (external risks),
    - Location of fire: site accommodations and facilities, open sites.
    - Cause of fires: energy, explosions, other sources of ignition.
- Classification and categorisation of data unclear: once again it was impossible to collect an accurate number of construction sites fires and thereby carry out a quantitative analysis. One of the member of the Expert Panel, Schaal (2001) argued this problem of categorisation and Celardo (2001) argued for a need to "reformulate the statistical classification to enhance statistical research outside of the scope of insurance organisations." He later raised the issue of the concern to categorise the fires in the right category, as a site, and not as its exploitation aim. Tephany (2001) restated he was "surprised the APASAD does not collect a sound set of information."
- No codification: Whether it came from a problem of classification of information or definition of each category, it the longer future it was argued that codification could be used to help the collection and classification of fires.

- The collection and dissemination of the data restricted: The access to statistical data being restricted and unreliable, the author argued that an effort should be made by the insurance companies to collect and categorise their own data. Celardo (2001) argued it was due to "a problem of mentality and the concept was affected by time." For historic buildings, Shaal (2001) added that an initiative to collect information at the EU level to coordinate the collection and analysis of statistics in historic buildings was developed by the Michel Angelo Commission. The reinsurance companies (Munich Re., Swiss Re) provide the most comprehensive set of data but it is restricted to CAR insurance, and not EAR and property insurance (Paulczinsky, 2001).

An attempt to discuss the validity of a short quantitative analysis of construction site fires, across a sample of 50 major fires in the UK was presented. The outcomes of the review were not conclusive and the panel agreed that 5% of the fires analysed in this mini research is not significative and representative of the construction industry problem and the depth of the research.

However in the long term, a need to develop a quantitative approach would be necessary and should look at the number, causes, consequences, losses/damages of construction related fires. An in-depth research would include a broader analysis of the data and extracting results from comparing:

- Losses vs. total surface of facility: smoke could damage an atrium of 6,000m3 and the cost of repair could only include cleaning. However, the loss of an archive room of 30m3, like in the FR Factory (1994) fire, could cost £,000s to repair and recover. This might actually explain the large losses following the Broadgate (1990) and Minster Court (1991) fires in London and the high cost of construction and destructive behaviour of the fire.
- Losses vs. value of the facility: in certain cases, losses could be difficult to assess, especially where facilities are of a special value. The loss of archives and valuable stock usually not replaceable like art pieces, museum items, collectable items, libraries and special book collection; are typical example of the need to consider losses vs. value of the

facility. The fire safety management model argues the need to consider the implementation of contingency plans to response major fire disasters.

- Losses vs. insurance premium: an insurance premium was usually around the 0.03% of the value of the property. Insurers would calculate the Maximum Estimated Loss and provide a cover for this maximum loss.

The Expert Panel recognised the problem of access of statistics and advanced that their organisation (Paulczinsky, 2001) would be able "to extract proper statistics with minimum changes to recording method and of the process." Celardo (2001) added that this was " a message to send to the organisation worldwide."

Pressure to approach the research from a qualitative angle, rather than quantitative: Because the analysis across 50 major fires (section 2.2.2) was not significant (Schaal, 2001; Tephany, 2001), there was pressure to move towards a qualitative analysis.

A misunderstanding and overlapping of current and existing obligations, duties and responsibilities of the parties involved was a significant problem. Schaal (2001) argued that outside the scope of public facilities (which have a specific set of regulation in France) it was difficult to target the adequate and right regulation. The author advanced that in the UK, actions to enhance fire safety on construction sites was clear through the publication of the JCOP, special perils clauses in insurance contract, the new edition of the standard forms of contract with compulsory compliance with the Fire Code (JCOP); however it took 10 years to implement (1990-2000). France was far behind and the implementation of a similar structure to the UK could take years. Celardo (2001) argued that "we can't say nothing exists in France: the health & safety plan is required." But "the requirements is to appoint a Planning Supervisor but not directly in fire safety" (Tephany, 2001). Risk of the duplication of work, overlapping of current requirements must be taken into account when modifying the FSMM. As explained in chapter 2, France had a very strong health & safety regulatory framework, which proved to be very efficient. However there wasn't any requirements for fire safety on construction sites. The strengths of the UK framework lied within their fire safety approach, integrated within the health & safety framework. Paulczinsky (2001) stressed the importance of the client's role to implement the approach because of the cost of fire safety. Consequently as the same time the regulatory framework is modified, a cultural change was required. Paulczinsky and Celardo supported this idea. This later questioned the problem of delegation of responsibilities and transfer of responsibilities for fire safety. Because there wasn't a clear definition of the responsibilities for fire safety on construction sites, often contracts were used to transfer the risks:

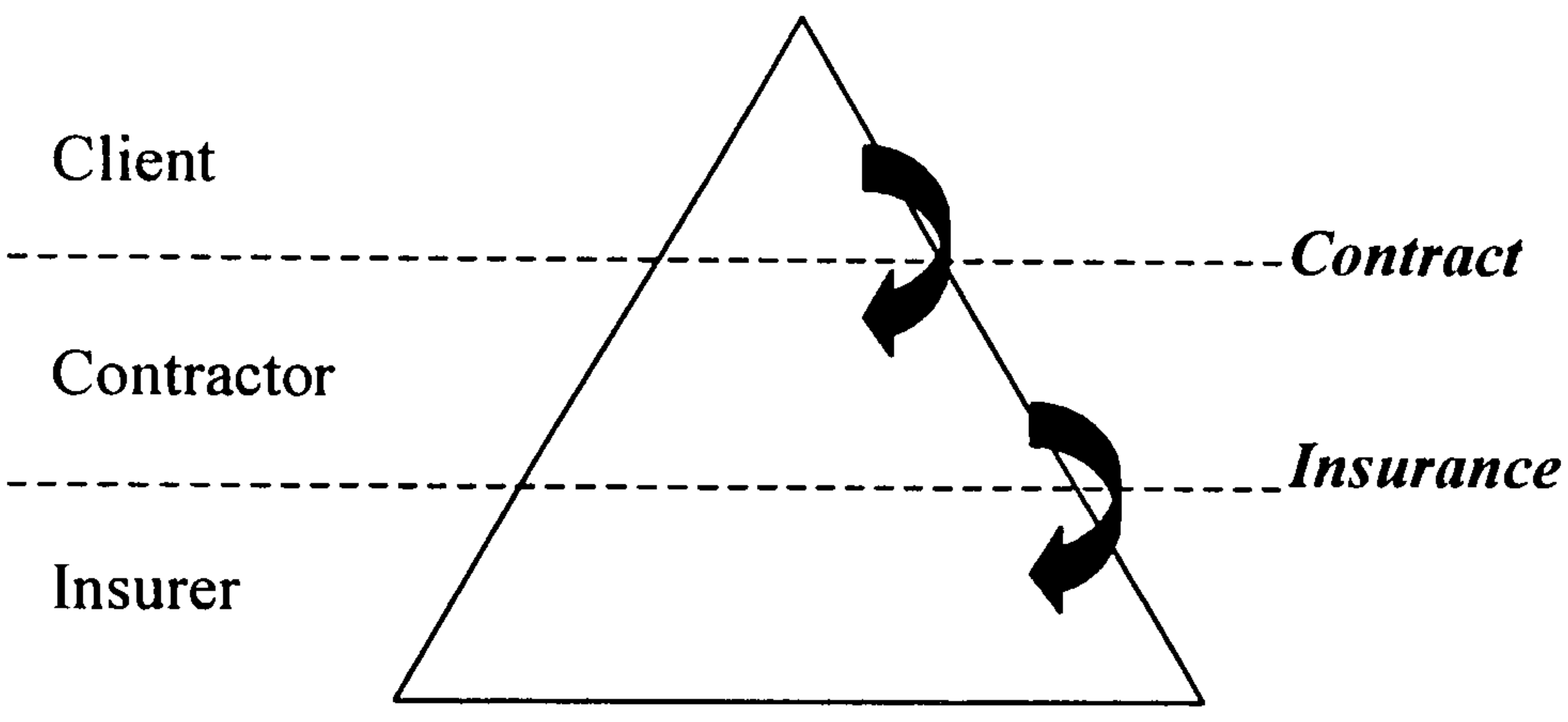


Figure 8.9: Transfer of risk

Another problem occured between the conception and execution phase. Schaal (2001) argued that the Architect was often the planning supervisor but there was no obligation to appoint the planning supervisor at the conception stage. A problem of transfer of responsibilities could occur. Celardo (2001) recognised that "the contractors need to be more engaged into the approach." And added, "there is only a contractual requirement to implement this." The confusion on the application of the law on fire safety to construction sites still remains unclear. Under the French Code du Travail and Decree 1993 considered, construction sites were recognised but the measures include general requirements. The Decrees of 92 and 94 were more specific on the need for a detailed risk assessment and the compliance with health and safety requirements, including specific provisions for fire safety. These regulatory documents were discussed in the section 2.2. This last comment took us back to the problem of the definition of a site as it was not always recognised as a place of work. And Téphany

(2001) argued that "it is important because a text designed for finished facilities can be apply to a site situation."

Schaal (2001) recognised there was a need for a regulatory framework under three types of obligations: regulatory, contractual and policy (insurance). There was a need to enhance loss prevention to develop awareness amongst participants to the construction process and develop Control, verification and inspection through the insurer.

An adequate **assessment of the risks** at the conception stage was essential to identify potential fire hazards during the construction stage and how a transfer of the facility to the owner and into an exploitation stage carry on the risks. Schaal (2001) argued that the idea could be based around the development of a SWOT analysis in a construction situation. A risk assessment approach was not systematic and not a requirement under the regulation. Core and non-core activities could be identified and a response structure developed around the existing structure implemented to support a free fire environment. Téphany (2001) added that there are documents of reference for these aspects of the model. The International Standard Organisation (ISO) /Sub Committee 4 was currently working on the development of a standard and it seemed the analysis focus more on the exploitation phase. Baron (2001) highlighted the need to have a dynamic management to support the implementation of the model and efficient monitoring and control of the strategy.

The second part of the expert review required the critical analysis of the Model A and to provide recommendations on improvement.

The first elements of discussion focussed **on the definitions of a 'Model', 'System', and 'Plan'**. In section 8.2, the author detailed the definition of a system and reviewed and discussed existing models in fire safety. This analysis was not integrated in the Interim report submitted for review to the Expert Panel. Also, the members of the panel were professionals with extensive working experience in the industry. The concept of 'Model' and 'System' was not common into their working environment and they didn't feel particularly easy about the use of systems. The basic understanding of a 'Model' was based on the idea of a graphical representation which can be followed to develop an action. The concept the author was trying to demonstrate was the idea of the development of a Model to enhance the implementation of a fire safety management strategy in organisations. However the notion of 'Plan' was very clear in their mind.

The Expert Panel agreed that the principles of fire safety on construction sites were all addressed in the FSMM:

- The strengths lied within:
    - **Choice of systems and plans**: the notion of life cycle was determinant into the strengths of the Model and its integration within the overall safety strategy.
    - **Integration of the full life cycle of the facility**: Conception / Execution / Exploitation. Téphany (2001) argued that the new idea of the research lies within the Global approach to fire safety and prevention.
    - **Involvement of the insurer** was key in the process of implementation and development of the fire safety framework. The earlier involvement of the insurer, usually at the conception stage, could be a break through the implementation of the fire safety strategy. With CAR insurance, often parties take a joint cover and the insurance policy was then transferred from the contractor at the execution stage to the client at the exploitation stage. Celardo (2001) stated that risk analysis was based on a general insurer approach and Schaal (2001) added that through a better relationship between client and insurer, the insurer could raise awareness of risk to the client and enforce the implementation of fire safety strategy.
    - **Risk assessment and risk mapping approach** was essential: Schaal (2001) reflected on the use of the model and comments that "it is the sort of model which would enable the client to analyse the risk which would affect its organisation's activities. He then might decide to delegate responsibilities or transfer some of the risks through the contractual agreement."

- Weaknesses were also highlighted in the review and analysis of the model:
  - **Inflexibility of the Model**: the two page Model was totally inflexible and the author could observe the two teams had problem to read the document, interpret the data and use the model against the hypothetical scenario. They didn't know how to start and where to start. Because the general understanding is that a risk analysis should be carried out prior to develop a strategy, this risk approach was missing. Téphany (2001) reported that there was a need to work on the matrix of the model and develop a simplified approach. Celardo (2001) admitted it was "not practical" and that the execution phase should separate from the exploitation phase. However, as explained earlier, the idea of the model was to develop a global approach throughout the full life cycle of the project.
  - Need for a more **ergonomic Model**: Bordas and Baron (2001) criticised the heavy format of the model and its lack of ergonomics. He later recommended, without conviction, that a 3D model would be ideal to demonstrate the depth of the strategy and it fits within the overall process.
  - **More adaptable to change and different project format**: the model should fit within the existing structure, which is to date very disparate. However a strong health and safety structure already exist and proved to be efficient and could be modified and adapted to suit the integration of a fire safety approach.
  - Consider a **separate Model for New construction / Maintenance / Refurbishment**: the author believed that this comment lied within the lack of flexibility of Model A as presented to the French Expert Panel and at the first review. The next section of this chapter will detail the second development of the model and its improvement.

Half of the members of the expert panel were working for insurance organisations and their recommendations were then aimed to insurers and their own interest. However a number if were very relevant to the development and improvement of the FSMM A.

Insurer's involvement:

- Cooperation
- Participation in the development of a risk assessment programme and analysis
- Improve risk programming
- Enforce risk inspection
- Enhance loss prevention
- Maintain the use of specific insurance clauses: Specific perils, Business Interruption, CAR/EAR/CEP
- Enforcement of the compliance with a code of practice equivalent to JCOP throughout the project cycle
- Integration of a fire safety approach in the full life cycle

The Expert Panel however concluded that the client would be in the best contractual position to support the implementation of the model throughout the project cycle, as there are involved at all stages of the project: conception (design and development of the contractual agreements), execution (project management and administration of the contractual agreements), exploitation (maintenance operations under the direction of the client, refurbishment works directed by the client).

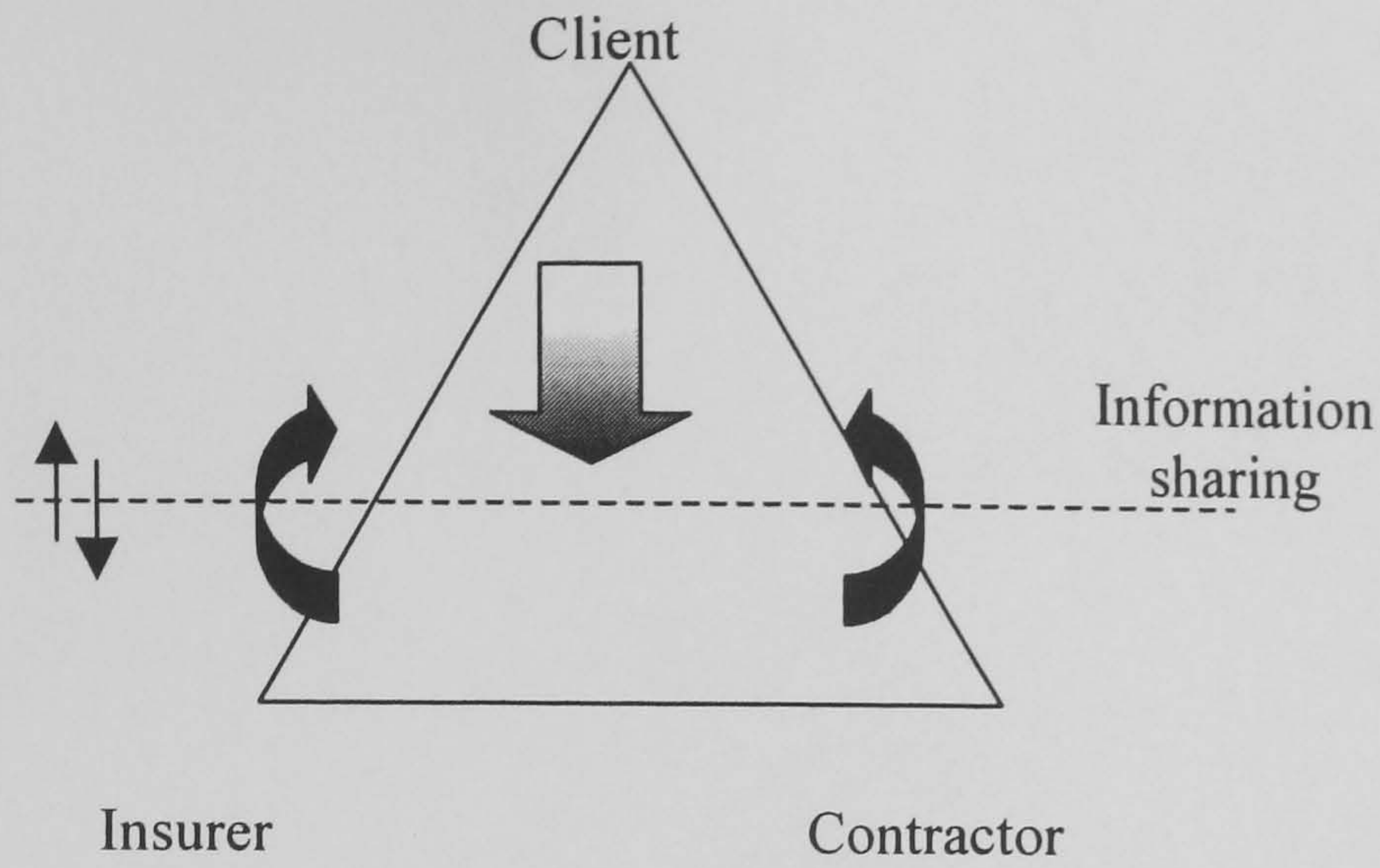


Figure 8.10: Contractual relationship and the exchange of information

8.3.2.1 Recommendations:

The recommendations of the French expert panel could be summarised as follow and in Figure 8.11:

- Increase the flexibility of the FSMM and its ergonomics
- Consider existing obligations
- Improve cooperation between Client/Insurer/Contractor(s)
- Project matrix needs to develop in order to enhance a better understanding of the approach and its global concept
- Enforce compliance through:
  - Insurance Clauses
  - Contractual documents and agreement
  - Regulation
- Develop Risk Mapping: event/fault trees
- Propose a ready to use Model, clear with all information available on the Model and presented in a simple way.
- Consider the visual impact of the Model for the user
- A 3D Model?

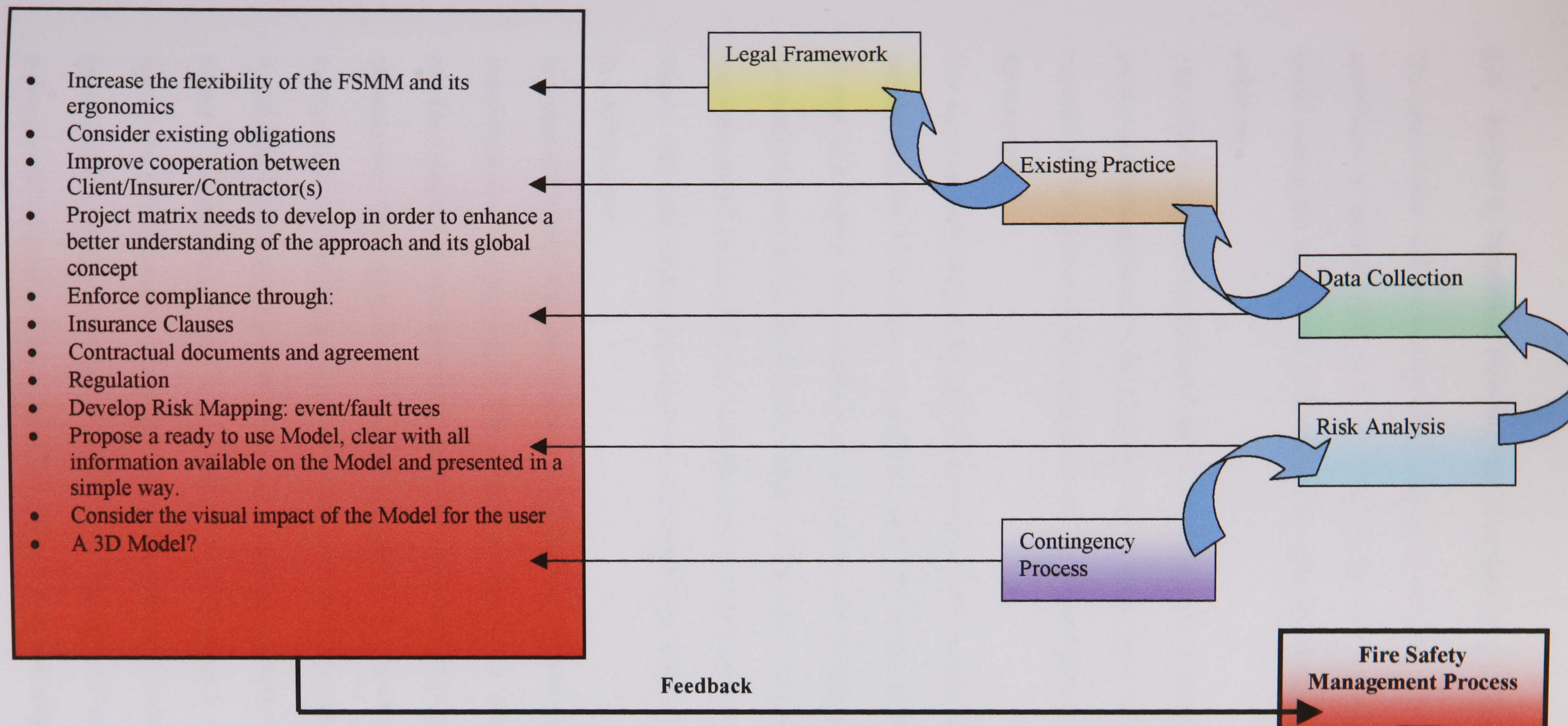


Figure 8.11: PhD Schematic Structure
French Expert Seminar / Model B

8.4 Model B: Modified Fire Safety Management Model (FSMM B).

The observation and recommendations extracted from the French Expert Panel Review contributed to greatly modified the existing FSMM and create an interactive Model which would answer the need of the professionals and targeted to the principal users: the client or employer.

The paper version developed in Model A presented a lot of inflexibility in its design. Based on the recommendations of the Expert Panel in France and their observations, the author remodelled the framework in a more dynamic way, allowing more changes and flexibility on the structure.

One key issue addressed on the day of the expert review, was the idea of developing a project management tool in the shape of a project matrix. This matrix could then be developed in 3D or with multi-layers. The complexity of the process and the approach required a much more thorough analysis and in-depth format. Based on the idea of a project matrix, the FSMM A was redeveloped and modified to fit within a matrix. The Table 8.2 below showed this Project Matrix. The same information have been transferred from Model A to Model B but presented in a different way.

In a second moment, the idea of risk management was developed in parallel to Model B to complement our existing matrix. The concept of construction fire safety as it stand, did not provide a proper risk management approach in construction and certainly not a systematic risk management. The role insurance companies played in raising awareness and promoting risk management was significant but not systematic. It seemed that only major projects and clients would benefit from this approach, especially when organisations transfer major risks to their insurer. The extensive work of reinsurance in developing a detailed risk management framework for their major clients demonstrates a raise of concern. The existing fire safety framework was mainly developed and implemented through the Joint Code of Practice for fire prevention (JCOP) and provided only a short paragraph and reference to risk management.

Three key issues emerged from this analysis:

- The need to develop a more extensive and flexible fire safety framework
- Systematic risk assessment and the implementation of a proper risk management strategy
- Integrated fire safety model within the existing framework

Table 8.2: FSMM B (Fire Safety Management Model)

FSMM	Conception	Design	Execution	Construction	FEEDBACK	Exploitation	Maintenance	FEEDBACK	Renovation Refurbishment	FEEDBACK
Continuity System	Risk Analysis Core Activities	Propose BCP Implementation	Implement Project BCP	Audit and Test BCP		Existing BCP	Review and Modify BCP		Review and Modify BCP	
Recovery System	Risk Assessment	Propose DRP Implementation	Implement Project DRP	Audit and Test DRP		Existing DRP	Review and Modify DRP		Review and Modify DRP	
Active System	Assessment Fire Hazards Risk Ranking Fire load	Propose Fire Protection Plan (FPP)	Risk Management Programme	Implement FPP: Passive Measures Active Measures		Existing FPP	Review and Adapt Existing: Passive Measures Active Measures		Review and Adapt Existing: Passive Measures Active Measures	
Operational **System**	Risk Assessment Strategy	Propose Fire Safety Plan (FSP)	Risk Management Evaluation	Hot Works Permit FSP JCOP Compliance Review/Control/I nspection		Risk Management Programme	Hot Works Permit FSP JCOP Compliance		Hot Works Permit FSP JCOP Compliance	
Planned System	Risk Assessment Exercise	Company Safety Policy Contractual Agreement Insurance Policy	Risk Management Strategy	Risk Inspection Loss Prevention		Risk Management Strategy	Risk Inspection Loss Prevention		Risk Inspection Loss Prevention	

Figure 8.3: Risk Management Framework:

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Table 8.3: Risk Management Framework

8.5 Model C: Interactive Fire Safety Management Model (FSMM C)

Model B was sent to members of the UK Expert Panel for review and analysis. The same interim report was submitted to the UK members but the format of the FSMM had been modified in accordance with the recommendations of the French Expert Panel. A second expert seminar was then planned and the same structure of analysis was used for the UK and French seminar. The hypothetical scenario did not change and the evaluation form remains the same.

After reflection on the modifications of Model B, the author worked on the idea of a 3D model, a recommendation expressed by the French expert panel. Model B was now slightly more flexible and the idea of a project Matrix enhance the format of the FSMM. However, it was the intention of the author to develop a guide alongside the Model and transform the FSMM into a managerial tool for fire prevention in construction operations. A series of document to support the implementation of the Model was therefore developed. These documents provide some background on the Model development, key benefits, business key factors, as listed below:

Key benefits:

- ✓ Enhance fire safety awareness amongst construction participants: clients, contractors/subcontractors, designers/consultants, insurers/re-insurers, planning supervisor...
- ✓ Improve control over the level of fire safety during the construction process: new construction, maintenance, refurbishment/renovation...
- ✓ Minimise business interruptions and the impact on the normal running of business
- ✓ Provide a business continuity throughout the building life cycle and its sustainability

Business key factors:

- ✓ Better Business Environment: modify organisational structure, enhance strategic objectives, improve legal framework
- ✓ Improve Business Strategy: project risk management (project management, safety management, business management) and risk identification
- ✓ Reduction and Control of Business Interruption
- ✓ Control of the impact of damages to life, property and the business as a whole

Key areas of focus:

- ✓ Failure scenarios and lessons learnt from their critical analysis.
- ✓ Expert reviewers advice and recommendations to enhance Fire Safety Management Model and the overall approach

8.5.1 A step-by-step guide to use the Interactive Fire Safety Management Model

In order to support the implementation of the FSMM in organisations, it has been necessary to develop in parallel to the FSMM a set of guidance and notes on the use of the model and the interrelationship between the systems and plan, and the risk management approach. A step-by-step guide was developed and is presented below. **The full links of the FSMM integral framework can be explored in the CD-ROM provided in Appendix C.**

Step 1: Project Specifications

Conception

Collect Project Data and Specifications

Go to Project Specifications

Go to Legal and Contractual Obligations

Step 2: Risk Management

Two important activities in a system for fire prevention are fundamental to fire safety management:

- the collection of information about fire risks; and
- the analysis and summarising of this information.

Go to Risk Approach

Conception

Carry out a Risk Assessment Exercise to determine a Risk Management Programme

Devise a Risk Management Strategy

Go to Risk Management Framework

Go to Response Structure

Step 3: Project Safety Case

Build up a project safety case to support the organisation's safety management

Go to Project Safety Case

Operational

Define your Health & Safety Plan and separate Fire Safety Plan

Go to Management of Construction Safety (Croner's Guide)

Go to JCOP for Fire Prevention on Construction Sites

Active

Develop a Fire Protection Plan supported by a proper Fire Safety Management Strategy

Go to Management of Construction Safety (Croner's Guide)

Design a contingency plan to cope with Disasters (fire, flood, lightning, shortage of supplies…)

Go to Contingency Plan

Continuity

Develop a Business Continuity Plan to avoid and control business interruption

Go to Contingency Plan

Step 4: Risk Log and Record Keeping

Keep adequate records of a very wide range of fire safety related actions.

Go to Fire Safety Log Book (FPA)

Step 5: Action Plans

Devise some Action Plans to improve fire safety and enhance its full integration within the project life cycle.

Go to Action Plans

The Fire Safety Management Model considered a global approach towards fire prevention on construction sites and for a given organisation. The set of requirements highlighted in the Model were generic and will greatly benefit from being refined and adapted by the organisation using it. However the framework proposed in this research must be considered in full, from the conception of the project, its construction and finally throughout the stages of life cycle of the property: maintenance and refurbishment. It is a perpetual Model, flexible and adaptable to change. The critical analysis is summarised in Figure 8.12.

8.5.2 FSMM's Schematic Framework:

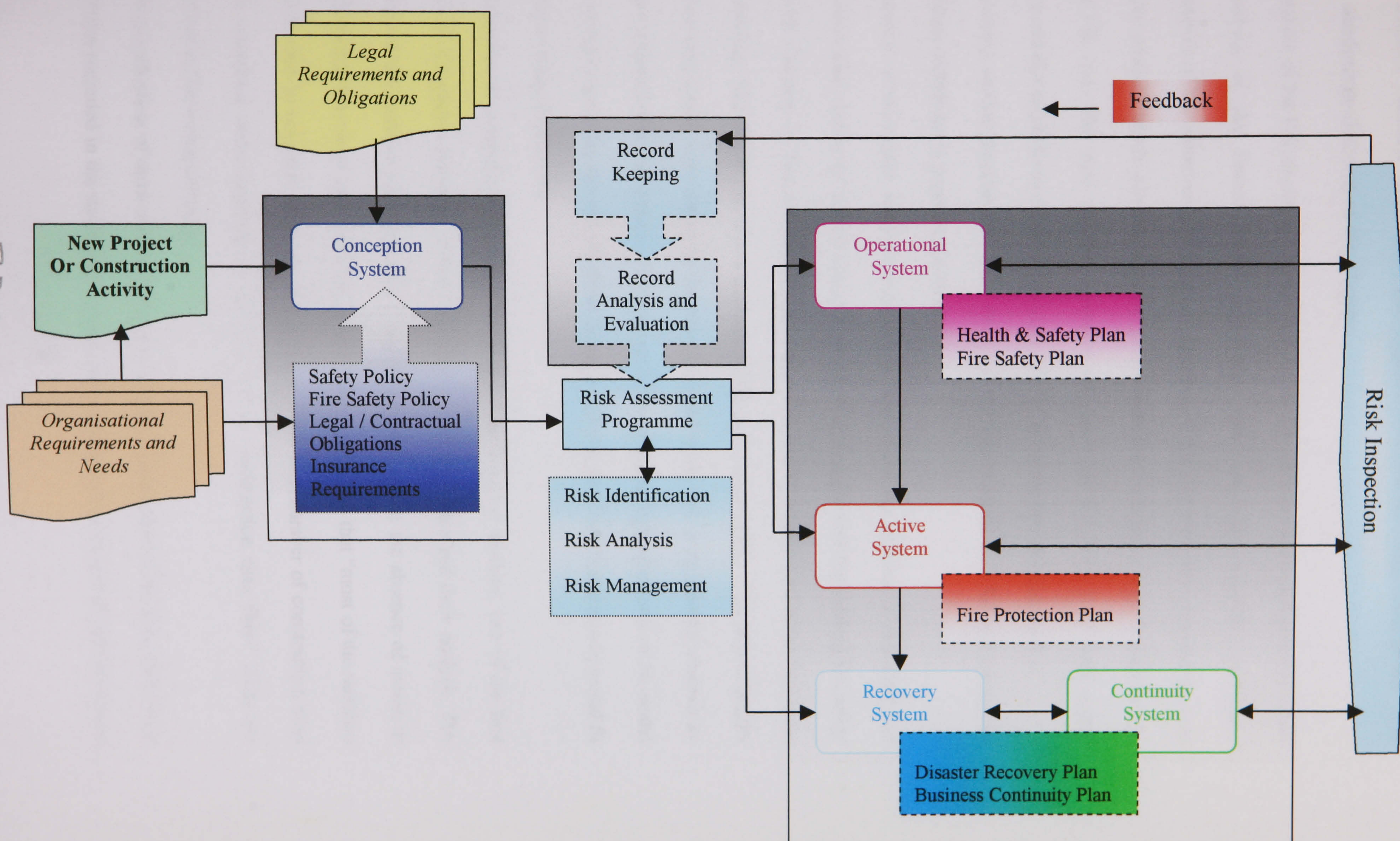
To demonstrate the interrelationship between each phases and risk assessment and management is articulated within the global strategy, the author prepared a schematic framework represented in Figure 8.13.

Model C was then sent to the members of the UK Expert Committee for review.

Figure 8.12: PhD Schematic Structure: Critical Analysis of Model B to develop Model C

Figure 8.12: PhD Schematic Structure
Complete Schematic Framework of FSMM

Figure 8.13: Schematic Framework of the FSMM



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8.5.3 Expert Review with the UK Expert Committee: the outcomes and recommendations of the Panel.

The members of the UK expert committee had equivalent positions and responsibilities from the members of the French expert committee: risks engineers, facilities managers, representative of the association of insurers, member of the fire protection association, loss prevention council. Much parallel can be draw between the outcomes of the French review and the UK one. The next chapter compares and contrasts the findings of both expert seminars and discussed these results against the FSMM structure and implementation.

The following section presents the outcomes of the UK expert Panel and analysed the results and did they contribute to improve the Model C.

The members of the expert seminars expected to learn about the problem of fire safety on construction sites, and to try to understand the mechanism lying behind the existing fire safety framework. Concern on fire risk assessment (Mapp and Lewis) were raised at the beginning of the meeting. The JCOP was also a concern (Mapp and Hautefeuille). The idea of profits and minimising losses were strong in the mind of insurers, as they were directly concern by the losses (Hautefeuille and Reiner). The concept of control and implementation of the model were a strong concern for the two facilities managers (Foley and Fisher) and how it would fit within the existing framework.

Categorisation of construction sites: Like in the French expert seminar, one of the first elements of discussion focussed on the collection of statistical data and their analysis. The argument for the need to move towards a qualitative approach in the absence of access to quantitative data was once again stressed. Lewis (FPA) confirmed that "most of the statistics on fires on sites in occupied buildings is lost. 80% of the total number of construction sites fires are classified under headings of industry, not as construction sites fires." Fires are recorded but in the wrong category.

Problem of **collection of data** and unavailability of a large proportion of the fires with losses £50,000 (not recorded in the statistics): Lewis (2001) confirmed, on behalf of the FPA that it was not possible to assess the total extend of the problem and total number of fires on construction sites. One difficulty raised by Lewis was the problem of recording of information by the Fire Brigade. There was pressure to simplify the fire investigation report and reduce its size. However the last modifications saw a simplification from 4 pages up to 12 pages (draft document). Moreover information were missing or misleading.

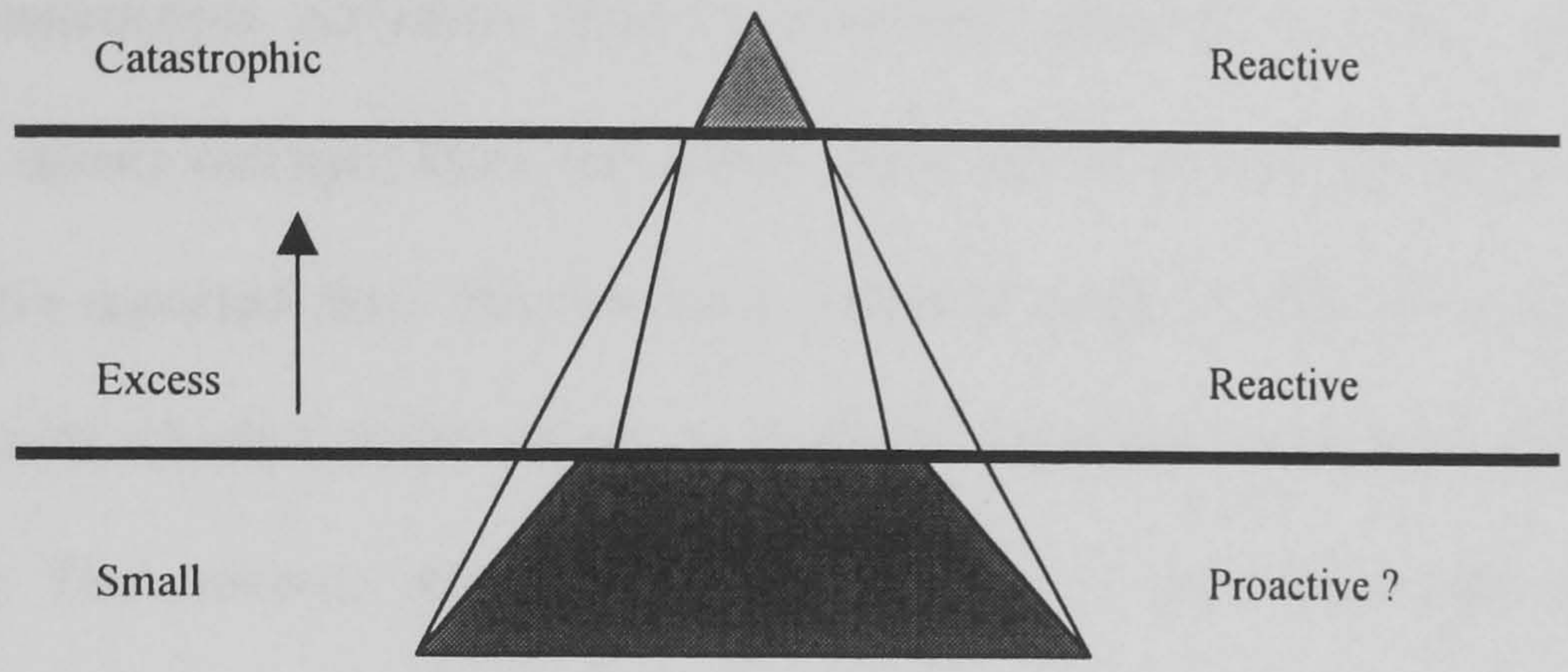


Figure 8.14: Distribution of fires: The 'Driver'.

This last point drove issues of qualitative dimensions to the fire and the research approach. The author early in the research approach decided to concentrate on a qualitative review and analysis of construction site fire scenarios and extract major findings which contributed to develop the FSMM. The qualitative framework of the model emerged from a lack of quantitative data.

This lack of statistical data and research on construction site fire safety proved the problem was not acknowledged corporately despite the JCOP compliance. The JCOP focussed on construction sites only, not maintenance phase. The definition of a construction site was not clear and there are difficulties to recognise a maintenance activities as construction works.

The author argued that insurance organisations did record enough data to identify a construction site, and use sub-categories to clarify the situation of the facility at the time of the fire. Also the type of insurance subscribed (CAR/EAR) helped to identify construction sites and extract the right information. Unfortunately, insurance archives were destroyed after two years and files were classified as soon as the claim was closed.

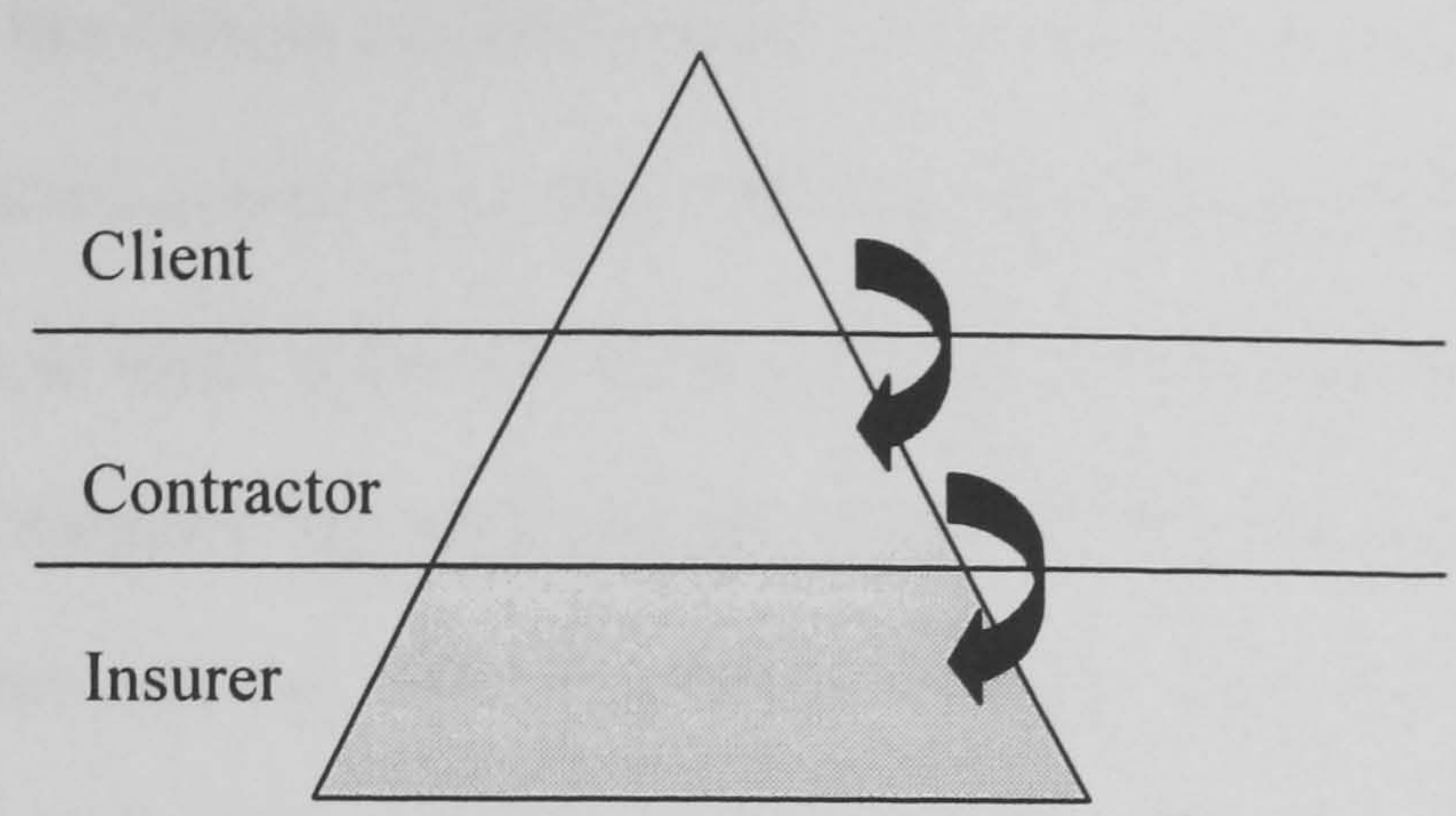
These elements explained the complexity of the problem and the research. **A case was built to examine the role of managerial and technical failures in fire scenarios** in order to develop a sound approach to fire safety on construction sites.

Need to **raise awareness**: Overall, the research findings collected in interviews and the outcomes of the construction fire safety failure scenarios revealed that organisations concerned in construction activities tend to overlook disaster recovery and business continuity. Other issues emerged from the cases and a list of lessons learnt was extracted. Hautefeuille (2001) reported that "the insurance industry finds it difficult to get clients to accept the higher bids which include risk assessment and a business continuity approach."

Risk assessment: The research also highlighted the lack of risk assessment and the non systematic risk approach in the construction industry. Mapp (2001) argued that the insurer has no influence on the design process and cannot be part of the full risk management approach. Design was a major cause of construction risks and construction cause unseen risks from design.

- **Business risk assessment**: Hautefeuille (2001) explained that "as soon as an employer hands over the contract to the contractor is not anymore liable for any sort of risks. There was a complete transfer of the risks to the contractor. It is down to the contractor to carry out a risk assessment during the building process." Mapp (2001) highlighted another problem linked to risk assessment and design. He reported that "the risk assessment process should start at the conception right through to completion, and the contractor can place risks which are created at the design process, by lack of awareness and vice versa."

The contract which enables to transfer the risks throughout the procurement route is an important tool in the fire safety management. The contract encourages transfer down the chain:



Transfer of risks

There was no obligation to carry out a risk assessment and the insurer couldn't put too much pressure on their clients to enforce it. The involvement of the Fire Brigade in helping to assess the risk was raised. There were again no obligations to declare the site to the fire brigade but on large sites, the fire brigade should be aware of the site and its layout. Reiner (2001) reported that the fire brigade was usually happy to inspect the site but the risk assessment needs to pull this. However Mapp (2001) argued that the Fire Brigade didn't always come when invited. The majority and small sites were not inspected. At a local level it is not clear although there is a high level of commitment. "the fire brigade visits relates to the weather. When the sun shines. When asked why, they answered that they don't want to bug down on site while an emergency call is issued." Reiner added that "it is a new element."

The author raised the minimal risk of life loss on sites which could explain the low involvement of the fire brigade on site. Reiner argued that they rightly focussed on life safety. Lewis agreed that "the fire brigade should be monitoring the high risks at areas and should make recommendations, and yes there can be potential for life loss on site, but where refurbishment and extension, the fire brigade makes inspection visits on request.

Implementing better **fire safety by design** was also one of the lessons learnt from the construction site fire safety failures. These issues limited the scope of the contractor to improve design to provide a higher level of fire safety as the contractor didn't have the control of the design phase and couldn't influence the design. The problem was therefore at the conception stage and in the hand of the client and its design team. The use of a different procurement strategy like Design and Build would allow the contractor to modify and adapt the design to his needs at a construction stage. However the cost implication was predominant and often led client s to reject a feasible project scheme. Lewis (2001) argued the need to consider a **fire safety engineering approach** and stated: "FSE is particularly relevant where fire protection systems can be made functional as work goes on. Passive systems is impossible on a daily basis." The use of a fire safety engineering approach for construction site fire safety was argued in chapter 2 of this thesis and the author concluded that the FSE method proposed in the BS DD240 (1997) had some limits into its application to construction sites. However the concept of qualitative design review was argued to provide valuable information for decision making at the conception stage. Mapp (2001) added that it was more and more common to use and installed temporary fire protection measures to ensure a minimum level of safety on site, combined with the zoning of the construction site in case of emergency. This technique would benefit from being further explore and analyse to see how it would fit within the existing construction process. Mapp argued for a move from prescriptive approach into performance specifications. However risk assessment may be neglected or misjudged and could lead to major consequences. Hautefeuille (2001) argued that a 'reasonable' risk assessment varies between viewers. There was **no consistent model across perceptions and risk assessment**. Consistency protocol was needed." This idea of protocol was supported by Mapp. Foley (2001) argued for the need to build in the impact of business matters more than cost of physical fabric at risk on site, and the concept of loss of income to the contractor. The author would like to see the promotion of a less adversarial stance and slow uptakes supported by a cultural change and Mapp added the value to agree benefits to implement the fire safety process. Hautefeuille (2001) argued the industry was under health and safety pressure with the CDM Regs and the implementation of EU directives. The industry seemed to provide a slow response to this change and still dealing with unknown investment issues, unknown liquidated damages.

The Expert Committee questioned the **real extend of the problem of fire on construction sites** and its threats to businesses. Reiner (2001) argued that fire was not the real threat for many projects, and insurance organisation consider flood also as a major problem. So "fire is not on the agenda." Reiner considered the Dusseldorf fire as "an unfortunate mistake" rather than a fire which was significant of the all industry. Lewis (2001) added that the 90s fires have been related to an economic cycle. This issue was also raised in an interview with the FPA Executive Director who stressed on the relation between high losses and a high value of the facility. In the case of Broadgate and Minster Court, they were unusual projects with a higher construction budget compared to other sites. The fact both fires happened at the beginning of the 90s might be hazards and if they had occurred in other circumstances, at other time it wouldn't have had such a major impact on the industry. Other EU countries like France and Germany (Reiner) didn't have similar problem, or maybe they didn't experienced major fires like in the UK. Reiner recognised that the Munich Re. has never been worrying about fires on German construction sites as with the UK. Mapp (2001) commented on the better waste management of sites since the mid-90s which could explain a reduction of fires. Hautefeuille (2001) argued the radical approach of the French system compared to the UK with high potential fines for non compliance with health and safety law. The UK safety seemed to be behind maybe due to **a problem of attitude,** or organisations were not facing the same threat. The JCOP addressed a problem at the time while it wasn't a problem in France. Moreover France had a different organisational point. It was a cultural issue and strongly linked to the legislative framework. The example of Japan (Hinks, 2001) demonstrated the **systematic improvement drive**. Risks were managed on a daily basis. The success of this approach was based a strong collaboration of the parties. A question emerged in the discussion: were we dealing with the lack of system in France which actually created a better situation, whereby in the UK we were trying to deal with problems which did not occur in France? "The UK is trying to put better system to solve the problem whereby the Japanese focus on avoiding the problem" (Hinks, 2001). Mapp (2001) commented on the "change of attitude of workers on site" and argued that an individual change of culture would be more efficient than a corporate change as the large proportion of fires are small fires and their source of ignition is down to individuals. The author insisted on the lack of penalties in the UK system compared to the French system, which motivates individual attitude and perception of safety. Hautefeuille (2001) insisted on the extend of the penalties at an individual level. The site manager has an individual responsibility of safety. Mapp (2001) argued for a need to pull out the issues in the JCOP which are directly related to the workers responsibility and those under the responsibility of the contractor, supported by the implementation of a penalty system. Hautefeuille (2001) argued for "a need to recognise the value of continued successful avoidance of incidents" and in a way promoting the charity donations as motivator to contractors. Unfortunately some of these systems encouraged under reporting or even competing to come at the bottom of the list (Mapp, 2001).

There was an interesting setting of regulations according to function (Mapp, 2001) and scope for insurers to reward compliance and encourage risk assessment, management and control.

The need to have a process for fire risk assessment for planners was an essential element of the success of a fire safety approach on construction sites. Mapp (2001) suggested the need to develop section 5 and 8 of the JCOP for risk assessment and "the lack of process" in the JCOP to support the approach. Mapp (2001) argued to "**think about a dynamic process of construction**" and the need for planners and designers to have their awareness raised.

The idea of **cultural change** to support the implementation of the fire safety process was discussed, especially coming from the top.

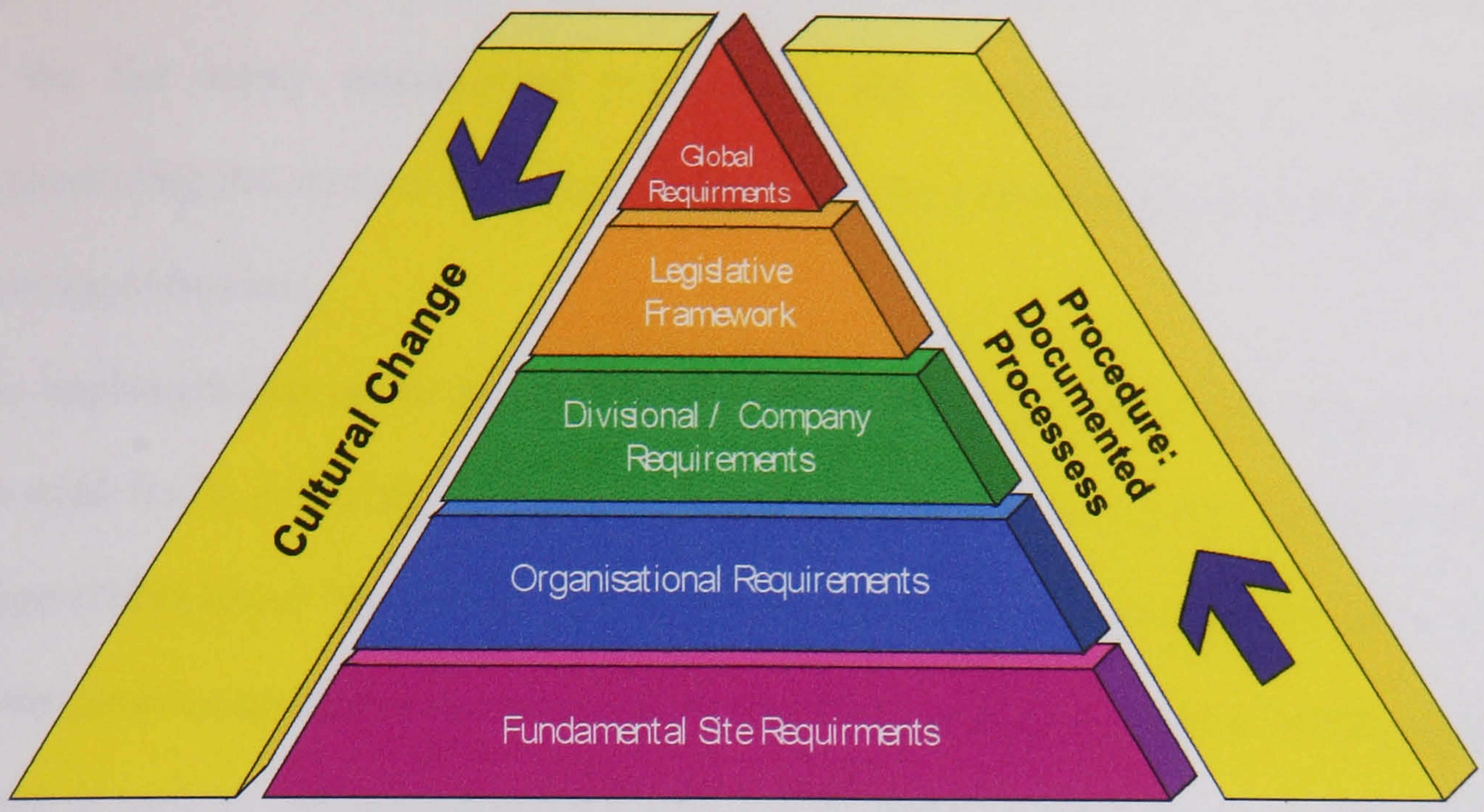


Figure 8.15: Corporate Cultural Change

The figure above illustrated the different layers of management and how they could activate change. Procedures and documented processes would come from the bottom of the pyramidal organisational structure up to the top. The total implementation of the process needed to be supported by a project management structure illustrated in the next figure.8.15.

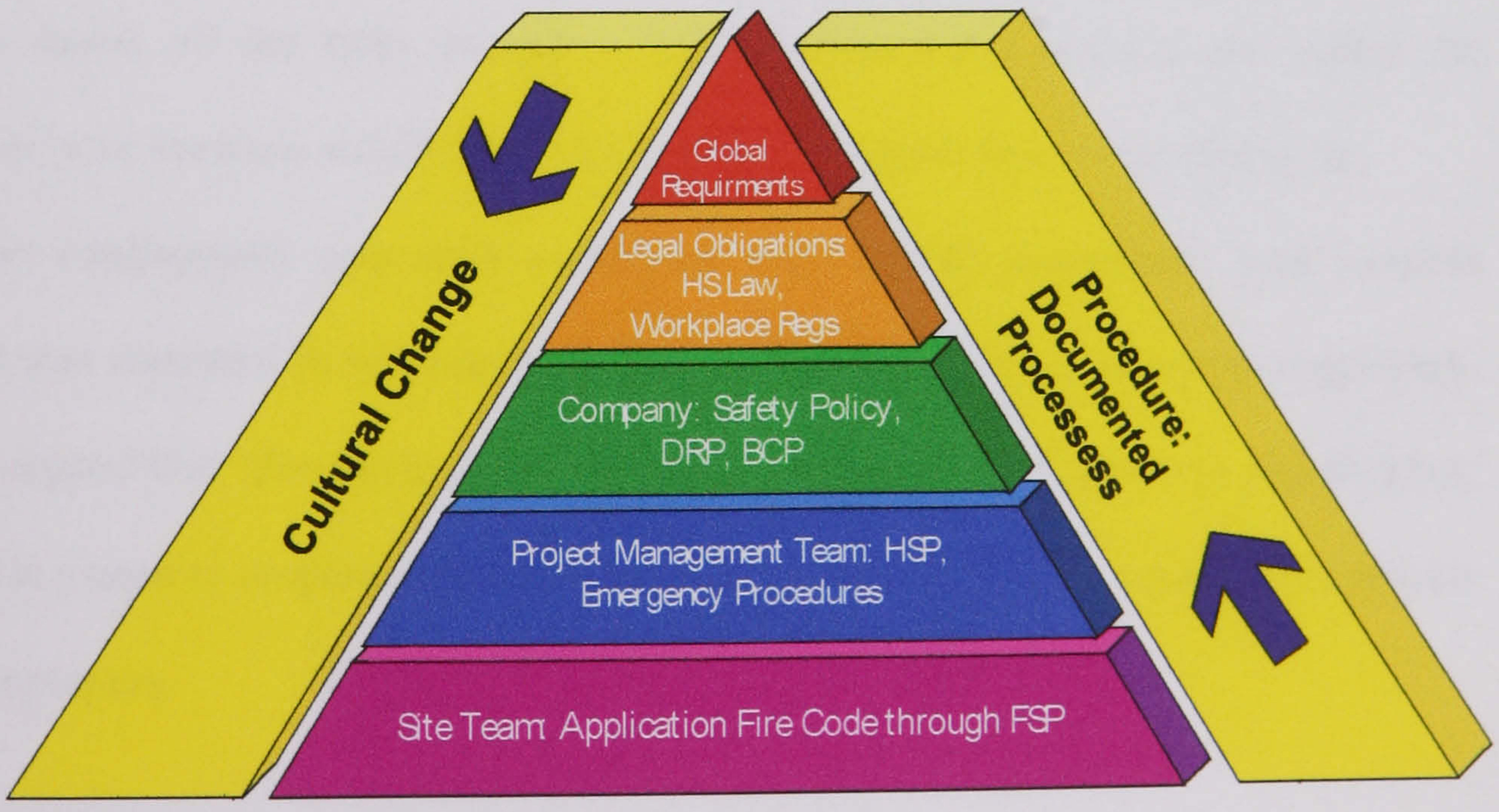


Figure 8.16: Operational Cultural Change

On the operational side, the management would be directly concerned by the implementation of the fire safety management process on site. Responsibilities for developing and implementing the systems and plans suggested in the FSMM are spread across the pyramid from top to bottom.

The implementation of the Model **calls for change in organisation**. Hautefeuille argued for the need for "a corporate decisions and push" to support the implementation of the model. Mapp (2001) added "the need for continual reinforcement." Fisher (2001) insisted on the role of the prime contractor in implementing the model at an operational level and the scope of the client to push to enforce compliance with JCOP. But how to be sure the contractor has the expertise to implement the process? Relying on another party to implement the process through the transfer of risks requires commitment, trust and control. Lewis (2001) suggested the idea of "certificate of competency" which is already applied in Scandinavian countries. The full process needs to be overshadowed by the client, because "if it comes from the employer, they have to do it" (Reiner, 2001). The **cultural change** needed the overall input of both the workforce and the management with a complete push from employers (Mapp, 2001). If the employer was to analyse the full facets of the risk properly and fully, then the knock on effects could lead to an adequate management of the risks. Mapp argued that there is a possibility to assess all the risks through a business continuity analysis and realise the potential losses your business would face if a construction related fire was breaking out.

The need for contingency approach combined with a risk assessment and hazards management was essential to implement a successful fire safety management approach. Hinks (2001) argued that "devolving risk to contractor would be a negligence to shareholders, and that there is a need to emphasis the implementation of the fire safety management process through the employers.

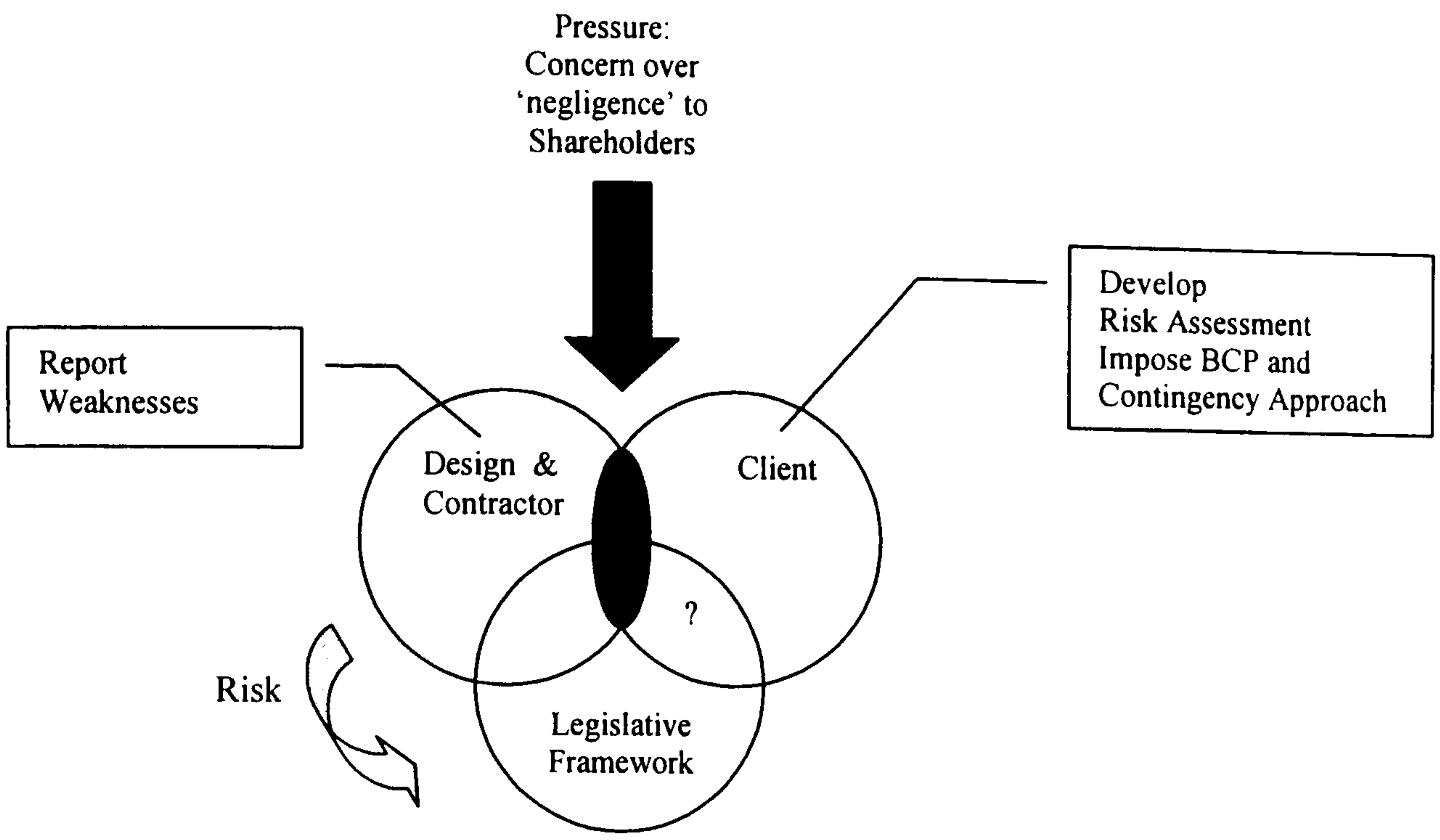


Figure 8.17: The effect of Shareholders Pressure

8.5.3.1 Recommendations:

The recommendations of the expert panel following the analysis of the Model in relation to the hypothetical scenarios were formulated and are highlighted below.

Cultural change:

i. **Individual and Corporate change** to support the implementation of the Model. The Expert Panel insisted on the key role of the employer in initiating the cultural change, supported by the insurer to control and inspect compliance with the statutory JCOP.

ii. **Global integration**: a change of culture from the top of the managerial structure, at a strategic level, to the bottom of the pyramid, at the operational level is required.

iii. **Operational level of the Model**: the Model will not work if it is not fully implement at an operational level and fully supported by the management at a strategic level. Investment into safety (both technically and financially) is essential.

Statutory regulations:

- JCOP: the JCOP was part of the existing structure and needs to be integrated within the framework of implementation presented in the Model.

i. The JCOP should be adopted as a tool
ii. However its use was limited (no use of section 5 and 8)
iii. Unfortunately it was applicable to construction only and does not offer enough flexibility for change and use in maintenance projects.
iv. No risk assessment process in the JCOP framework

- CDM Regs 1994: the JCOP overlapped with the CDM Regs and brought confusion on the duties and responsibilities of the parties in health and safety, and fire safety. The preparation of the HSP was a requirement of the CDM Regs and the FSP should be developed separately. The Model highlighted the overlaps and interaction of the systems and plans.
    - CDM limited to health and safety only.

Contractual agreement: compliance with JCOP was now compulsory under the JCTs contracts. However there were rules registering the bespoke forms of contracts and no requirement to comply with JCOP.

i. Very rigid, i.e. the JCT forms of contract
ii. Align a set of prescriptive requirements
iii. Should be bespoke forms of contact
iv. Requires compliance with JCOP

Insurance cover: the success of the JCOP implementation lied within the role of insurers in enforcing its implementation and compliance through the CAR and EAR insurance.

i. No legal rule to control compliance with JCOP
ii. Risk inspection (random of) and record keeping essential to formulate recommendations to improve fire safety management approach

Pre-qualification process and tender documents: much issues were raised about the need to set standards and problem of competencies of the contractors to develop and implement a sound fire safety process during construction activities. More control at a tender stage on the qualifications of the contractors, their internal fire safety management structure. Monitoring and control throughout the construction activities was also essential to ensure compliance.

i. Should highlights standard to achieve
ii. Introduce to top management rather than site management
iii. Recommends adoption of FSMM and the JCOP as a complement
iv. Formulate questionnaire and check list to control progress

Implementation of FSMM: Like the French Expert Panel, the UK Expert Panel recommended the implementation of the FSMM through the employer. Cooperation and collaboration with the insurer would be essential to sustain compliance with the JCOP and enforce risk management. There was still a need to convince employers of potential losses.

i. Through the client and the insurer
ii. The FM cannot be considered at this stage as the profession is not fully recognised by the industry
iii. Role of the planners in taking on the fire safety and using their pool of knowledge

FSMM linked all the partners together:

- Much concerns were raised on the overlap between the contractor/designer, the client and the insurer.

9 DISCUSSION

9.1 Analysis of the data and findings

The methodology followed to complete this research comprises five different stages detailed in chapter 5. The initial formulation of basic ideas through the development of the research proposal, the specification of research design after the literature review, followed by the fieldwork (site investigations), then the data processing and qualitative analysis and finally the writing of the final research report. The review and critical analysis of the fire safety management models through the two expert seminars were an excellent exercise to test the viability of the developed framework, the process of fire safety management during work operations and how the industry perceived the new managerial process.

The following chapter intended to summarise and discuss the research findings and explore future development works to enhance the use of the proposed fire safety management model. The author explored the depth of knowledge covered in this research and how the project contributed to knowledge. The views of the Expert Committees were related on the steps forward and the applicability of the FSMM as a component (along the RAMP and the JCOP) in executing a broader client and contractor-oriented push towards better fire safety on site and managerial attitudes. In the following discussion, the author provided a retrospective vision of the research and its findings which have been interpreted with "a wisdom of hindsight". The final chapter concluded the thesis and provided recommendations for future works.

9.1.1 Research Analysis:

As explained in the first chapters of this thesis, the research concept emerged after a lengthy literature review which revealed many gaps and a dearth of research in the field of fire safety management on construction sites. The comparison of legislative frameworks in the UK and France, and other EU countries, revealed a need to improve the existing framework and integrate the concept of fire safety as a separate element. There were many lessons we learnt from other countries and how their experience in fire safety can benefit our industry to prevent fires during the construction process. Certainly the proactive approach of the Canada in decentralising the legislative framework and offering more flexibility to adapt the national framework to local needs was a rational approach. The long term history of the US legislation for fire safety proved the importance of fire safety in the earlier part of the century, and especially applied to the construction of ships, which offer various engineering complexities (shape, function, type of risks, works in confined space, use and choice of material...). The pressure of the EU for harmonising legislation in Member States demonstrated the quality of a common approach and comparative process of development of the directives, and still allowing much flexibility for the implementation of the directives in Member States. The success of the implementation of CDM regulations (1994) in the UK and the 1994 Decree in France proved to increase the level of safety on site and redistribute the responsibilities equally between the parties. However the scope of the planning supervisor's EU regulation does not provide any direct recommendations for fire safety on site. The non statutory JCOP for fire prevention on construction sites seemed to have been a success but the lack of statistics on its use and efficiency limit the conclusions we can draw from its implementation in 1992.

The research first focussed on the construction industry and the current state of research in the field of fire safety. The author explored the possibility of using a fire safety engineering approach but soon realised the limitations of this method for fires on construction sites. A review and analysis of methods and techniques used in other industries, like offshore, chemical, ship building, revealed that some of the principles could have been transferred to a building process, but others were engineering based and didn't fit the construction principles. It has been necessary to go back to the basic principles registering the definition of construction sites in order to clearly assess the scope and boundaries of a site and explore the characteristics of the growth of a fire. The factors affecting the duration of the growth period of a fire taking into account a site characteristics were analysed and illustrated the complexity of the site, its geometrical change and how it affects the spread of fire within the construction facility.

The cycle of analysis and pattern of the research process in this thesis was sequential and interactive. The collection and display of data started with the management of these data, and in a second time with the data analysis. Storage and retrieval of data which is at the heart of the data management was enhanced by the use of strict classification process of raw field notes, transcriptions of interviews over two years and a collection of relevant documentation and materials. The use of the qualitative software to enable an easier analysis and pull out the relationships between data helped to explore the full strengths of the data and how they will contribute to build up the fire safety management model.

The outcomes of the critical analysis of the qualitative data and the formulation of a series of fire safety management models expressed the depth of the problem researched in this thesis and the benefits of implementing a fire safety process to prevent fires on construction sites. The series of schematic structures of the thesis, spread throughout this document, illustrates how ideas and findings contributed to build the FSMM and extract major findings from the complete research process. The process of critical analysis of the models was proved to be successful by presenting the results to two expert panels. The validation of the data was carefully thought through. However the scope of this research did not comprise the testing of the Model and in the conclusion, the author suggested that further research should be carried out to test the FSMM in industry and how it fits within an organisational framework.

9.1.2 Research Findings:

The **progressive research and accumulation of findings** in order to develop the FSMM have been critically analysed in the previous chapters. The way in which the findings contributed to build up the models are presented in chapter 7 and 8. The **results of the critical analysis** are highlighted in Figure 9.1 below. It is now the right opportunity to discuss those findings and see how they contributed to knowledge in the field of fire safety.

Figure 9.1: PhD Schematic Structure Critical Critical Analysis of the Research Findings

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This research assessed that unless the government and other safety bodies (HSE/HSC, FPA, ABI, LPC in the UK and the APSAD, OPPBTP, FFSA in France) implement **a protocol of data mining and analysis** and recognise the true extend of the problem, fires on construction sites will remain and continue to happen. The patterns of distribution of these fires will continue to deliver a large proportion of unknown and unrecorded small fires (<£50,000 /75,000), a series of medium size fires (>£75,000 to £500,000) and the unusual and exceptional large fires (>£500,000). This voluntary protocol of data collection could be compared to other statistical processes whereby accidents would not be recorded under an estimated loss (physical, financial, moral, and political). In trying to draw a parallel between construction site fires and car accidents, the government could have decide not to record accidents if no injury happened or no physical damages occurred. Such an approach would not permit an accurate assessment of the level of safety of the public roads infrastructure and would not enable the authorities in charge to make appropriate decisions on safety improvement without a true idea of the extend of the problem. Unfortunately today the author proved in this research that information regarding fires on construction sites were not collected because the current system does not allow for the collection of data on fires below £50,000 losses and/or where no injuries occurred, which eliminates a very large (and still unknown) proportion of the fires. Therefore ignoring the true facet of the problem the government is not in a position where he can react and take decision to improve the level of fire safety on sites.

The interpretation of the results obtained from the literature review to develop the prospective fire safety management model (Model A) focussed on three main issues:

i. The need for a **global approach** throughout the full life cycle of the facility and an Integral concept of fire safety

ii. The needs for **systems and plans** to implement the fire safety management structure within the existing framework

iii. The necessity of an **integration of a contingency process** in the fire safety management approach to ensure business recovery and continuity

Model A was presented to the French Expert Committee for review and analysis and the outcomes of this expert seminar revealed many weakness in the existing structure and the prospective model. The recommendations focussed on several areas: the structure and flexibility of the model, its integration within the existing safety framework, and the development of risk management framework throughout the full life cycle of the facility.

Based on these recommendations, Model B was completely redeveloped and its structure rethought through in order to address the recommendations of the experts. The objective was to present the second FSMM to the UK expert committee for a deeper critical analysis as the UK is more advanced than France on fire safety issues on construction sites. Model B addressed the recommendations of the French expert committee but did not provide enough flexibility and adaptability as required. The author worked on developing the model in a more interactive version using innovative graphic techniques. To enhance the presentation of the FSMM and optimise the use and display of information and their links with the research findings, the author decided to present the model in html format (used for web sites design). The results of this work was loaded on a CD-ROM where the users could explore the format of the FSMM, using the step-by-step guide and any supporting information linked to each phase of the development. Model C was created and presented as professional executive tool to raise awareness of fire safety during construction operation and offer to the user (employer/client, contractor/sub-contractor, design team, insurer…) a ready to use executive tool. The quality and depth of the qualitative analysis demonstrated the success the research concept and how the findings fit within the development of the FSMM and its relevance for the industry.

Many parallel can be draw from the observations and recommendations of the expert panels even if they each analysed two separate models. As our literature review confirmed, there is a dearth of research in fire safety on construction sites, and a need to focus on a qualitative analysis of the problem rather than moving directly towards a quantitative analysis.

The **life cycle concept of the FSMM** was widely discussed with the experts and they recognised that the innovative concept of the model lied within its integration throughout the full life cycle of the project. From an early stage of the development of the fire safety framework, the concept of phases (conception, execution, and exploitation) has been recognised, as well as the translation of these findings through systems and plans which interact throughout the process. The current legislative framework for safety on construction sites focuses on health and safety matters during the construction and refurbishment (execution) periods and tends to ignore other site circumstances (maintenance operations). The FSMM aimed to address the problem of fire safety throughout the full life cycle of the project, from conception through execution and exploitation.

The **adoption of the FSMM as part of the Employer's risk assessment / risk management strategy** encourages them to consider the construction project as part of their on-going business activity will encourage Employers. It relieves the "mental block of having a fire" and they accept that their businesses might be at risk which would affect the continuity of the business activities for all parties. The role of the insurer in enforcing this new fire safety concept on construction sites already proved to be successful with the development and implementation of the JCOP in the 1990s. The **integration of the concept in the existing safety structure** (legislative, contractual, perceptual, social, political, financial, and economical) would be an essential factor to enable the organisations to adopt the FSMM as an integral organisational tool. The **implication of cost and finance of fire safety of**

construction operations was a major issue as there is still a general belief that safety should be improve but it shouldn't cost.

The underlying rationale of Business Continuity is to prevent a crisis occurring either through proper identification of risks. Where these risks cannot be recognised or quantified then plans need to be put in place to overcome these unplanned interruptions. Planning a response to the eventuality of a disaster is not a simple task. The concept of the FSMM aimed to promote the importance of the contingency process for fire safety on construction operations. The review and post analysis of construction fires and their failures proved that organisations involved in the fire incident were not ready to respond to the disaster on time. The impact on their businesses proved the lack of awareness and poor managerial approach to cope with fires during the construction process.

The **protocol of risk assessment** presented in this thesis was proved to be unrefined and lacking in perception. The expert panel defined it as "coarse" and lacking in perception and depth, and providing a loose framework. The lack of quantitative data to sustain the implementation of a risk management framework for fire prevention on construction sites restrains the development of sound risk framework. Reliance on qualitative data could be argued. However the concept of risk assessment cannot be rejected and therefore was integrated in the FSMM. The weakness of this risk concept lies within the links and overlaps of systems and plans from construction stage to the facility in-use as it might require the reformulation of risks and hazards depending on the stages of the development and life of the facility. The research investigations also revealed that the parties to a construction contract rely on their insurance cover (CAR/EAR) to respond to the disaster, ignoring that money cannot always repair the damages. The interruption of a business activity could lead to a loss of the market share and forthcoming contracts, as well as the public image of the organisation like for Bovis in 1990s.

An attempt to use a fire safety engineering approach for construction sites proved to be limited. However the **design process** is closely linked to the fire safety strategy. The early commissioning, of protection systems and the use of temporary fire safety measures combined with the choice of materials was put forward as good practice to prevent fires on construction sites. The validity of a qualitative design review was assessed as a successful method to enhance design and conception of the facility. Construction fire safety was seen as a separate to fire safety design issue to the design solution for finished buildings to reduce fire risks through an engineering approach (FSE approach).

9.2 Evaluation of results and their significance

Attitude to risk in construction was mainly affected by two factors. The first was the awareness of the possibility of a catastrophic event to which all employees are exposed. The second was the extent to which individuals, both employees and employers, believe that they are capable of controlling the risks that they face. The management team will have an active role throughout the whole project. The qualitative analysis and design of the FSMM contributed to identify significant findings and based on the results and interpretation of these findings the author generated recommendations and conclusions under an action plan. The action plan focussed on the following issues:

i. The integration of a Safety Culture
ii. The development of a Risk Management Approach
iii. The need to plan for uncertainty and risk
iv. The improvement of Collaboration and creation of a Partnership
v. The adoption of a Global Approach through an Integral Concept of Safety
vi. The need to develop a large scale Quantitative Analysis
vii. Enforcement of the Contractual Framework
viii. Enforcement of the Insurance Policy
ix. Enforcement of Risk Inspection on site
x. The reduction of Fire Risk through an engineering approach

Figure 9.1 summarised the action plan and the needs for each of them.

Level	Objectives	Action	Needs
1	Integrate a Safety Culture	Ensure safety is integrated in the organisational strategic objectives of the enterprises	Change safety Culture Develop a Safety Policy and Fire safety policy
2	Develop a Risk Management Approach	Develop and implement a Risk Management Programme for each project and by each party, either independently or in partnership.	Implement a Risk Management Strategy Develop a complete Risk Assessment Strategy
3	Plan for uncertainty and risk	Integrate planning procedures and models within the organisation, be prepared for change, and identify potential failure activities.	Plan for Disaster and prepare DRP: crisis management, salvage plan, disaster response... Implement a proper BCP to respond to business interruptions.
4	Improve Collaboration Create a Partnership	The dearth of collaborative initiatives on large and complex projects enhanced failures and participated to increase fire risks.	Regulate the balance between power, influence and risk between the parties.
5	Adopt a Global Approach through an Integral Concept of Safety	Develop a Project Safety Case at the conception stage and ensure the transfer of this approach throughout the other stages.	Improve existing safety concept (CDM Regs) and integrate fire safety approach in existing framework.
6	Develop a large scale Quantitative Analysis	Record keeping and analysis should be a systematic approach on site. The Project safety Case should specify how information and data should be compiled and analysed, and the results interpreted and feedback to the organisation.	Record data and centralised statistical data collection. Uniform sources of information and collection strategy. Analyse and interpret data. Develop research & development.
7	Enforce Contractual Framework	Enforce Contractual requirements and obligations	Modify standard form of contracts and regulatory requirements in fire safety on construction sites.
8	Enforce Insurance Policy	The role of the insurance companies to enhance safety culture on-site proved to be effective and will need to be sustained to benefit from safety in the long term.	Better involvement of insurers in the project development. Systematic fire survey reports for construction sites. Record keeping and action plans.
9	Enforce Risk Inspection	Systematic risk inspection and risk recording would improve risk analysis and evaluation.	The collection of quantitative and qualitative data to enhance the risk assessment process and modify current practice to prevent fires on construction sites.
10	Reduce Fire Risk through an engineering approach	Choice of materials and equipment should be carried out to achieve a better level of safety by reducing the risk of a fire outbreak, its propagation and spread and its development on site.	Designers to understand the importance and need to adopt a systematic fire risk approach while designing the facilities to be built and used.

Table 9.1: FSMM's Actions Plan

10 CONCLUSION AND RECOMMENDATIONS

The objective in writing up this thesis was to pitch the account of the research to meet the expectations of the industry whose views have always been considered as important when it comes to evaluate the quality of the findings. The FSMM was an expression of this account and it was addressed in the industry. The author's editorial decisions have been shaped by the researcher's needs.

This PhD focussed on details on the qualitative data collected, the rigour of the qualitative analysis and its significance for the researcher, precision of the qualitative analysis and its research findings, the coherence of the research findings and outcomes and how they contributed to develop the FSMM for the industry and the originality of the research concept.

10.1 Summary of the research findings and their significance

This research formed a contribution to the knowledge of fire safety on construction sites and a leading piece of work on this subject. The evidence and originality of the research concept in tackling the problem from a qualitative approach showed new facts and delivered to the industry an independent set of findings which highlighted the depth of the problem (The full set of findings is available in Figure 10.1):

- Inadequacy of past research to reflect fully upon the factor affecting fire prevention on construction sites.

- A need to stimulate the industry to re-think their perception of fires on construction sites and integrate a proper and unique fire safety strategy to eliminate and control fires during construction activities.

- The recognition of the increasing value of qualitative studies to enhance managerial approaches for construction project management and an emerging attempt to determine the cultures of the industry.

- Integrate a fire safety concept in organisations through the implementation of fire safety strategy to prevent and control fires on construction sites.

- Adopt a Global Approach through an Integral Concept of Safety by adopting the FSMM as an executive tool to integrate the fire safety management strategy.

A qualitative development model was created from the research analysis and related findings and offered to the industry an executive tool developed from an analysis of construction fire safety failures.

However the research also identified major outcomes articulated around the need to:

- Modify and adapt Legal Framework to integrate the fire safety strategy and allow for change (Calls for change).
- Analyse and Improve Existing Practice to allow the integration of the FSMM and its concept.
- Develop a protocol for Data Collection to support quantitative studies of the problem.
- Implement systematic Risk Analysis and need to have a process for fire risk assessment as an essential element of success of the fire safety approach.
- Integrate the concept of Contingency Process combined with a risk assessment and hazards management.

	Literature Review	Cases and Post Fires Analysis	Professional Interviews	French Expert Seminar	UK Expert Seminar	Observations
Consider existing fire safety requirements	V					Flexibility of fire safety framework for adaptation to changes
Integrate Model within existing safety framework				V	V	Strategic implementation of the concept in organisations
Definition of a site and its boundaries	V	V	V	V	V	Essential ingredient of the research concept
Need for a change of managerial culture	V		V	V	V	Integrate a safety culture approach in organisations
Dearth of research in fire safety on construction sites	V					Inadequacy of past research to address the problem in details
Limited scope for the use of FSE method	V	V		V	V	Complexity a nd constant evolution of a site
No reliable statistics on fires on sites	V			V	V	Lack of quantitative data on fires
No possibility to develop quantitative analysis	V				V	Lack of cooperation of industry
Disparities in the collection of information and data	V		V		V	No coordination of collection of information
Lack of awareness of the extend of the problem	V	V	V	V	V	Is there a problem...?
Need to move towards a qualitative analysis	V		V		V	Research revealed the validity of a qualitative approach
Risk analysis limited by the access to reliable data	V			V	V	Limited scope of a quantitative risk analysis
Assimilitation of fire prevention measures into mangt	V	V		V	V	Need for a project management approach
Need to develop a Project Safety Case	V					Integration of fire safety approach in existing framework
Inadequate analysis of the business threats and impact	V	V		V	V	No recognition for contingency issues
Need to include an analysis of the needs for business recovery	V	V		V	V	No recognition for contingency issues
Need to consider a contingency approach	V	V		V	V	No recognition for contingency issues
Scope to develop a global fire safety management process	V			V	V	Lead to the develoment of the FSMM
Need to create a Fire Safety Management Model	V	V				An executive tool to enhance fire safety and prevention on sites
Assess the legal and managerial failures in post fires cases	V	V				Analysis based on failures scenarios
Create a flexible, adaptable and global FSM framework				V	V	Adapatble to change and the fit the structure of organisations
Weakness in the existing fire safety structure	V		V	V	V	Limited scope of JCOP to address the full extend of the problem
Lack of practicality of JCOP			V		V	Depth of the JCOP to be refined an improved
Need for the pressure of insurers to enforce compliance			V	V	V	Role of insurers in enforcing implementation of the FSMM
Low investment into safety			V	V	V	Raise the profile of fire safety on sites
Need for contingency planning				V	V	Approach through Business Impact Analysis
Improve design decisions at conception stage		V	V	V	V	FSE method and QDR address some of these issues
Develop a risk management strategy		V	V	V	V	Limited by lack of quantitative data
Reinforce control and management on site		V		V	V	Implementation at an operational level to support full concept
Develop and implement a fire safety strategy		V			V	Strategic implementation of the concept in organisations
Preparation of contingency planning for site activities and BC	V	V	V	V	V	Approach through Business Impact Analysis
Need for a global approach throughout the full life cycle				V	V	Integration of the concept from conception to exploitation.
Develop an integral concept of fire safety	V			V	V	Strategic implementation of the concept in organisations
Needs for systems and plans to implement FSM structure	V			V	V	Concept of fire safety developed through plans and systems
Need to ensure business recovery and continuity				V	V	Approach through Business Impact Analysis
Integration of contingency process in the FSM approach	V			V	V	Approach through Business Impact Analysis
The implementation of the Model calls for change				V	V	Need for corporate decisions to support implementation FSMM

Figure 10.1: Matrix of Research Findings

The **innovative concept of this research and the recognition of the validity of the findings** were a successful outcome in the light of the expert committees. The final FSMM was a success and the different phases of reshaping and restructuring of the original concept expressed the depth of the problem for the industry. Even if the scope of this research limited the testing of the model with the industry, the quality of the expert panels and their experience in construction industry and fire safety issues provided to the research an excellent critical analysis and review of the outcomes and findings. The author realised the need to pursue this research and enhance the performance of the model by fitting the concept within the existing safety framework and the industry and test the viability of the approach in organisations. The **implementation of the concept and approach at a strategic level** is essential. Cultural issues have been argued and the need for cultural change was demonstrated through the qualitative analysis. The **recognition of the need to implement the model throughout the organisation**, taking into account the existing organisational concept of safety, was strong and the role of the operational branch of the organisation necessary to implement the model during construction operations. Figures 8.15 and 8.16 illustrated this concept: Corporate cultural change / Operational cultural change.

These **"calls for change"** have been completely recognised in this research, by the author and the industry through the interviews and the expert panels. The need for fire safety on construction sites was even greater in France as the industry fire safety concept is behind compared to the UK (JCOP implementation, JCT form of contracts and the Fire Code). On the other hand the UK industry could learn from the French approach especially in considering the implementation of a stronger health and safety structure. The implementation of EU directives is actually an excellent response to the need to harmonise safety framework and how to benefit from good or best practice from other EU member states.

The research **revealed that the transfer of information and the fire safety concept from a phase to another one** was proved to be difficult and to maintain a high level of safety one entity should be in charge ("the lever") to enforce its implementation (the client/employer with the support of the insurer and the cooperation of the contractors and sub-contractors).

The FSMM is **an executive tool to enhance fire safety management** during construction operations and raise awareness of employers and contractors in developing a fire safety management approach along the line of the existing JCOP and health and safety requirements. Through the qualitative research, the author demonstrated a need to investigate the problem and the roots of the failures. A lack of cooperation of the industry and the government in providing adequate information and data on fires on construction sites, and the lack of awareness of the industry on the depth of the problem, limited the development of a quantitative analysis. However at this stage of the research and looking back at the findings and outcomes of this PhD project, the author would like to suggest the validity of a quantitative approach now that the ground and strengths and weaknesses of the problem have been assessed and discussed in this PhD.

The value of this research lies within:

i. The synthesis of information and the presentation of the findings through a fire safety management model in an innovative and interactive manner (CD-ROM) to ease access to information and its use.

ii. The idea that a consensus between experts from different background was reach.

The research hypothesis was based on the concept that the JCOP did not provide a satisfactory level of control over the construction works, and that **a managerial framework needed to be developed in parallel to support a free fire environment** on site and address the fire safety management during the complete life cycle of the project: conception, execution and exploitation. The **implementation of a fire safety management system needed to be encompass by a cultural change** in organisation to support the full and successful integration of a total fire safety concept.

This hypothesis has been demonstrated and the Fire Safety Management Model encompassed the strengths and weaknesses of the research findings. It is agreed that the JCOP was an essential element of the framework and the objective of the FSMM was to act as an executive tool to enhance the implementation of a fire safety framework in organisations. The implementation of this fire safety concept for the prevention and control of fires during construction activities should be established at a corporate level and implemented at an operational level. The integration of this concept required a change of organisational culture. The model needed to be tested in organisations to shape it and adapt it to the needs of each individual structure.

10.2 Dissemination of the results

Strong links have been established with the industry and amongst the collaborative establishments, some organisations expressed their interest in developing the research further and look at the integration and testing of the model in industry.

The significance of the research findings and their interpretation will need to be refined in the future and the author stressed on the importance of disseminating the results to the industry. A series of professional seminars in the UK and France is already planned and the publication of research papers forthcoming.

The international character of the study and its focus on British and French practices suggest that primary data will be disseminated in Europe. However this research being unique and leading in the field of fire safety on construction sites, other industries would benefit from the results and interpretation of the findings. The Canada and US could perceive this research as a major step forward towards the improvement of fire safety in construction activities.

10.3 Recommendations for future work

The ground of the research and the significant failures of the existing fire safety system have been assessed in this thesis. The scope of the research was limited to a detailed qualitative analysis and it is hoped that further research will lead this field towards a large scale quantitative analysis.

The author would like to stress the importance of the primary qualitative research which enabled the industry to realise the potential dearth of research and the extend of the problem. Without this leading research, the industry would still be at a standing stage and ignoring the true identity of the problem.

The recommendations for future works are as follow:

i. To raise awareness by disseminating the results of this research to the industry and the need to implement a fire safety concept and the FSMM along the side of the existing JCOP. The author is already planning to launch a fire safety campaign to raise awareness amongst contractors and insurers and their clients.

ii. To test the FSMM in industry by developing industrial projects with major contractors and clients involved in construction activities. The collaboration with members of the Expert Committees provided strong links with businesses to disseminate the FSMM.

iii. To develop a large scale quantitative analysis which will lead towards a fire safety engineering approach. This research requires the full cooperation of the industry in providing access to data and fire scenarios. The insurance organisations and insurance bodies would be in an excellent position to initiate and support this type of research.

iv. The transfer of knowledge from the construction industry to other industries (offshore, chemical...) needs to be explored to enhance the use and implementation of the fire safety concept presented in this thesis.

10.4 Final thoughts

It was not a hazard or lack of work if the research took five years to be complete. The restricted access to publication on the subject and availability of statistical data to support the development of a quantitative analysis was a major barrier in the first years of the research. The lack of robustness of the data from the industry and their lack of cooperation by ignoring the problem of fire safety on sites forced the author to shift her research methodology towards a qualitative research concept. The success of this research concept was widely proved and demonstrated in this thesis, but the author wished more cooperation between industry and academia was made to enhance research and development in this field. The willingness of the industry to improve fire safety on site is obvious, however information sharing is not systematic. The cases used in this thesis were issued by various organisations which accepted to collaborate because they recognised the problem as a major issue for their organisations. The strengths of this research lies within the strong relationship the author developed over five years with members of the industry and their willingness to be part of a leading research in fire safety on construction sites. An earlier collaboration with industry would have been a major benefit in this research and would have widened the scope of the research, the testing of the Model and why not its implementation in organisations.

10.5 Lists of recommendations

- To develop the use of a qualitative approach in construction industry: The richness of the qualitative analysis for this type of research and the high quality of findings and how they contributed to formulate the FSMM.

- The implementation of the concept described in this thesis should be forward by the industry in order to enhance fire safety on construction sites and prevent fires from occurring. The concept of contingency process is a strong selling point if the industry recognised the importance of business continuity to sustain their organisational survival.

- To develop a stringer relationship between the industry and academia to allow the multiplication of this type of research, not only in the construction industry but in other industries such as off shore, chemical, nuclear, etc. where high risk of fires during construction operations could lead to major disasters and a business interruption.

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Other EU countries:

The next part of this chapter will be concentrate on an analysis of the Fire Safety Framework in other Member State on the EU. Each of them will be compared with the UK Framework outlined above. Where international construction is concerned, Bunni (1991)identified four major groups of legal systems. Two of these are the common law group, applicable to the UK, and the Roman-Germanic group or civil law group as its is also called, which includes Spain. Two principle distinguishing features of the civil law group exist. Firstly, the division of private and public law. Within public law, administrative law covers public works contracts, while private law applies to contracts between individuals and legal entities. Secondly, the codification of law, or the "law of the book" as Nicholas (1992) calls it, whereas common law is largely a law of the case created by the courts. Klimit (1998) (observes that the English system has become more and more codified in recent years, for example, with legislation such as the CDM Regulations, the Arbitration Act and the Construction Act (Bunni, 1991). Though as Bunni (1991) notes, once an Act comes into force, and then becomes a matter of dispute, interpretation in the courts will provide precedents which become law itself.
Countries within the civil law group also have distinguishing features, for example the adoption by some, to varying degrees, of the Napoleonic Code, which in the European Union includes Spain, France, Belgium, Holland, Luxembourg, Italy, and Portugal (Bunni, 1991). In contrast, others such as Germany have adopted a different code. In addition, there may also be variances in the meaning of certain legal terms (Nicholas, 1992). Given this different source of law, the interpretation of legislation can be different in the two systems. English courts may see legislation as an inroad on the basic written law found in the decisions of the courts and interpret it restrictively, whereas legislation for the civil law group is the basic law itself. Legislation drafting, particularly as in the Civil Code, can be different in approach as well. For example, the civil law group simply tries to establish a framework for the law to provide a judge with guidelines to form a decision. In contrast, the English drafting is often complex and aims to provide solutions to disputes by trying to anticipate every eventuality. This is traditionally true for the drafting style of construction contracts, for example the JCT forms (Fundacion Tomas Moro, 1999). Much of Spanish construction legislation though, while retaining a general simplicity, can be very specific and procedural.

The Legislative situation in Spain:

The Spanish Constitution, the highest point of authority, was approved in 1978. It defines the form of government, the powers of the Head of State and Executive with respect to Parliament and also Fundamental rights and freedoms and their protection (Spanish Constitution, 1978, Section VII). The Constitution recognises seventeen Autonomous Regions, *Comunidades Autónomas*. These have extensive legislative powers in addition to those at state level. Judicial power extends from local, then municipal courts, through to the courts of first instance and finally to the Supreme Court (Almaraz & Sanchez, 1999).
In the Spanish Legal system, it is essential to make a clear distinction between the Spanish Legislation and the Autonomous legislation. If the Spanish Legislation can be applied throughout the all country, the autonomous legislation in only applicable within the Autonomous Community which writes it and controls it. Spanish law is considered to be the most complex amalgamation of customary Roman, local and modern codified law. The Constitution also recognises local customary laws know as Foral Law, *Derecho Civil Foral*. The foral regions are Aragon, Balearic Islands, Catalonia, Galicia, Navarre, and Vizcaya and Alava (provinces of the Basque Country). Foral Law places the Civil Code in a position of a

supplementary but independent source of regulation, though not extending to contractual obligations (art. 13 CC).
Under the Central Legislation (*Las Cortes: el Parlamento y el Senado*), in the Spanish Constitution of 1975, *Las Cortes* are defined as the Legislative powers. In Spain, Law could be either made through the citizenship (at least 500 signatures required and submitted to the Parliament) or through the Government (proposal to the Parliament:).
Spain is divided into 17 Autonomous Communities (with an Autonomous Government and an Autonomous Parliament -*Parlamentos Autonomicos*) which are given by the Constitution some power to develop their own Legislation (*Competencias Trasladadas*).
There are two main pieces of law related to Fire Safety in Buildings:

- *Norma Básica de la Edificacíon – Condiciones de Proteccíon contra Incendios, 1991 (NBE.CPI.91)* (Spanish Parliament, 1991), which deals with the general requirements about Fire Protection in buildings.
- *Reglamento de Instalaciones de Proteccíon contra Incendios, 1994* (Spanish Parliament, 1994) (Fire Protection Equipment Regulation 1994) which deals with the requirements regarding any Fire Protection Equipment.

Figure 3.6 represents the Spanish Fire Safety Framework.

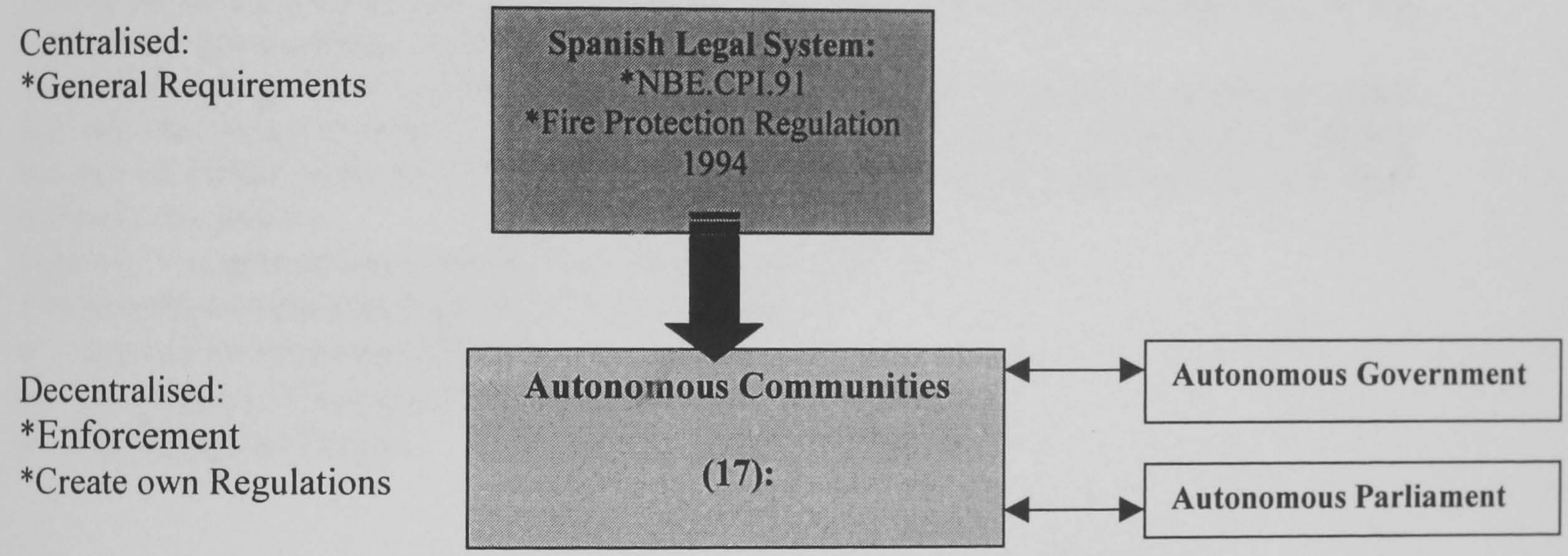


Figure 0.1: Spanish Fire Safety Framework

NBE.CDI.91 applies to all type of buildings that fall into the following categories:

- New construction
- Refurbishment and Renovation Projects
- Change of Use Buildings

NBE.CDI.91 intends to establish those conditions and rules to which buildings must comply in order to protect the occupiers from fire and to prevent damage to third parties. A range of appendix provides specific information for different type of buildings, i.e. Administrative Establishment, Commercial Properties, Schools, Garage and Parking, Hospitals, Hotel and Boarding Houses and Dwellings.
The Fire Protection Equipment Regulation 1994 describes the provision and standard of installation of fire protection appliances, equipment and systems.
The Legislation and Regulations fall into two main streams:

- The Protection against fire once the fire started
- The Prevention falls under separate regulations

The Spanish regulation encompasses all aspects of fire safety design. Regulations are compulsory and any deviations must be justified and make adequate fire safety provision. They are no reference about Control or Inspection throughout the legal documents.
The idea of decentralisation in Spain is very strong and the power of the 17 Autonomous Communities is not comparable to the UK Framework. On the other hand the Direct Cost of

Fire Losses is higher (0.25% of GDP) but Fire deaths per 100,000 persons are lower (1.19 against 1.41 for UK) (Geneva Association, 1997) and detailed in Table A.

The Legislative situation in Germany:

Power to Local Authorities is also an approach adopted by the German Government. Article Two of Germany's Constitutional Law says that "Everybody has the right to live and to live unharmed" (Stein, 1997). All Laws and orders concerning fire safety are derived from this Article. Fire prevention and Fire Safety in Germany is covered in Federal State laws. One is the Building Regulations (*Bauordnung*), and the other is the fire service law (*Feuerschutzgesetz*).

The basis of the building regulation in Germany is the *Musterbauordnung*. This model is prepared at the Federal level and gives guidelines for the separate regional building regulations (*Landesbauordung*) which are issued by each Land. There are now in Germany 16 separate *Laender* with their own separate *Landesbauordnung* and each Land has the right to modify the regulation. The *Landesbauordnung* specifies that building installations shall be designed such that the occurrence of a fire and the propagation of fire and smoke is prevented and, in the event of a fire, the rescue of people and animals as well as the performance of fire extinguishing procedures is possible.

The Building Regulations contain in Germany requirements to ensure public health and safety but also requirements related to the design and layout of buildings. Building and Planning law are contained in the same Federal Building Code and are operated within the same local authority department.

Figure 3.7 represents the German Fire Safety Framework.

Fire Protection measures comprise three main streams:

- Active Fire Protection Measures
- Prevention of Fires and Fire Fighting Facilities.
- Fire Safety by Design

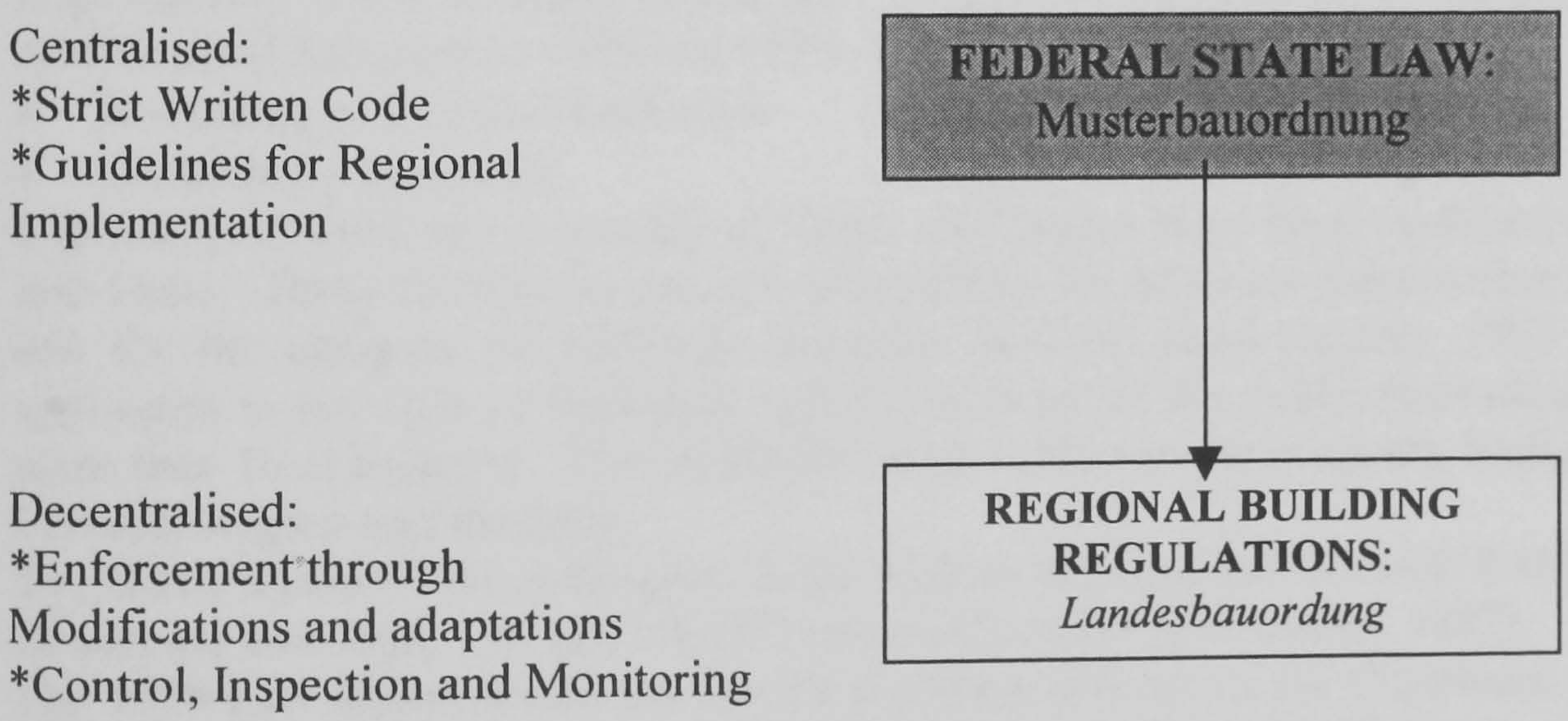


Figure 0.2: German Fire Safety Framework

The requirements for Fire protection in Buildings are set out in the regulation *DIN4102*: Fire Behaviour of building materials and building components (*Deutche Normen DIN 4102, Teil 4*) (Deutches Institut fur Normung, 1981), and *DIN 180*** series for Fire Barriers, and DIN 18230 on Structural Fire Protection in Industrial Buildings. *DIN 4102* is divided in eighteen parts which cover everything from the behaviour of materials to the stability of structure and fire resistance, building services and fire, etc.

Germany has a reputation for having a strict written code of fire related regulations covering both the construction and occupation of buildings (Barham, 1996).
The German Fire Safety Framework is decentralised compared to the UK Framework, which is now slowly moving towards it. The Surveyor's offices in Germany are responsible for ensuring that the rules are followed by builders and owners (Stein, 1997). In order to assess building applications, the surveyor's office asks other Authorities for advice. The idea of collaboration and teamwork is present like in Netherlands. Where fire safety is concerned, this advice is given by the professional brigades who usually maintain separate departments to deal with applications. In smaller towns and countryside, the district Authorities employ fire safety officers to do this job. The Fire Service is then responsible for checking requirements and the owner or the occupier has met operational demand.
One stream of the new regime adopted by the UK last April joins this approach by adding duties on the "responsible person", i.e. owner or occupier. This last issue is also very close to the French system i.e. Control of fire precautions of building by the Fire Brigade, detailed later in this paper.
Several issues have been identified within the German Fire Safety Framework:

- Guidelines issued at the Federal Level.
- Enforcement through separate regional Building Regulations.
- Implementation and Control at a Local Level with the Fire Services.

The cost of direct fire loss (Geneva Association, 1997) in Germany is estimated around 0.19% of the GDP. The population comparison for Fire deaths (1992-1994) report 1.04 deaths per 100,000 persons and is amongst the lowest of the EU countries (2nd after Spain: 0.86 per 100,000).

The Legislative situation in Belgium:

Belgium is a Federal Parliamentary Democracy under a Constitutional monarch. Its Legal system is a Civil Law system influenced by the English constitutional theory and a judicial review of legislative Acts. In 1976, following a series of major fires (69 nightclubs of *La Louvrière* and the shopping centre *"L'Innovation"* in Brussels which kills 322 persons), the Chamber worked on a new project of Law which emphasised on Prevention under the responsibility of the Ministry of Interior. This project became a Law on 30 July 1979, later modified and enforced in 1989 and 1990. It deals with two main aspects:

- Prevention of Fire and Explosion
- Compulsory Insurance.

It is not until 1994 that a number of Codes of Practice have been modified and transformed into Laws. Those documents are now compulsory for any new construction since May 1995 and for the category of buildings classifies as Low since January 1997. Any norm is applicable to any type of buildings, accessible or not to the public (including dwellings with more than 10 occupants). The legislation is also different between the Walloons Region, the Flamand Region and Brussels.
The Direct Cost of Fire in Belgium is the highest amongst the EU with 0.40% of GDP. Fire Deaths are also high, 1.47 per 100,000 persons (Geneva Association, 1997).
The 1979 Law decentralised the Decision-making process to the Commune or *Bourgmestre*. This gives the power to control the implementation of fire safety measures in buildings. The *Bourgmestre* can therefore decide to close a building if he/she considers it does not satisfy the regulation requirements. On the other hand the Ministry of Interior has the ability to issue some derogation to the conditions fixed under Articles 3 and 4 of the *Arrêté Royal* of 7 July 1994 modified on the 19 December 1997 which fixed the main standards and norms (Herousse, 1996). This creates a confusing system which leaves the Control process within the Fire Safety Framework unclear. Figure 3.8 presents the Belgium Fire Safety Framework.

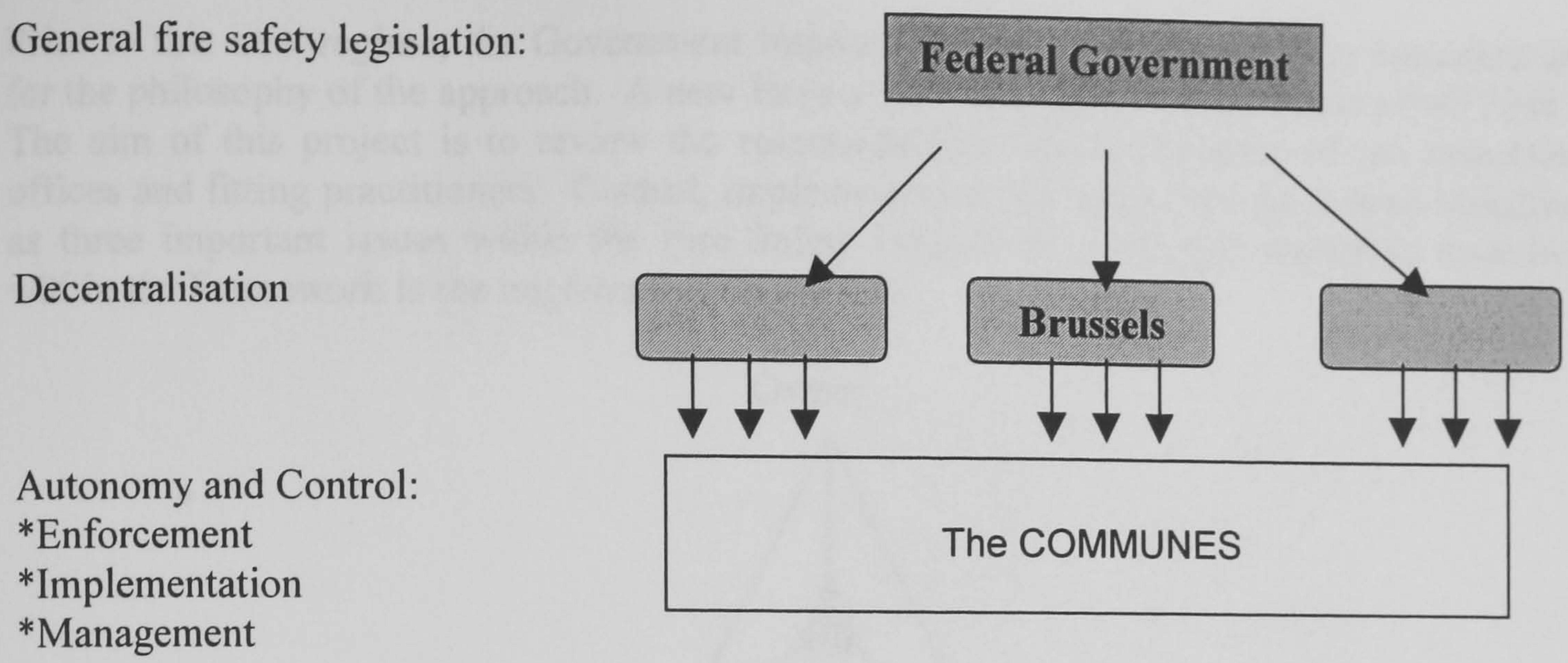


Figure 0.3: Belgian Fire Safety Administration Framework

The Legislative situation in Netherlands:

Netherlands is a Constitutional Monarchy. The legal system is a Civil Law System incorporating French penal theory. There are three levels of Government, the state, province and 700 municipalities. Fire Deaths in Netherlands is the lowest of UK: 0.60 deaths per 100,000 persons (Geneva Association, 1997).

The principal legislation for Building Control is the Housing Act 1972 and Physical Planning Act 1962. In 1993, the Ministry of Interior decided to implement a new Fire safety Framework in order to reduce Fire Losses. They previously identified lack into the existing Framework and concluded after an analysis of Fire incidents within the previous 20 years that (Baes, 1996):

- Control of fires was not efficient
- Fire fighting operations were not operatives.

Figure 0.4 describes the existing Fire Safety Framework in the Netherlands.

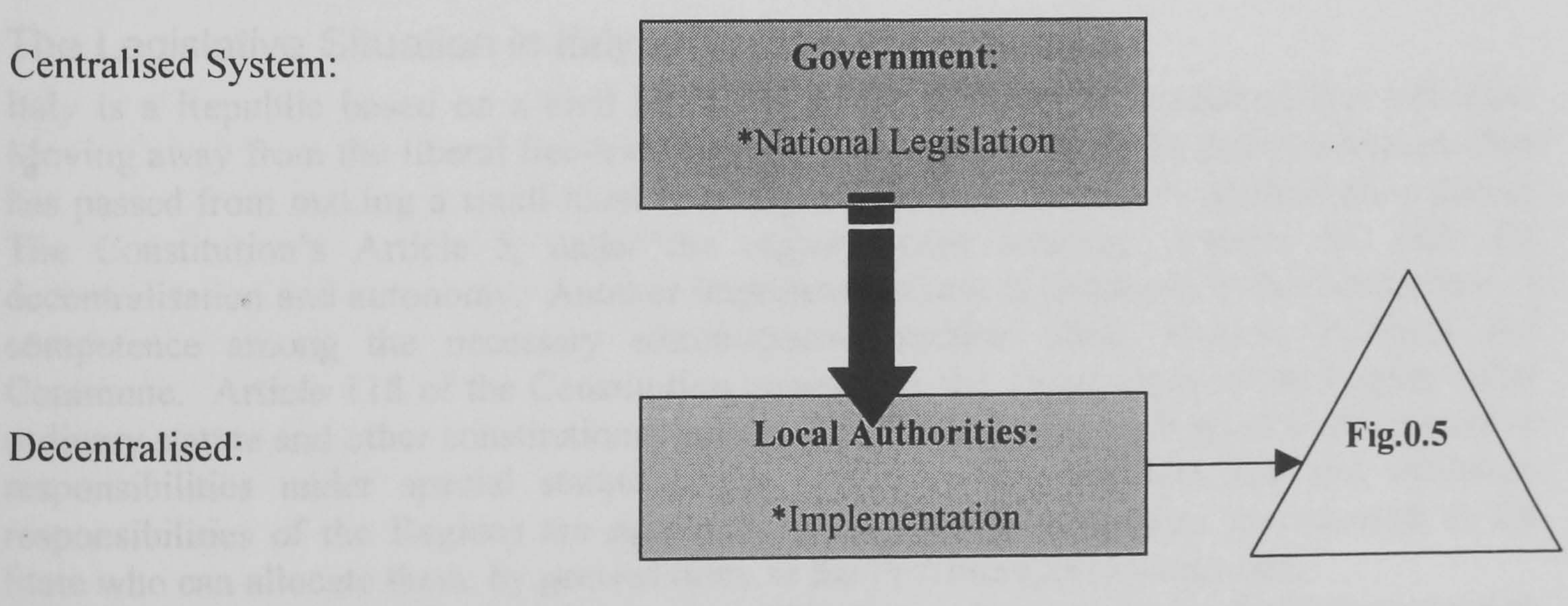


Figure 0.4: Fire Safety Framework in the Netherlands

The Fire Protection Concepts or *Brandveiligheidsconceoten* Project was launched in 1993 and the results were published in 1995. These concepts of Fire Protection are not some regulations comprising a range of provisions but describe a new approach. The Netherlands Government is now taking into account this concept to integrate it into the new regulation.

Prior to this new regime, the Government imposed requirements without any consideration for the philosophy of the approach. A new Project was launched in 1995 "Project BvS 2000". The aim of this project is to review the responsibilities and competence of the inspection offices and fitting practitioners. Control, implementation and inspection have been identified as three important issues within the Fire Safety Framework. Another aspect to underline within the Framework is the implementation process.

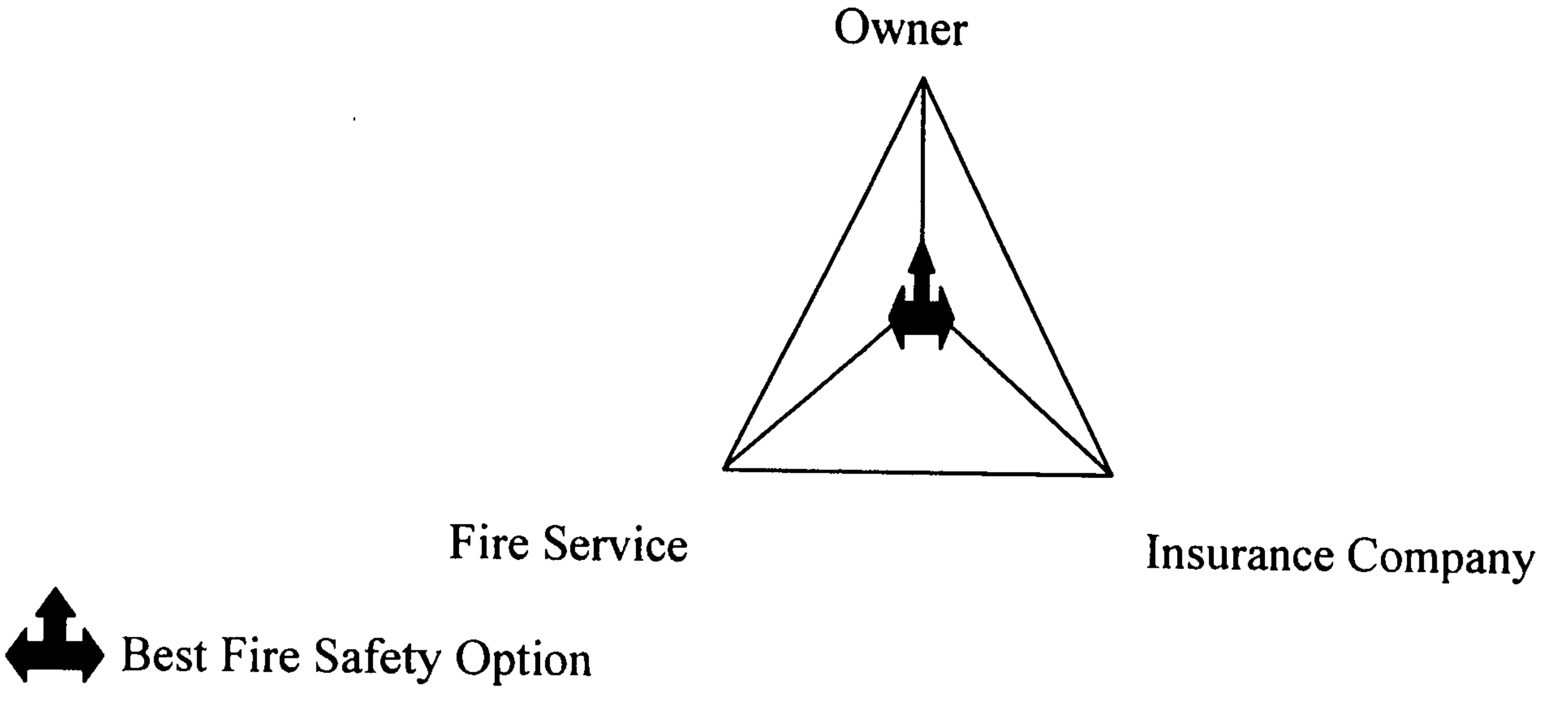


Figure 0.5: A triangular approach towards Decision-Making in Netherlands

The Fire Service, the Insurance Company and the Owner must come together and discuss the fire measures for the particular building. Fire Service and Insurance should work together and highlight to the owner the fire risks and take into account his requirements to select the best fire protection solution for the building. This is illustrated below in Figure 3.10: A triangular approach towards Decision Making in the Netherlands. Such a process is not developed in any other Member State of the EU.
A strong link between the Owner/Occupier/Insurance Company and the Fire Service is clear both at a pre-construction/renovation stage and during the building use. Fire Prevention is not only achieved through the strict application of law but other options should be considered to achieve the required level of safety.

The Legislative Situation in Italy:

Italy is a Republic based on a civil law system with a strong ecclesiastical law influence. Moving away from the liberal free-trade origins of the Italian State, the public administration has passed from making a small number of significant interventions by authoritative means. The Constitution's Article 5, under the organisational heading, contains the rules for decentralisation and autonomy. Another important element is contained in the distribution of competence among the necessary administrative entities: State, Region, Province and Commune. Article 118 of the Constitution enumerates the competence of the Region under ordinary statute and other constitutional level norms, while fixing the Region's administrative responsibilities under special statute (Anon, 1997). This signifies that the minimum responsibilities of the Regions are rigorously fixed and the remainders are reserved to the State who can allocate them, by general rules, to the Provinces and Communes.
The Italian Legislative Framework, represented in Figure 3.11, is decentralised and power to provinces is much more important in this system than in other EU Member State.

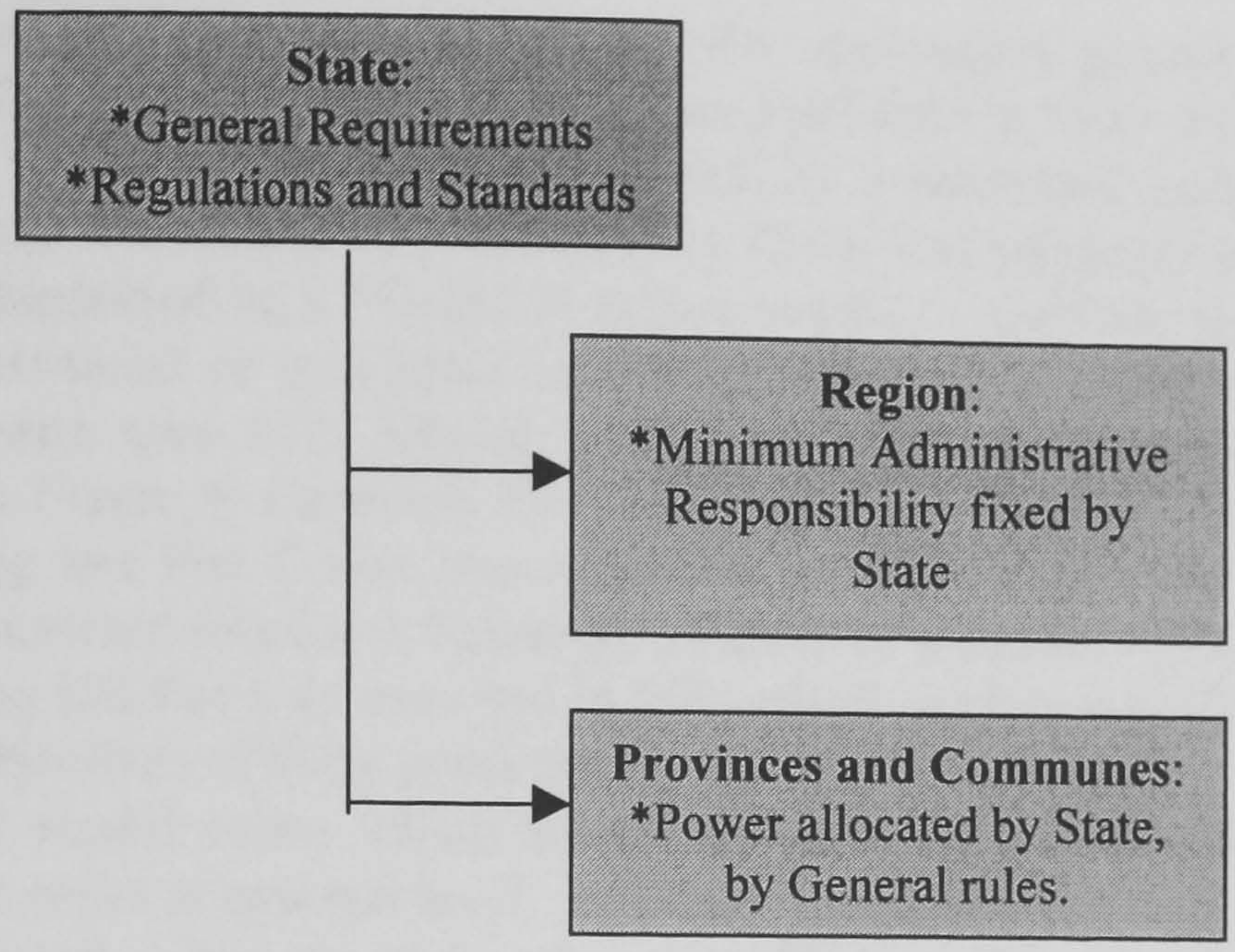


Figure 0.6: Italian Fire Safety Framework.

European Community and Canada:

Throughout the first part of the paper we detailed the different Fire Safety Framework of seven European Countries. We found that some of the EU countries analysed had a very decentralised approach towards the implementation of Fire Safety Legislative Framework. Germany and Spain are two excellent examples. In addition, direct fire losses (Germany: 0.19% of GDP and Spain: 0.12% of GDP (Geneva Association, 1997)) are lower in those countries and fire deaths (Germany: 1.04 per 100,000 persons and 0.86 for Spain (Geneva Association, 1997)) is amongst the lowest, as described in Table A. Further investigations will be necessary to explore whether there is a direct component of the relationship implied in these figures and develop an accurate analysis.

Such diversity between EU countries is not a disadvantage and should provide enough case studies to develop a new European Framework in the view to propose a harmonised system throughout the Member States. There seems to be the case that a more decentralised approach could be beneficial. Autonomy to the Local Authorities would provide the users, i.e. owners, occupiers and the all Community, a more flexible approach towards fire safety in building. This is a feature of the Canadian approach to Fire Safety Legislation. The structure of Canada has a lot of similarities with Europe. First, its size is comparable to Europe and second the Canadian Government decided to recognise the jurisdictional powers of provincial/territorial authorities to establish their own building and fire regulations, and to act in liaison with regulatory authorities, industry and the public. This approach is very similar to the EU approach. Canada comprises 10 provinces and 2 territories. Each Province/Territory have different needs (Legal system based on Common Law, except for Quebec where civil law system is based on French law prevails) and therefore their framework.

The Canadian Framework:

Canada is updating and enforcing their existing Fire Safety Framework since 1995. Under Canadian law, the regulation of building construction is the responsibility of provincial Governments, who in turn can delegate this power to their municipalities (Hansen, 1985). The objectives of the fire safety requirements are to prevent fires, particularly those that may present a hazard to the community, and to limit damage should fire occur. Fire Codes in most provinces are administrated by the fire services. Each province has a fire marshal and a fire commissioner whose office generally responsible for administering fire prevention acts. The municipal fire service normally acts on behalf of the fire commissioner or fire marshal to enforce fire prevention regulations.

Until 1975, the National Fire Code established in 1956 encouraged greater uniformity in matters of fire safety. The first edition of the NBC was published in 1963 and was prepared in the form of a model by-law to permit direct adoption by a municipal authority (Hansen, 1985). This approach was abandoned in 1975 and the Code was prepared instead a set of technical requirements supported by a "Guide to Enforcement" to facilitate its application at either the provincial, territorial or municipal level of government. Canada moved from a highly decentralised system (pre 1975 Model) to a more centralised approach (post 1975 Model), as illustrated in Figure 9: Canadian Fire Safety Framework. By1991, the Canadian Commission on Building and Fire Codes was created to promote uniformity of policy and format an all Code documents (National Research Council of Canada, 1995). A five-year strategic plan on Building and Fire was launched in 1995 which contain 6 goals, 22 objectives and 58 strategies. The objectives of these goals are:

- To provide national model codes which meet the needs of all code users in Canada: referenced/guideline codes at national level
- To have future national codes adopted without modification by all authorities having jurisdiction in Canada.
- To have uniform interpretation and understanding of code requirements throughout Canada.
- To have a responsive, objective, efficient and effective code development system: user-oriented, feedback.

The present Canadian Fire Safety Framework presents three main distinguishing characteristics compared with the European models discussed earlier:

It is an open system: flexible boundaries, consider cost/economics approach

Acceptance of new national Codes go through a process of Public Review: flexible, adaptive, and innovative and user orientated.

Constantly updated: Feedback and communication between different levels of Government (territory, municipal and provincial), higher involvement of the Community, cycle of revision of the code influenced by industry needs.

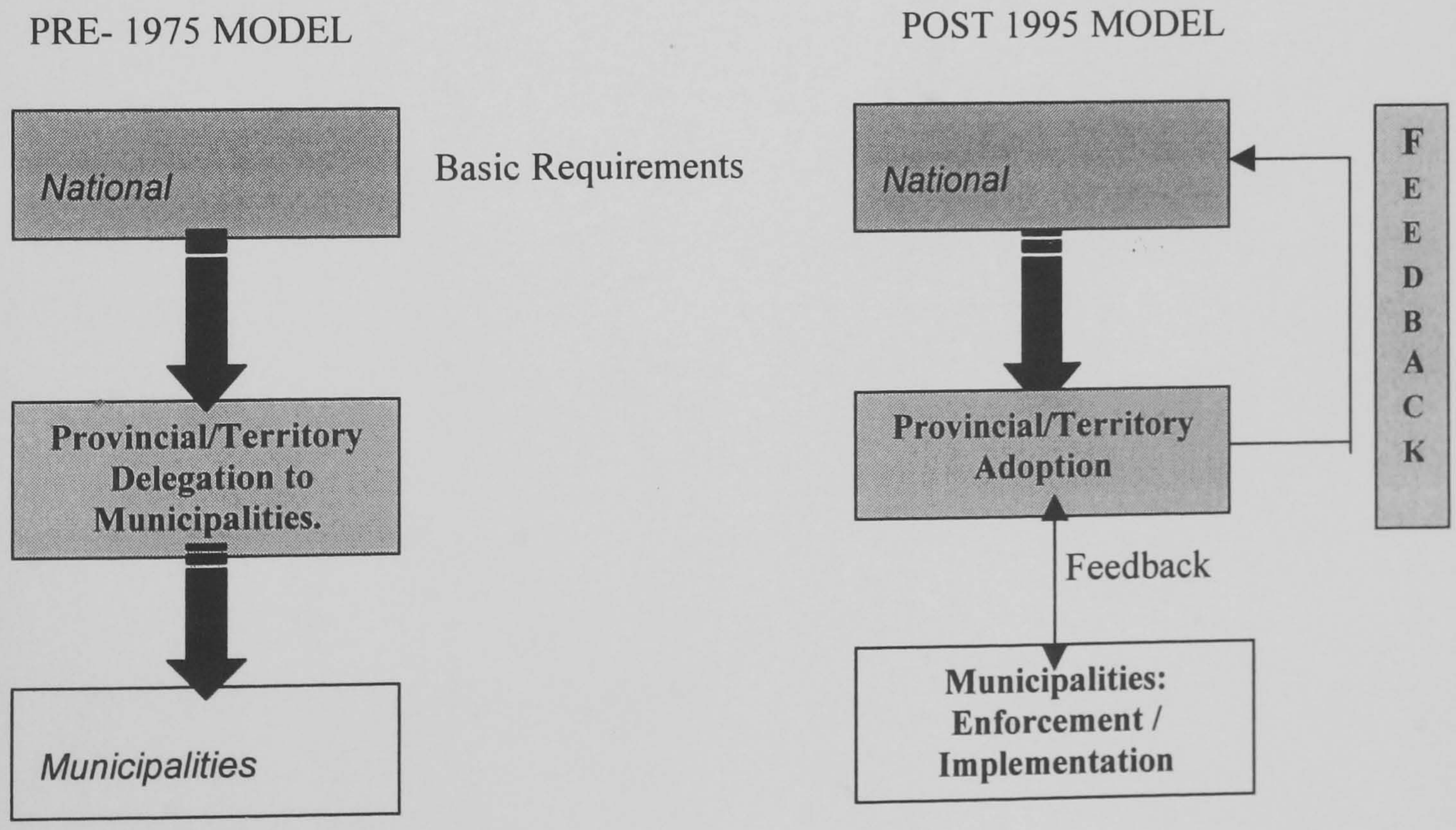


Figure 0.7: Canadian Fire Safety Framework.

In October 1997 (Canada NewsWire, 1997a), the Fire Protection and Prevention Act was proclaimed into law. The new Act will enable municipalities to provide the best level of protection from fire in the most efficient manner. Prior to this acceptance, municipalities asked to reject new fire law. The main subjects of concern (Canada NewsWire, 1997b) are that its provisions could allow municipalities to lower level of public safety through slower response times, fewer fire fighters available in emergency due to the privatisation of fire services. Provinces feared that prevention and public education, the most important factors for fire safety, would be neglected.

Country	Direct Losses % of GDP	Indirect Losses % of GDP	Population. Comparison for Fire Death /100,000 (92-94)	Fire Protection to Buildings Average % of GDP (92-94)	Cost of Fire Fighting Organisations
UK	0.16	0.018	1.41	0.13	0.26
France	0.25	0.027(1993-94)	1.19 (1992-93)	0.16	/
Spain	0.12 (1984)	0.029	0.86 (1991-92)	/	/
Germany	0.19	/	1.04	/	/
Belgium	0.40 (1988-89)	/	1.47 (1989-91)	0.21 (1987-88)	0.18 (1987-89)
Netherlands	0.20	/	0.60	0.31	0.16
Italy	0.30 (1993-94)	0.014 (1993-94)	/	0.38	/
Average EU	**0.231**	**0.022**	**1.095**	**0.238**	**0.20**
USA	0.13	0.012	1.91	0.28	0.28
Canada	0.23	0.022 (1991)	1.11* (1995)	0.45*	0.32* (1994)
Average USA/CAN	**0.18**	**0.017**	**1.51**	**0.365**	**0.30**

NB: These figures should be regarded with serious reservations. The figures are produced on widely varying bases and some of the differences look too large for credibility.

* Human Resources Development Canada, The REcord1995 and IRC, Institut de Recherche en Construction.

Table A: Fire Statistics

Appendix B: Hypothetical Scenario

A processing factory (Cookies Co) is undergoing extension works. The fire breaks out on site, while a sub-contractor was cutting a sandwich panel to create a large opening (4000x4500) between the existing storage facility and the new production line and packaging area under completion. The spark ignited the insulation and the fire spread very rapidly inside the sandwich panel. Extensive fire and smoke damage to the storage area was made worse by water damage due to action by the fire brigade. The fire destroyed part of the new production line facility (50%) with extensive smoke damage to the equipment. The smoke also affected the existing production line and all the machines and equipment had to be cleaned by a specialist. The fire spread to the newly built roof under completion and the smoke released by the burning roof material spread into the administrative office at the first floor. This area sustained minor smoke damage, but the external wall along the site will need to be fully rebuilt.

The processing factory:

The factory specialised in the production of cookies, package the boxes in-house and store part of the production (25% stored for more than two week and 75% distributed within the week of production) on site, in a separate building. In order to ease the manufacturing process and cope with an increase of 25% of new orders in 2000 and an expected 30% in 2001, the management decided to invest into the construction of a new production line and a modern packaging area. See plan A for more details of the layout.

Cookies Co had to maintain full production throughout the course of the extension works and ensure their employees were working in a safe environment. It was planned the openings linking three buildings together would be carried out over a holiday period or week-end in order to minimise the disruption of the production line. However works on the existing storage building could be carried out at any time, as long as the Facility Manager is aware of the works and a method statement is submitted.

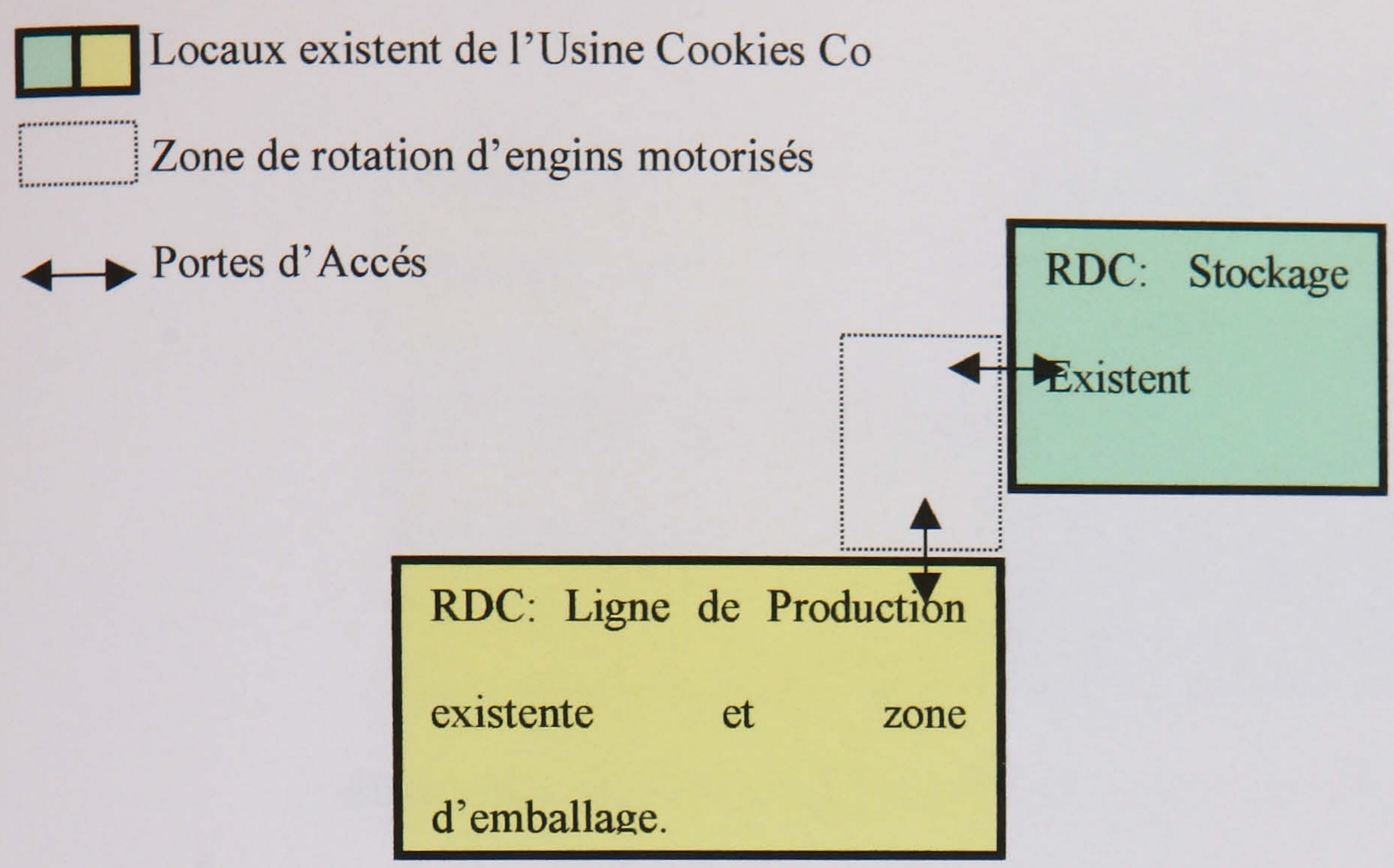
On the day of the fire, 200 employees were present in the facilities. 110 were working on the production line, 15 at the packaging area, 20 in the administrative offices above the existing production line. The maintenance team comprised 5 staff: the facilities manager, two electricians, one plumber and one general worker.

The advancement of the works was at the fit-out stage and the main contractor was expecting to deliver the building one month later. At the same time, the supplier (Dutch Engineering) whom Cookies Co procured the new production line, had a specialist team on site (3 engineers) to install the machines. The work was 50% complete, as only 50% of the equipment has been delivered.

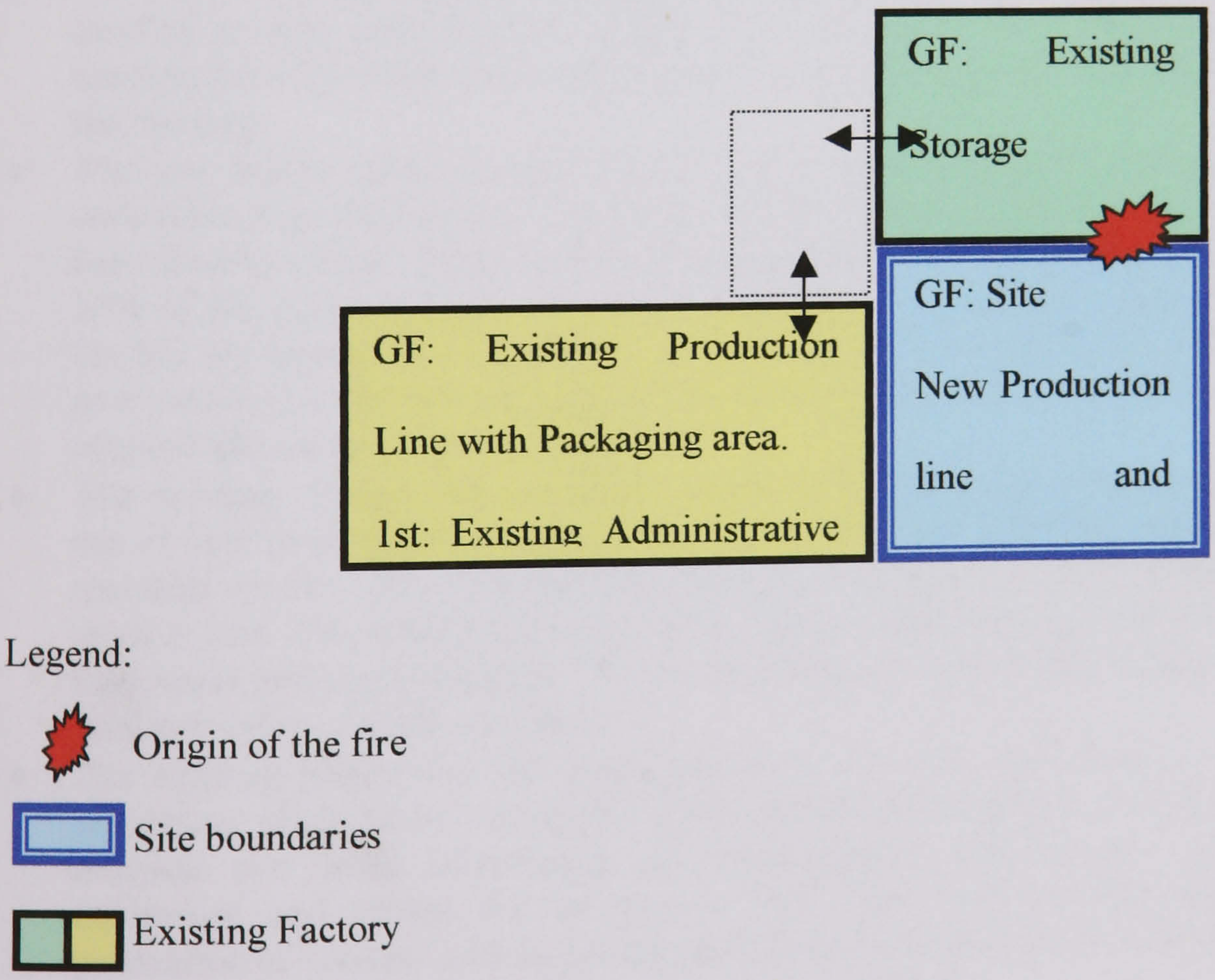
Events leading to the fire:

At the time of the fire, a sub-contractor was working on one of the openings between the existing storage and the site. The existing wall was made of sandwich panel. The cutting operation released sparks which instantly ignited the insulation and very rapidly spread inside the sandwich panel.

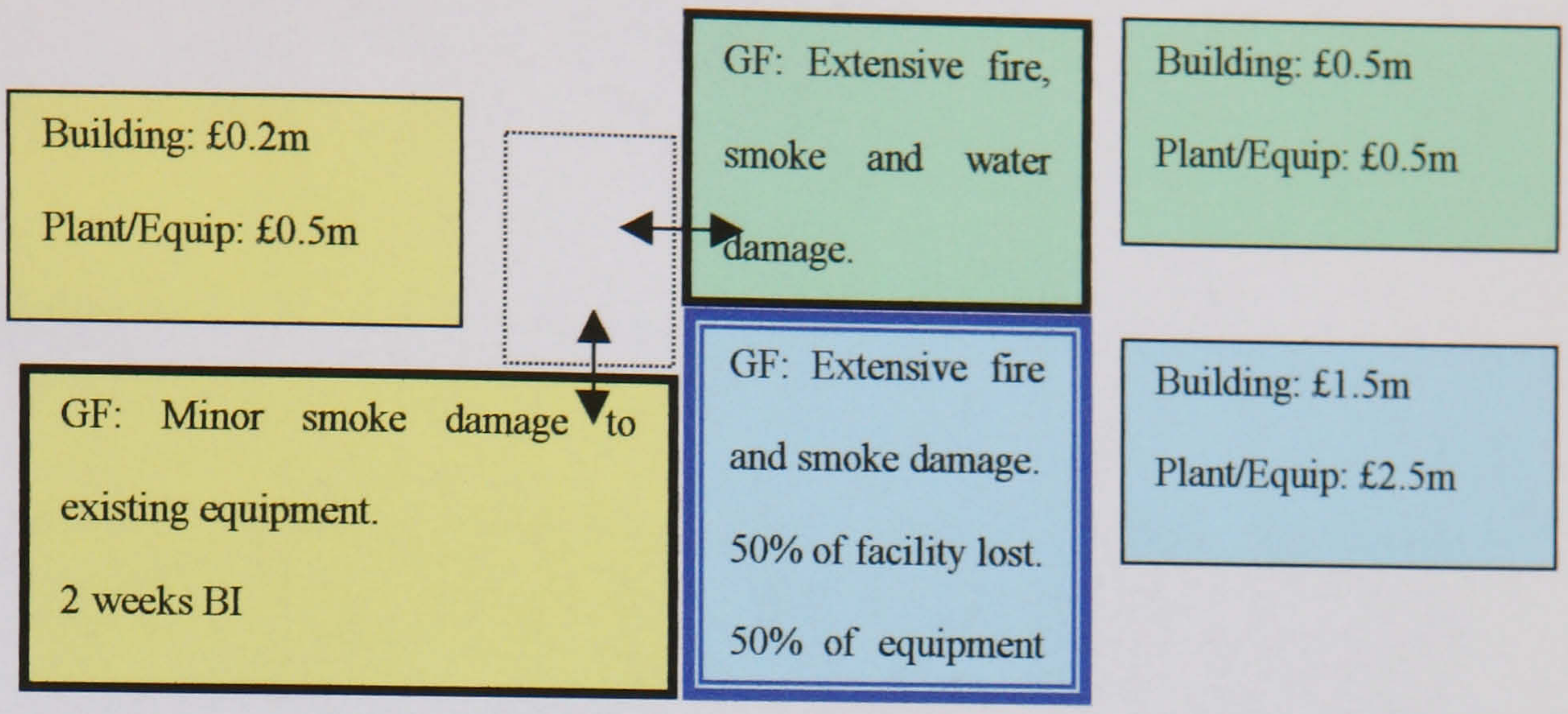
The alarm was raised 5 minutes after an attempt to extinguish the fire with a "half empty" fire extinguisher hang on a wall of the storage area. The alarm was raised by a member of Dutch Engineering team and signal to evacuate the entire facilities was given. The site workforce was forced to evacuate the building at the same time, the smoke released being too dangerous. The Fire Brigade reached the site within 5 minutes of the alarm raised and discovered a major fire: the fire had already spread to the storage area, to the new roof under completion, smoke was found in the existing production line but none in the administrative offices. They were told by the Main Contractor in charge of the site works, that a fire wall had been built between the existing production line and the site, but that a protected (M0) opening had been built over the last week-end. However the opening between the storage area and the site was not protected as one of the sub-contractor was working on it at the time of the fire.



Plan A: Plan au sol de l'Usine Cookies Co avant les travaux



Plan B: Layout of the Project



Plan B: Loss and Damages, Business Interruption (BI)

Loss and Damages:

The facility sustained major smoke and fire damages: Plan B.

- There were extensive high level smoke and heat damage throughout the ground floor facilities and smoke had vented from the eaves at the rear of the building.
- However there was very little damage to the First Floor offices.
- The direct fire damage was spread between the new built facilities (the site) and the existing storage area. It was evident from the examination that the fire started in the opening between these areas and is most likely due to the welding works carried out in the opening.
- The new facility under completion (the site) sustained extensive fire and smoke damages with 50% of the facility lost. On top of this, 50% of the equipment installed and stock had been destroyed and cannot be reused. Luckily there was a delay to supply the remaining 50% of the equipment on site. One month prior to completion, further works following the fire are planned for an extra 4 months (at least) to rebuilt and repair and installed a new production line and packaging area. We are planning a 4 month interruption after the original date of delivery of the facility.
- The existing storage area sustained extensive fire and smoke damages increased by the use of very large quantity of water by the Fire Brigade. This area wasn't equipped with a sprinkler system. As a consequence of the fire and action of the Fire Brigade, 80% of the stock is lost. The turnaround value of the stock is estimated to be £0.5m and as much for equipment and plant materials. We are planning a 2 month interruption of the use of this facility to allow rebuilt and repairs.
- The existing production and packaging area was only damaged by smoke but all the equipment needs to be completely clean (health and hygiene issues) before re-use. We estimate one week interruption for investigations and another week to clean the equipment and restore the production line. The stock of ingredients used for the production of cookies will be destroyed and was estimated to be of a value of £0.2m. The total cost of business interruption is estimated at £1m.
- The office, situated at the first floor of the existing production and packaging line sustained only minor smoke damages and minimal repairs is required. An interruption of the work for investigations and cleaning is estimated at 1 week.

Building: £2.7m
Plant and Equipment: £3.5m
Stock: £0.7m
Business Interruption: £5m
Total: £11.9m

Business Interruption:

The main factory was the target risk, with no possibility to transfer the business to another partner factory or other facility. The Estimated maximum Loss were in the region of 70 % for Buildings, 50% for Plant and Equipment and 80% for the Stock. The Insurance Survey Report highlighted major weaknesses in the design of the factory and its fire protection measures. No effective internal separation and fairly extensive use of composite panels were a major issue. Cookies Co did not have an operational Business Continuity Plan (BCP) in place, baring in mind the major weaknesses of the business if affected by a disaster. Their Recovery Plan is proved to be inefficient.

It is difficult to limit the business interruption in such a situation as the core activities of the factory (the production, packaging and storage of cookies) is carried out in one single factory which has been partially or completely destroyed. The existing production line and packaging area have been affected by the smoke released during the fire and the storage facility is out of use for two months. Critical activities to maintain:

- Engage the repair and cleaning of existing production line and packaging within two weeks.
- To prospect for a new storage facility, within a two mile radius of the factory within two weeks, and arrange for transport from the factory to the new storage area.
- Carry out repairs of the destroyed storage area within two months.

The new production line aimed at increasing the productivity of the factory and expected a 30% increase of orders in 2002, which is now compromised but could be limited to a 10% increase if the rebuilt and repair works are completed within 5 months from now. Critical activities:

- Engage repair and rebuilt work as soon as possible and plan a new completion date within 5 months.
- Order and replace the new production line and packaging machines and equipment

APPENDIX C:

Fire Safety Management Model C: CD-ROM Version