

Application of fire safety engineering principles to the design of buildings —

Part 0: Guide to design framework and fire safety engineering procedures

ICS 13.220.01

Confirmed December 2011

Committees responsible for this Published Document

The preparation of this British Standard was entrusted by FSH/24, Fire precautions in buildings, to Subcommittee FSH/24/1, upon which the following bodies were represented:

- BASA — British Automatic Sprinkler Association
- BRE/LPC Laboratories
- DETR
- Fire Safety Development Group
- Home Office
- Institute of Building Control
- IFE — Institute of Fire Engineers
- London Fire and Emergency Planning Authority
- NHBC — National House-Building Council
- Nuclear Industry Fire Safety
- Fire Brigades Union
- Timber Research and Development Association

This Published Document, having been prepared under the direction of the Health and Environment Sector Policy and Strategy Committee, was published under the authority of the Standards Policy and Strategy Committee on 23 September 2002

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Amendments issued since publication

Amd. No.	Date	Comment

The following BSI references relate to the work on this Published Document:
Committee reference: FSH/24/1

ISBN 0 580 40169 3

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Foreword

This Published Document (PD) was published under the Fire Standards Policy Committee and is published as part of the PD 7974 series. Other parts published or about to be published are as follows:

- *Part 1: Initiation and development of fire within the enclosure of origin;*
- *Part 2: Spread of smoke and toxic gases within and beyond the enclosure of origin;*
- *Part 3: Structural response and fire spread beyond the enclosure of origin;*
- *Part 4: Detection of fire and activation of fire protection systems;*
- *Part 5: Fire service intervention;*
- *Part 6: Evacuation;*
- *Part 7: Probabilistic risk assessment.*

These Published Documents are intended to be used in support of BS 7974:2001, *Application of fire safety engineering principles to the design of buildings — Code of practice.*

It has been assumed in the drafting of this PD that the execution of its provisions is entrusted to appropriately qualified and competent people.

Drafting of this publication was completed in July 2001.

Acknowledgement is made to the contribution of Dr D. Charters of Arup Fire and Mr J. Barnfield of Tenos Ltd. in the preparation of this publication.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a Published Document does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to ii, pages 1 to 45 and a back cover.

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1 Scope

This Published Document provides guidance on the use of BS 7974:2001 as a framework for an engineering approach to the achievement of fire safety in buildings. It gives guidance on the application of scientific and engineering principles to the protection of people and property from fire. It also gives a structured approach to assessing the effectiveness of the total fire safety system in achieving the design objectives.

It provides guidance on the design and assessment of fire safety measures in buildings. It provides some alternative approaches to existing codes and guides for fire safety and also allows the effect of departures from more prescriptive codes to be evaluated.

It recognizes that a range of alternative and complementary fire protection strategies can achieve the design objectives.

This Published Document is intended to provide a framework for a flexible but formalized approach to fire safety design that can also be readily assessed by the statutory authorities.

It is intended that this Published Document, when used by persons suitably qualified and experienced in fire safety engineering, will provide a means of establishing acceptable levels of fire safety economically and without imposing unnecessary constraints on other aspects of building design.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this Published Document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 7974:2001, *Application of fire safety engineering principles to the design of buildings — Code of practice*.

PD 7974-1, *Application of fire safety engineering principles to the design of buildings — Part 1: Initiation and development of fire within the enclosure of origin* (Sub-system 1).

PD 7974-2, *Application of fire safety engineering principles to the design of buildings — Part 2: Spread of smoke and toxic gases within and beyond the enclosure of origin* (Sub-system 2).

PD 7974-3, *Application of fire safety engineering principles to the design of buildings — Part 3: Structural response and fire spread beyond the enclosure of origin* (Sub-system 3).

PD 7974-4, *Application of fire safety engineering principles to the design of buildings — Part 4: Detection of fire and activation of fire protection systems* (Sub-system 4).

PD 7974-5, *Application of fire safety engineering principles to the design of buildings — Part 5: Fire service intervention* (Sub-system 5).

PD 7974-6, *Application of fire safety engineering principles to the design of buildings — Part 6: Evacuation* (Sub-system 6).

PD 7974-7, *Application of fire safety engineering principles to the design of buildings — Part 7: Probabilistic risk assessment*.

3 Terms and definitions

For the purpose of this Published Document, the following terms and definitions apply.

3.1

available safe egress time

ASET

calculated time available between ignition of a fire and the time at which tenability criteria are exceeded in a specified space in a building

3.2

code compliant

where a building or part of a building complies with the recommendations of an appropriate prescriptive code

3.3

compartment

building or part of a building comprising one or more rooms, spaces or storeys, constructed to prevent the spread of fire to or from another part of the building, or an adjoining building

3.4

common mode failure

failure that is the result of an event(s) that, because of dependencies, causes a coincidence of failure states of components in two or more separate channels of a redundancy system, leads to the defined system failing to perform its required function

3.5

detection time

interval between the onset of combustion and its detection by an automatic system or otherwise

3.6

deterministic study

methodology, based on physical relationships derived from scientific theories and empirical results that, for a given set of initial conditions, will always produce the same outcome

3.7

enclosure

space defined by boundary elements (on all sides) around the point of origin of the fire

3.8

escape time

calculated time from ignition until the time at which all the occupants of a specified part of a building are able to enter a place of safety

3.9

exit

doorway or other suitable opening giving access towards a place of safety

3.10

fire hazard

source of possible injury or damage

3.11

fire load

sum of the calorific energies which could be released by the complete combustion and all the combustible materials in a space, including the facing of the walls, partitions, floors and ceilings

3.12

risk

product of the probable rate of occurrence of a hazard causing harm and the degree of severity of the harm

3.13

fire safety engineer

person suitably qualified and experienced in fire safety engineering

3.14

fire safety manual

document providing all necessary information for the effective fire safety management of the building

3.15

fire safety engineering

application of scientific and engineering principles to the protection of people, property and the environment from fire

3.16**fire safety strategy**

combination of fire safety measures that has been shown by reference to prescriptive codes or a fire engineering study to be capable of satisfying the specified fire safety objectives

3.17**fire scenario**

set of circumstances (taking account of the building, its contents and occupants) chosen as an example that defines the development of fire and its effects in a building or part of a building

3.18**management**

persons or person in overall control of the premises whilst people are present, exercising this responsibility either in their own right or by delegation (of statutory duty)

NOTE This could be the owner.

3.19**means of escape**

means whereby safe routes are provided for persons to travel from any point in a building to a place of safety

3.20**place of safety**

predetermined place in which persons are in no immediate danger from the effects of fire.

NOTE The place of safety may be inside or outside the building depending upon the evacuation strategy.

3.21**pre-movement time**

time interval between the warning of fire being given, by an alarm or by direct sight of smoke or fire, and movement towards an exit

3.22**probabilistic study**

methodology to determine statistically the probability and outcome of events

3.23**tenability limit**

maximum exposure to fire hazards that can be tolerated without causing incapacitation

3.24**travel distance**

actual distance that needs to be travelled by a person from any point within a building to the nearest exit, having regard to the layout of walls, partitions and fittings

3.25**trial design**

group of fire safety measures which, in the context of the building parameters, might meet the specified fire safety objectives

3.26**worst case scenario**

set of credible conditions that, when taking account of the building, its contents and occupants, gives rise to the highest level of fire risk

4 Background

4.1 General

Historically, fire safety measures have been specified by reference to prescriptive codes that provide standard solutions for a given set of building parameters. For many buildings of straightforward construction, layout and use, prescriptive codes and standards provide the designer with an acceptable solution.

However, these codes have to account for a wide range of buildings and will often not provide the optimum solution in terms of:

- a) life safety;
- b) property protection;
- c) cost-effective fire protection;
- d) operational requirements.

The prescriptive approach often does not meet the needs of building owners, designers or approvals bodies, particularly for more complex buildings or processes or where there is a potential for substantial financial loss arising from a relatively small fire.

Similarly, prescriptive codes for fire protection systems such as sprinklers, detectors and smoke control do not always take account of all significant design factors (e.g. the effect of height on the speed of sprinkler activation and consequential extinguishing effectiveness).

Some of the advantages and disadvantages of the traditional prescriptive codes are summarized in Table 1.

Table 1 — Advantages and disadvantages of prescriptive codes

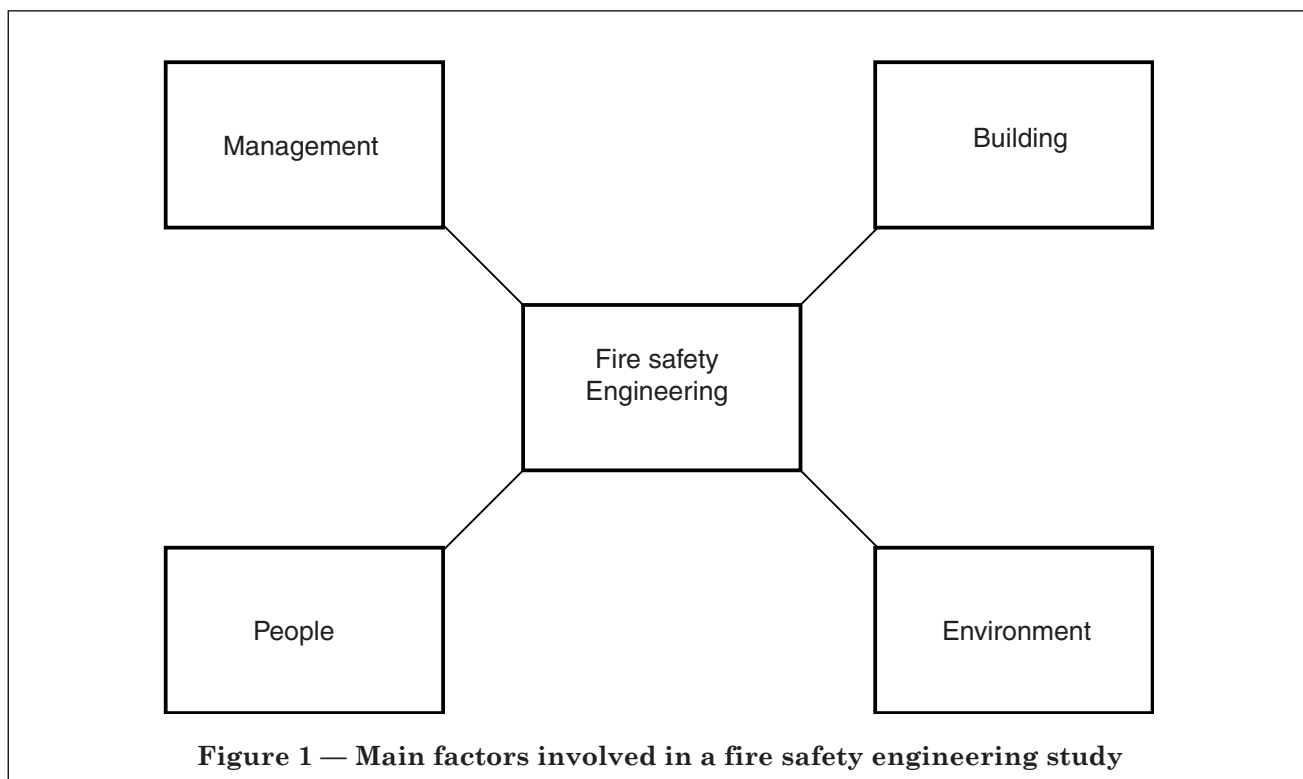
Advantages	Disadvantages
Simple to use	Often not flexible
Embody past experience	Unable to anticipate all eventualities
Provide a consensus view	Do not necessarily provide optimum solution
	Might lag many years behind design practice

A particular weakness in the prescriptive approach was recognized in the conclusions of the Cullen report into the Piper Alpha offshore disaster which stated that:

“Many regulations are unduly restrictive in that they are of a type that impose “solutions” rather than “objectives” and are out of date in relation to technological advances. There is a danger that compliance takes precedence over wider safety considerations...”

This conclusion is equally applicable to building design and BS 7974:2001 has been developed to provide an objectives-based approach to fire safety in buildings. It gives guidance on the application of engineering principles to the protection of people and property from fire. However, fire safety engineering (FSE) is a developing discipline and BS 7974:2001 should not be regarded as yet another prescriptive set of rules but as a structured framework for the evaluation of the interactions between fire, people and buildings.

Figure 1 illustrates the main features of the fire-people-building system. The framework presented in BS 7974:2001 is intended to ensure that these are adequately evaluated and that specified fire safety objectives are achieved.



4.2 Benefits of fire safety engineering

A fire safety engineering approach that takes into account the total fire safety package can provide a more fundamental and economic solution than traditional approaches to fire safety. It might be the only viable means of achieving a satisfactory standard of fire safety in some large and complex buildings.

The objectives of BS 7974:2001 and this Published Document (PD) are to:

- a) provide a structured framework for assessing the interaction between buildings, people and fire;
- b) enable an objective assessment of the fire safety measures required to achieve defined objectives;
- c) assist in developing alternatives to prescriptive codes and enable the effect of these to be evaluated;
- d) facilitate innovation in design without compromising safety;
- e) identify requirements for further research.

BS 7974:2001 provides a performance-based approach to design in which the specific fire hazards and their potential consequences are identified and fire safety measures can be introduced, as necessary, to ensure that the design objectives are met. It also enables the results of recent research into fire and human response to be translated directly into the building design process.

A FSE approach might initially result in higher design costs due to the increased engineering effort but the potential improvement in safety and the construction and operational savings can far exceed the increased design cost.

The main benefits and disadvantages of fire safety engineering compared to the more traditional prescriptive approach are summarized below in Table 2.

Table 2 — Advantages and disadvantages of fire safety engineering approach

Advantages	Disadvantages
Fire safety measures tailored to risk and specified objectives	Suitably qualified and experienced personnel are required to carry out and assess FSE studies
Facilitates innovation in building design without compromising safety	Might involve increased design time and costs
Fire protection costs can be minimized without reducing safety	Lack of data in some fields
Provides a framework to translate recent research into practice	Might be restrictive unless future flexibility of use is explicitly considered as a design objective
Enables alternative fire safety strategies to be compared on cost and operational grounds	
Enables cost and benefits of loss prevention measures to be assessed.	
Requires design team and operator to explicitly consider fire safety	

4.3 Common misconceptions

4.3.1 General

There are a number of common misconceptions regarding the use of FSE rather than traditional prescriptive approaches and some of these are discussed in this section.

4.3.2 “An FSE design is more dependent upon management controls”

Whether designed in accordance with prescriptive codes or FSE principles, good fire safety management is essential to the safe operation of any building. The FSE approach presented in BS 7974:2001 requires that management issues are taken into account and any specific management requirements are addressed explicitly.

4.3.3 “FSE should not be applied to just one aspect of the design”

The most common use of FSE is to justify one or two specific departures from prescriptive codes. There is generally no need to apply FSE to all aspects of a project if it is otherwise code-compliant.

4.3.4 “An FSE design provides less flexibility for future use”

During the QDR, the team should identify potential future changes of use and should, where practical, ensure that the design will accommodate these. If this is not feasible, any potential restrictions should be highlighted. A lack of flexibility is a function of poor engineering design rather than an inherent function of FSE.

4.3.5 “An FSE design is more dependent upon the correct performance of fire protection systems”

There is no reason why a wedged-open fire door or poorly maintained sprinkler system should be any less of a problem in a code compliant building than in a building designed on the basis of FSE principles.

BS 7974:2001 requires a “what if study” to be carried out to assess the potential impact of system failures and, therefore, the impact of such failures will often be less in a building designed on FSE principles.

4.3.6 “The accuracy of many FSE calculations is unknown”

The accuracy of the calculation procedures presented in the PDs supporting BS 7974:2001 (and other appropriate publications which have been subject to peer review) will generally be sufficiently accurate for engineering design purposes if they are used within their limits of applicability.

However, the old adage of “garbage in – garbage out” applies and, in most cases, uncertainties in the calculation procedures will be outweighed by any errors in the initial assumptions (e.g. the rate of fire growth).

4.3.7 “An FSE solution always requires calculations and a numerical solution”

BS 7974:2001 provides a design framework and does not necessarily require a quantified analysis.

Very often, it will be possible to reach a solution without recourse to numerical calculations. During the QDR process, it might be possible to establish simply by logical deduction that a trial design is at least as safe as the code compliant solution without the need for any calculations.

4.4 Structure of BS 7974:2001

BS 7974:2001 provides the basic framework for the application of FSE but it is supported by a series of Published Documents (PDs) that contain guidance on specific aspects of FSE. The PDs are a summary of current information. It is intended that they will be regularly updated as new data and analysis procedures become available. Whilst the PDs provide useful information and guidance, the use of other data and calculation techniques are equally acceptable, provided that their validity and applicability has been adequately demonstrated. Figure 2 shows the basic structure of BS 7974:2001 and its supporting Published Documents.

5 Design approach

5.1 Experience and qualifications

The complexity of the interactions between people, buildings and fire is such that no single set of calculation procedures can be applied to all types of buildings in all circumstances. Therefore, FSE requires a greater degree of care and responsibility by the designer than does the application of prescriptive codes. It is therefore essential that the application of FSE be entrusted to suitably qualified and experienced personnel.

In assessing the suitability of FSE design, personnel professional qualifications (e.g. Chartered Membership of the Institution of Fire Engineers) and experience of fire safety engineering on projects of similar scale and complexity should be taken into account.

5.2 Framework

BS 7974:2001 provides a performance based framework for an engineering approach to fire safety in buildings. It can be used to show that statutory requirements can be satisfied but may also be used as part of a cost–benefit analysis to establish the value of property protection measures or to evaluate the environmental impact of fire.

The design framework may be applied to the design of new buildings or the appraisal of existing buildings. Whilst FSE procedures may be used to evaluate the entire set of fire people and building interactions, in many practical applications their most common use will be to evaluate specific departures from prescriptive codes (e.g. the evaluation of extended travel distances in an otherwise code compliant building).

The general approach to FSE described in BS 7974:2001 and this PD may be applied to all types and uses of buildings or to facilities such as tunnels and process plants. However, the risks associated with installations used for the bulk processing of explosives or flammable liquids and gases will necessitate special consideration which is beyond the scope of BS 7974:2001 and its supporting documents.

The basic design process presented in BS 7974:2001 comprise the following main stages, as illustrated in Figure 3:

- a) Qualitative Design Review (QDR);
- b) quantitative analysis;
- c) assessment against criteria;
- d) reporting of results.

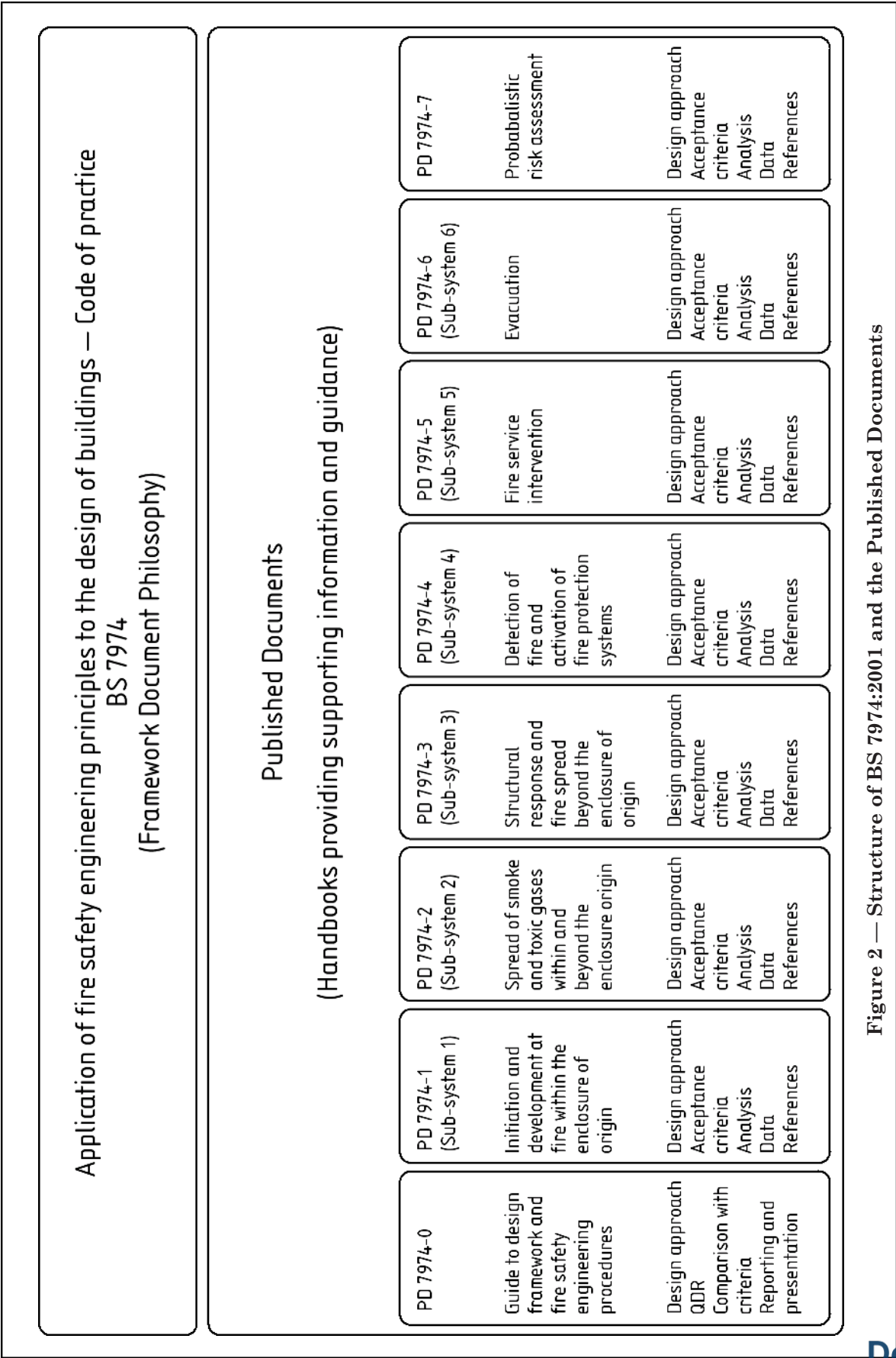


Figure 2 — Structure of BS 7974:2001 and the Published Documents

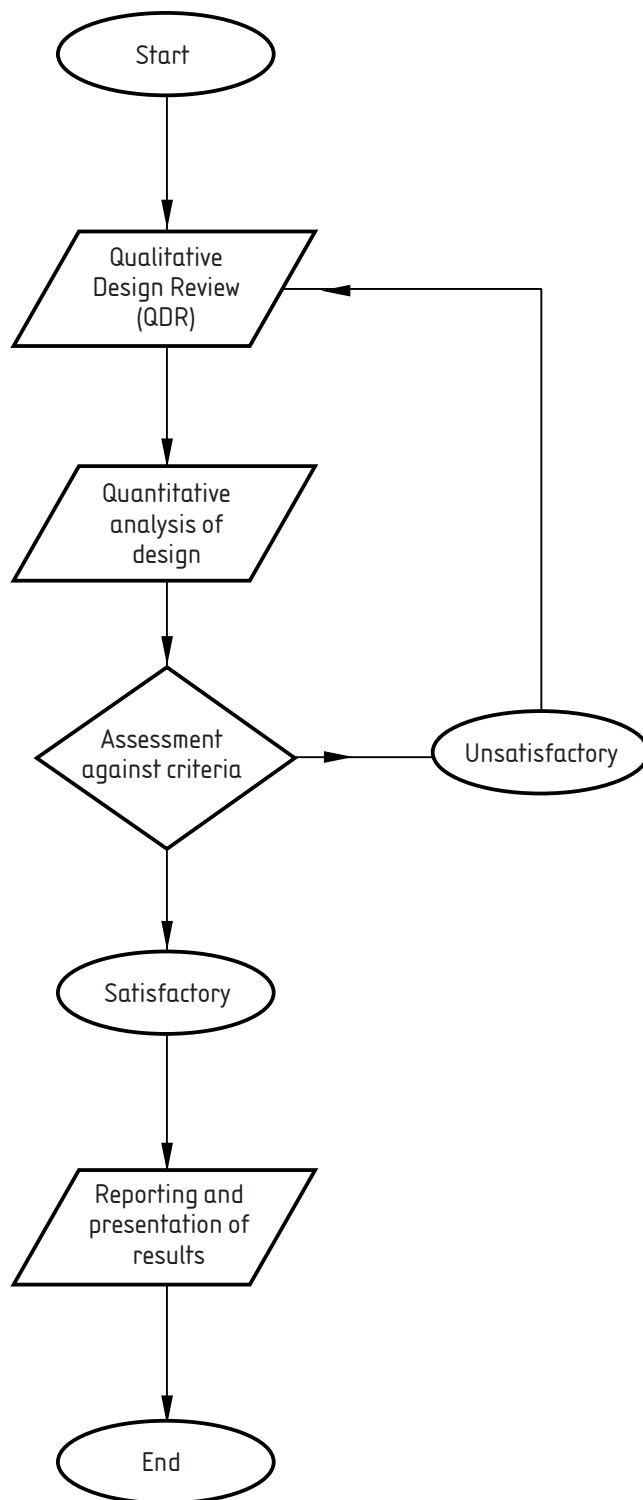


Figure 3 — Basic fire safety design process

5.3 Qualitative Design Review (QDR)

The first stage in any engineering design is to establish the basic parameters of the project. This includes a review of the scheme, identification of any overriding constraints and definition of the design objectives. This initial stage will draw on the expertise and experience of the engineer and design team. Quantification will normally only follow when the design parameters have been established. For the purposes of FSE, this preliminary stage is described in BS 7974:2001 as the Qualitative Design Review (QDR).

During the QDR process, the scope and objectives of the fire safety design are defined, performance criteria are established and one or more potential design solutions (trial designs) are proposed. Key information is also gathered to enable detailed evaluation of the design solutions in the quantitative analysis.

5.4 Quantitative analysis

Following the QDR, a quantified analysis can be carried out if necessary. It has been found convenient to split information on various aspects of FSE into a number of separate parts, referred to as sub-systems in BS 7974:2001. Guidance on each of the sub-systems is published in the supporting series of PDs.

The PDs provide selected guidance on the underlying principles and the type of calculations that may form part of a fire engineering study. However, it should be noted that the use of data and calculation procedures from other sources is not precluded and can often be essential to reach a solution.

One or two of the sub-systems may be used when analysing a particular aspect of design or they may all be used in combination as part of an overall fire engineering evaluation of fire safety in a building.

The quantitative analysis may use probabilistic or deterministic calculation procedures or a combination of both.

5.5 Assessment against criteria

5.5.1 General

Following the quantified analysis, the results need to be compared with the acceptance criteria identified during the QDR.

If none of the trial designs satisfies the specified acceptance criteria, the QDR and quantification process should be repeated until a fire safety strategy has been found that satisfies the design criteria.

Three basic approaches can be considered by the QDR team when setting acceptance criteria:

- a) comparative;
- b) deterministic;
- c) probabilistic.

One or more of these approaches may be utilized as part of a FSE study. Whichever approach is adopted, the criteria should, in general, satisfy the objectives of legislation and/or client requirements depending on the defined fire safety objectives.

5.5.2 Comparative criteria

It can often be difficult to establish the level of safety achieved in absolute terms. However, it might be relatively straightforward to demonstrate that the design provides a level of safety equivalent to that in a building that complies with recognized prescriptive codes. A comparison may be made on the basis of deterministic or probabilistic approaches or a combination of both.

5.5.3 Deterministic criteria

In a deterministic study, the objective is to show that on the basis of the initial (usually worst case scenario) assumptions a defined set of conditions will not occur (e.g. the smoke layer will not fall below head height during the evacuation period).

5.5.4 Probabilistic criteria

In a probabilistic study, criteria are set to ensure that the probability of a given event occurring is acceptably low. The risk criteria are usually expressed in terms of the annual probability of the unwanted event occurring (e.g. the probability of death in fire is less than 10^{-6} per annum). Guidance regarding probabilistic risk assessment techniques is given in PD 7974-7.

5.5.5 General

Table 3 illustrates the different types of acceptance criteria that may be adopted.

Table 3 — Typical examples of acceptance criteria

		Fire safety objectives	
		Deterministic	Probabilistic
Analysis method	Comparative	Time available for escape is at least equal to that in an equivalent code compliant building	Level of risk to life equivalent to code compliant building
	Absolute	The time available for escape exceeds the time to untenable conditions	Expected number of casualties per year.

5.6 Reporting and presentation

Most buildings designed in accordance with the provisions of BS 7974:2001 will be subject to review and approval. It is therefore essential that the findings of the fire engineering study and any assumptions made are presented in a form that can be readily understood and thoroughly checked by a third party. A clear, concise and complete report is therefore an essential requirement for an FSE study.

BS 7974:2001 does not recommend a fixed format for the report but does make recommendations regarding the minimum information that should be documented.

6 Qualitative Design Review

6.1 Overview

6.1.1 General

The interaction of fire, buildings and people gives rise to an almost infinite number of possible scenarios and it is not feasible to evaluate every conceivable case. Therefore, before attempting to carry out a detailed quantified study, the significant fire hazards should be identified, the problem simplified and the required extent of quantification established. This process is described as the Qualitative Design Review (QDR).

The QDR is essentially a qualitative process that draws upon the experience and knowledge of the fire safety engineer and a team of others involved in the design and operation of the building.

6.1.2 QDR Team

For very large and complex projects, it is recommended that the QDR be carried out by a study team involving one or more fire safety engineers, other members of the design team and a member of operational management. It might also be appropriate to include representatives of approval bodies or the insurers to ensure that their views can be accounted for.

For smaller projects or where FSE is being applied to a limited and well defined aspect of a project, the QDR may be carried out by a smaller study group which in many cases might only involve the fire safety engineer and architect. However, the same basic review process should be followed to ensure that no significant factors are missed.

The QDR team on a major project might include the following:

- a) fire safety engineer (chair);
- b) architect;
- c) services engineer;
- d) structural engineer;
- e) member of operational management;
- f) approvals body and/or insurer.