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Application of fire safety engineering principles to the design of buildings – Code of practice

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Contents

Summary of pages
This document comprises a front cover, and inside front cover, pages i to iv, pages 1 to 61, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 March 2019. It was prepared by Technical Committee FSH/24, *Fire safety engineering*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 7974:2001, PD 7974-0:2002 and PD 7974-8:2012, which are withdrawn.

Relationship with other publications

BS 7974 is intended to provide a framework for the application of fire safety engineering principles to the design of buildings. It is supported by the PD 7974 series of Published Documents, *Application of fire safety principles to the design of buildings,* that contain guidance and information on how to undertake detailed analysis of specific aspects of fire safety engineering in buildings. PD 7974-1 to PD 7974-7 provide a summary of the state of the art and it is intended that they are updated as new theories, calculation methods and/or data become available. The parts of PD 7974 are structured as follows:

- PD 7974-1, *Initiation and development of fire within the enclosure of origin (Sub-system 1)*;
- PD 7974-2, *Spread of smoke and toxic gases within and beyond the enclosure of origin (Sub-system 2)*;
- PD 7974-3, *Structural response and fire spread beyond the enclosure of origin (Sub-system 3)*;
- PD 7974-4, *Detection of fire and activation of fire protection systems (Sub-system 4)*;
- PD 7974-5, *Fire and rescue service intervention (Sub-system 5)*;
- PD 7974-6, *Occupant evacuation, behaviour and condition (Sub-system 6);* and
- PD 7974-7, *Probabilistic risk assessment*.

PD 7974-4 has now been withdrawn; it provided guidance on the detection of fire and activation of fire protection systems. This guidance is now included in the various parts of the PD 7974 series and other standards covering the subject. PD 7974-4 is referred to as part of the PD 7974 series for the sake of completeness but is no longer maintained as a current document.

Information about this document

This British Standard can be used to identify and define one or more fire safety design issues to be addressed using fire safety engineering. The appropriate part(s) of PD 7974 can then be used to set specific acceptance criteria and undertake detailed analysis.

This is a full revision of the standard, and introduces the following principal changes:

a) the incorporation of recommendations previously contained in PD 7974-0:2002 and PD 7974-8:2012;

b) a greater emphasis on the competence of the fire safety engineer;

c) additional recommendations for the quality assurance and verification of fire safety engineering reports; and

d) the terminology used has been simplified and consolidated.

The underlying process of fire safety engineering based on the qualitative design review has not changed, but every effort has been made to ensure that the terms used to describe that process are consistent throughout the standard.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Where words have alternative spellings, the preferred spelling of The Shorter Oxford English Dictionary is used (e.g. “organization” rather than “organisation”).

Contractual and legal considerations

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

Compliance with a British Standard cannot confer immunity from legal obligations.

Attention is drawn to the following statutory regulations: the Building Regulations [1], [2], [3], [4], [5], and Regulatory Reform (Fire Safety) Order 2005 [6] and Fire (Scotland) Act 2005 [7].

0 Introduction

0.1 General

For most buildings, the recommendations in existing design codes such as BS 9991 and BS 9999 are generally adequate. Where they are not, this British Standard can be used for developing and assessing fire safety engineered proposals.

A fire safety engineering (FSE) approach that takes into account the total fire risk management package specific to the building can often provide a more fundamental and economical solution than design codes. It might in some cases be the only viable means of achieving a satisfactory standard of fire safety in some large and complex buildings.

FSE can have many benefits. The use of this British Standard is intended to facilitate the practice of FSE and, in particular, to:

a) provide the designer with a disciplined approach to fire safety design;

b) allow the safety levels for alternative designs to be compared;

c) provide a basis for selection of appropriate fire protection systems;

d) provide opportunities for innovative design; and

e) provide information and assessment methods to support the design, construction, management and operation of buildings.

Fire is an extremely complex phenomenon and gaps exist in the available knowledge and technology. This British Standard is intended to provide a framework for a flexible but formalized approach to fire safety design by which an adequately fire safe building can be constructed while allowing for inevitable uncertainties in the development of a fire and the response of the building and occupants to it. It also sets out a reporting methodology which allows for the design to be readily assessed by approvals bodies.

This British Standard is supported by a series of Published Documents that contain guidance and information on how to undertake detailed analysis of specific aspects of FSE. This does not preclude the use of appropriate methods and data from other sources. Figure 1 shows the structure of this British Standard and the Published Documents.

This British Standard:

1) provides a framework for and describes the philosophy that underpins FSE;

2) outlines the principles involved in the application of the philosophy to the FSE of particular buildings;

3) provides means of establishing acceptable levels of fire safety without imposing disproportionate constraints on aspects of building design;

4) provides guidance on the design and assessment of fire safety measures in buildings;

5) gives a structured approach to assessing the effectiveness of the fire safety strategy in achieving the functional objectives;

6) can be used to identify and define one or more fire safety design issues to be addressed using FSE;

NOTE The appropriate part(s) of PD 7974 can then be used to set specific acceptance criteria and undertake detailed analysis.

7) provides alternative approaches to existing standards for fire safety and also allows the effect of departures from design codes to be evaluated;

8) recognizes that the functional objectives can be achieved by a range of alternative and complementary fire protection strategies;

9) aims to facilitate innovation in design without compromising safety;

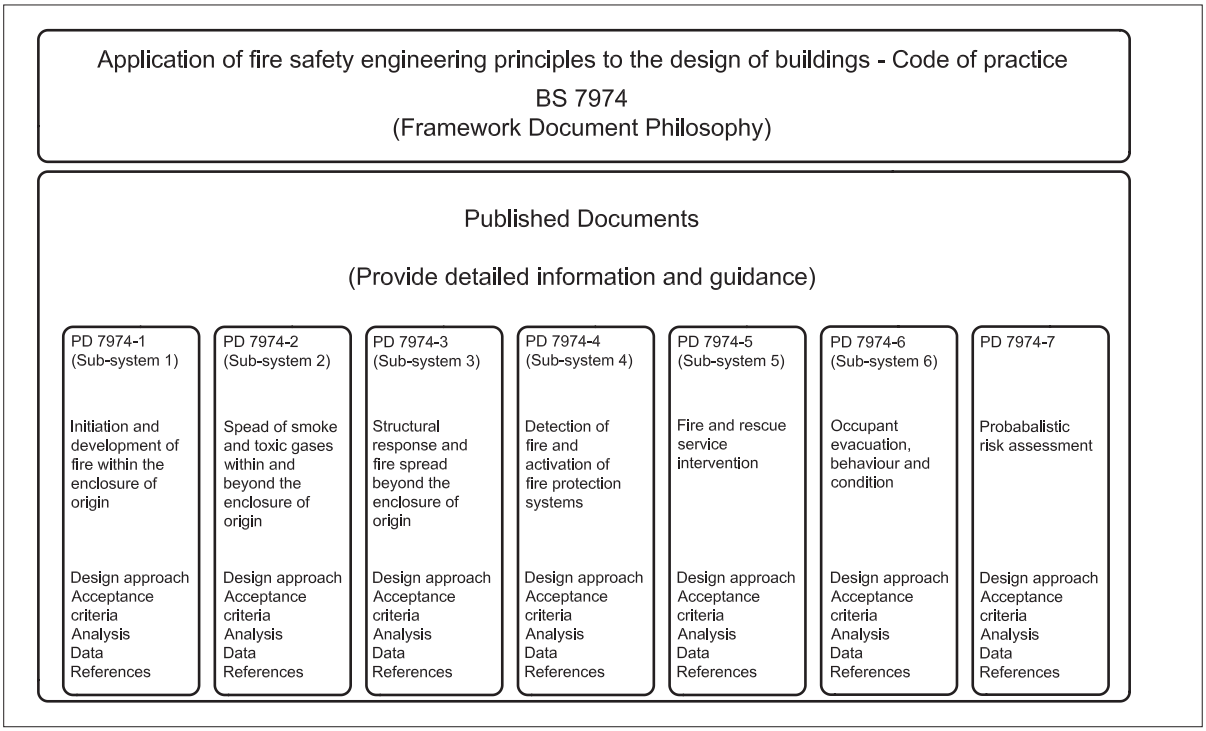
10) provides guidance to ensure that the building is constructed such that: it can withstand fire actions that are reasonably foreseeable; its layout and configuration does not prejudice its integrity; and foreseeable life-cycle fabrication, construction, commissioning, operation, modification, maintenance and repair can proceed without prejudicing its integrity; and

11) provides a flexible framework that can be used for simple aspects of fire safety design (e.g. a minor variation from prescriptive guidance) using perhaps only part of a single sub-system of this standard, to complex fire safety challenges (e.g. a major departure from prescriptive guidance) that require use of all sub-systems.

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

There are some frequently cited misconceptions about FSE and its applicability. These are discussed in Annex A.

Figure 1 — *The structure of the British Standard and the Published Documents*



The framework for an engineering approach to fire safety described in this code of practice is applied using the following three main stages.

- Qualitative design review (QDR): The scope and objectives of the fire safety design are defined, performance criteria established and one or more potential design solutions proposed. Key information is also gathered to enable evaluation of the design solutions in the quantitative analysis.

- Quantitative analysis: Engineering methods are used to evaluate the potential solutions identified in the QDR. Quantitative analysis can be time-based analysis using appropriate sub-systems (see **0.2**) to reflect the impact of the fire on people and property at different stages of its development. Steady state and limit state analysis can also be used.
- Assessment against criteria: The output of the quantitative analysis is compared to the acceptance criteria identified in the QDR to test the acceptability of the proposals.

In order to substantiate a FSE design, these three distinct stages are worked through, with each of the stages being fully documented so that they are readily accessible to a third party, e.g. approvals bodies, insurers, owner occupiers of buildings.

0.2 The sub-systems

0.2.1 General

To simplify the evaluation of the fire safety design, the FSE process can be further broken down into six sub-systems. The sub-systems can be used individually to address specific issues or together to address all of the main aspects of fire safety.

The sub-systems can be used as follows.

a) Sub-system 1: initiation and development of fire within the enclosure of origin (see PD 7974-1). Sub-system 1 provides guidance on evaluating fire growth and/or size within the enclosure taking into account the four main stages of fire development:

   1) pre-flashover (including early growth and development);
   2) flashover;
   3) fully developed fire (where all the fuel is burning); and
   4) decay.

b) Sub-system 2: spread of smoke and toxic gases within and beyond the enclosure of origin (see PD 7974-2). Sub-system 2 provides guidance by which the following can be evaluated:

   1) the spread of smoke and toxic gases within and beyond the enclosure of fire origin; and
   2) the characteristics of the smoke and the toxic gases at the location of interest.

c) Sub-system 3: structural response and fire spread beyond the enclosure of origin (see PD 7974-3). Sub-system 3 provides guidance so that the following can be evaluated:

   1) the fire size, in terms of temperature and heat flux within the enclosure; and
   2) the ability of the elements forming the enclosure, directly or in part, to withstand exposure to the prevailing fire size.

d) Sub-system 4: detection of fire and activation of fire protection systems (see PD 7974-4). Sub-system 4 gives guidance on the calculation of the following with respect to time:

   1) detection of the fire;
   2) activation of the alarm and fire protection systems, e.g. sprinklers, smoke management systems, roller shutters, etc.; and
   3) fire service notification.

e) Sub-system 5: fire and rescue service intervention (see PD 7974-5). Sub-system 5 provides guidance on the evaluation of the rate of build-up of fire extinguishing resources of the fire service, including the activities of in-house or private fire brigades and in particular:

   1) the time interval between the call to the fire and rescue service and the arrival of the fire and rescue service's pre-determined attendance;

   2) the time interval between the arrival of the fire and rescue service and the initiation of attack on the fire by the fire and rescue service;

   3) the time intervals related to the build-up of any necessary additional fire and rescue service resources;

   4) the extent of fire-fighting resources and extinguishing capability available at various times; and

   5) the provision of additional access and facilities for fire-fighters to improve the likelihood of successful fire-fighting.

f) Sub-system 6: occupant evacuation, behaviour and condition (see PD 7974-6). Sub-system 6 provides guidance on how to assess the response of people to fire, including their evacuation time from any space inside a building and time to loss of tenability in any occupied space. Once the evacuation time has been established it can be compared with the outputs from sub-systems 1 to 4 and the calculated available safe escape time from system 6, within the quantitative analysis. Acceptance criteria are contained in this sub-system.

NOTE The various parts of PD 7974 (PD 7974-1 to PD 7974-6 respectively) give selected data and engineering relationships (including information on their applicability) that may be used for design. However, this British Standard recognizes the use of alternative information.

All six sub-systems together can be used to produce a time-based analysis of fire safety.

0.2.2 Relationship between sub-systems

A FSE solution might make reference to only one or two sub-systems or there might be a complex series of interactions involving all of the sub-systems. For instance, the activation of sprinklers (sub-system 4) and fire service intervention (sub-system 5) can influence the rate of fire growth (sub-system 1). The flow chart in Figure 2 is an example of the order in which the sub-systems are normally evaluated. The solid lines indicate the order of calculation and the links that are normally required from other sub-systems. The dotted lines indicate the links that can be included depending upon the complexity of the analysis being undertaken.

Analysis adheres to a formal framework following a preliminary review, the QDR, which sets out functional objectives. Achieving the functional objectives set by the QDR can involve using one or all of the six sub-systems whereas to achieve a specific design objective, such as structural failure, it might only be necessary to consider sub-systems 1 and 3. The ways in which sub-systems can be linked together in typical life safety and structural analyses (where the development of fire is not controlled by active suppression systems) are illustrated in Figure 3 and Figure 4. However, these examples do not represent the only acceptable method and the fire safety engineer is expected to establish the most appropriate approach.

Figure 2 — *Example of the complexity of the linkages between the sub-systems that can arise if the analysis is not simplified*

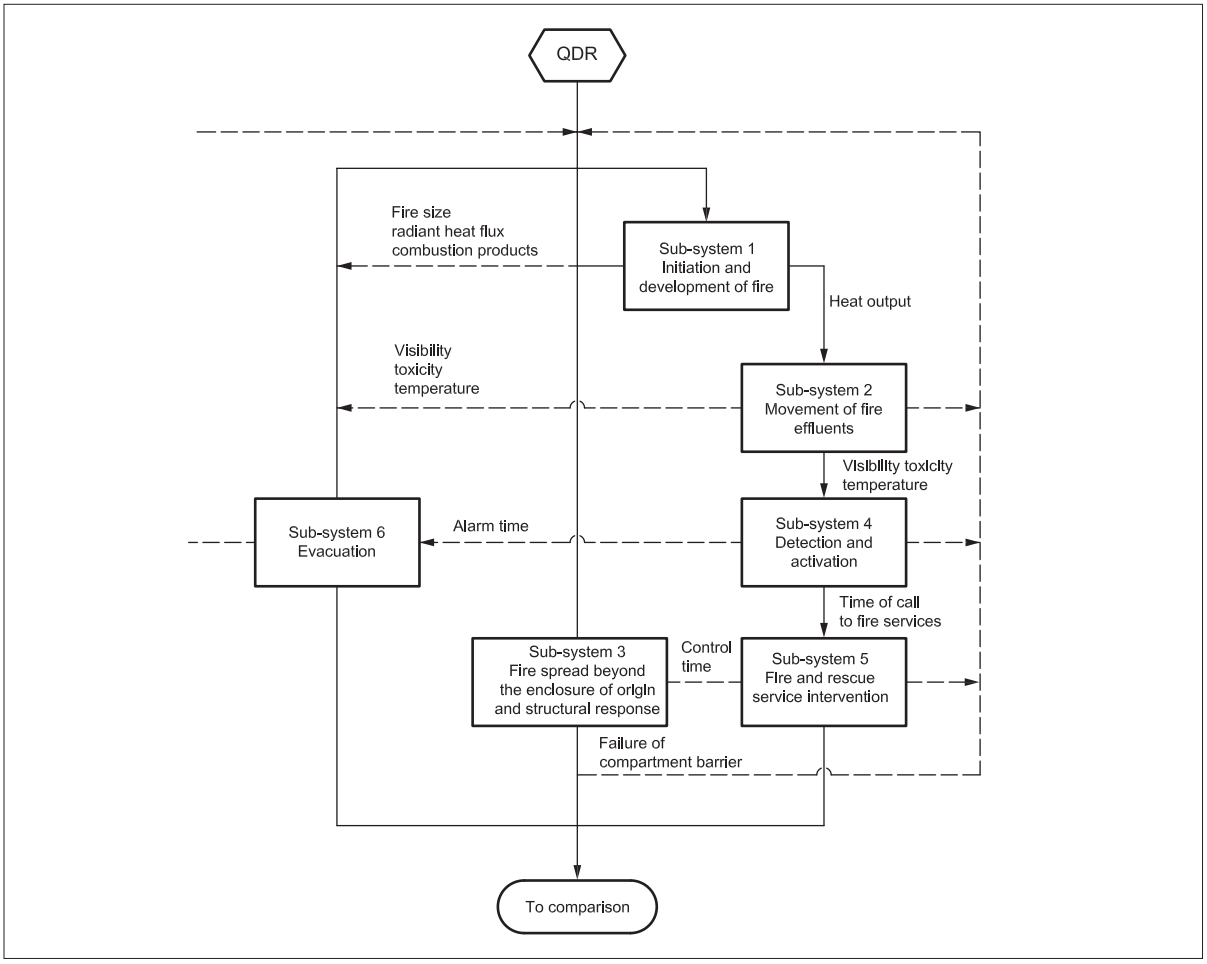
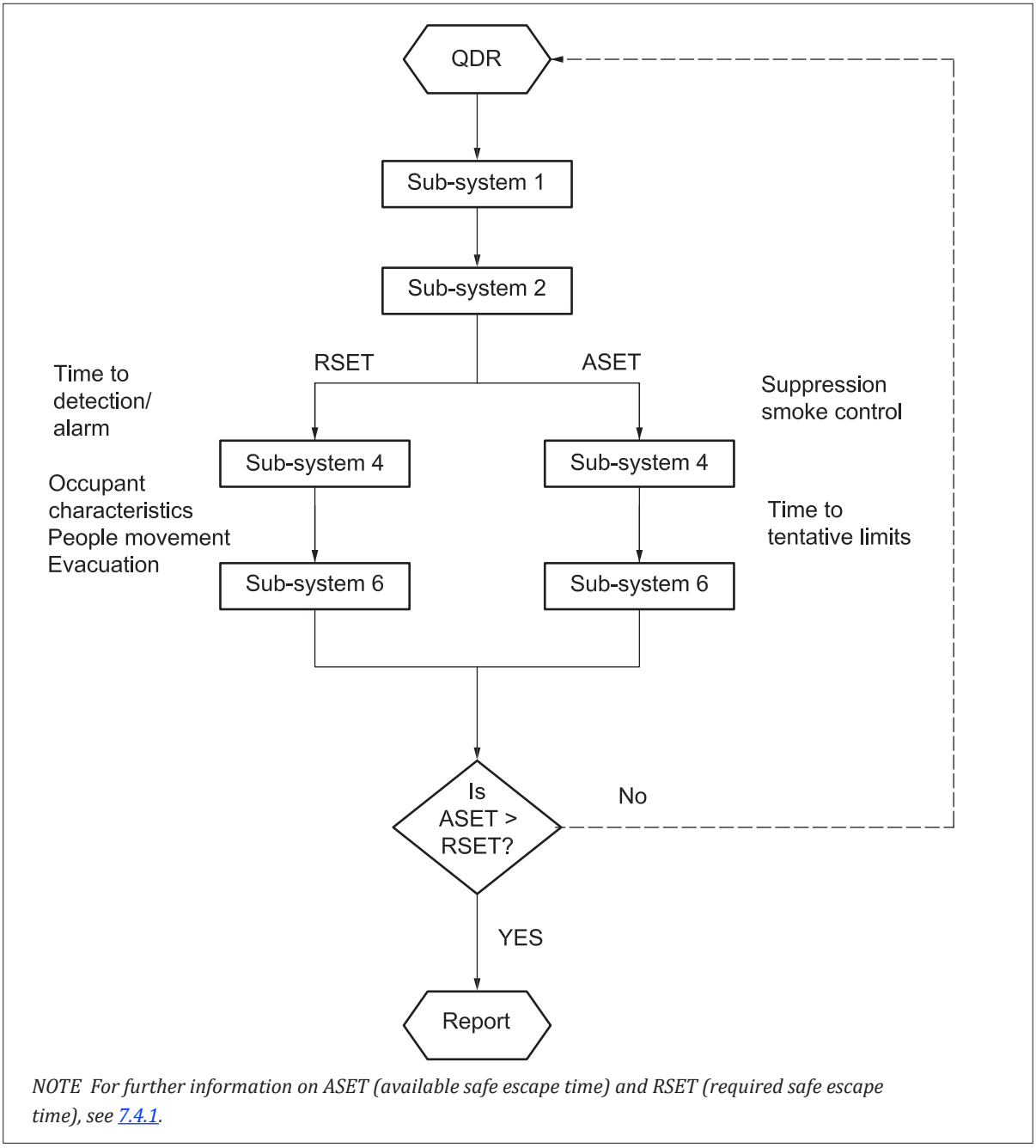
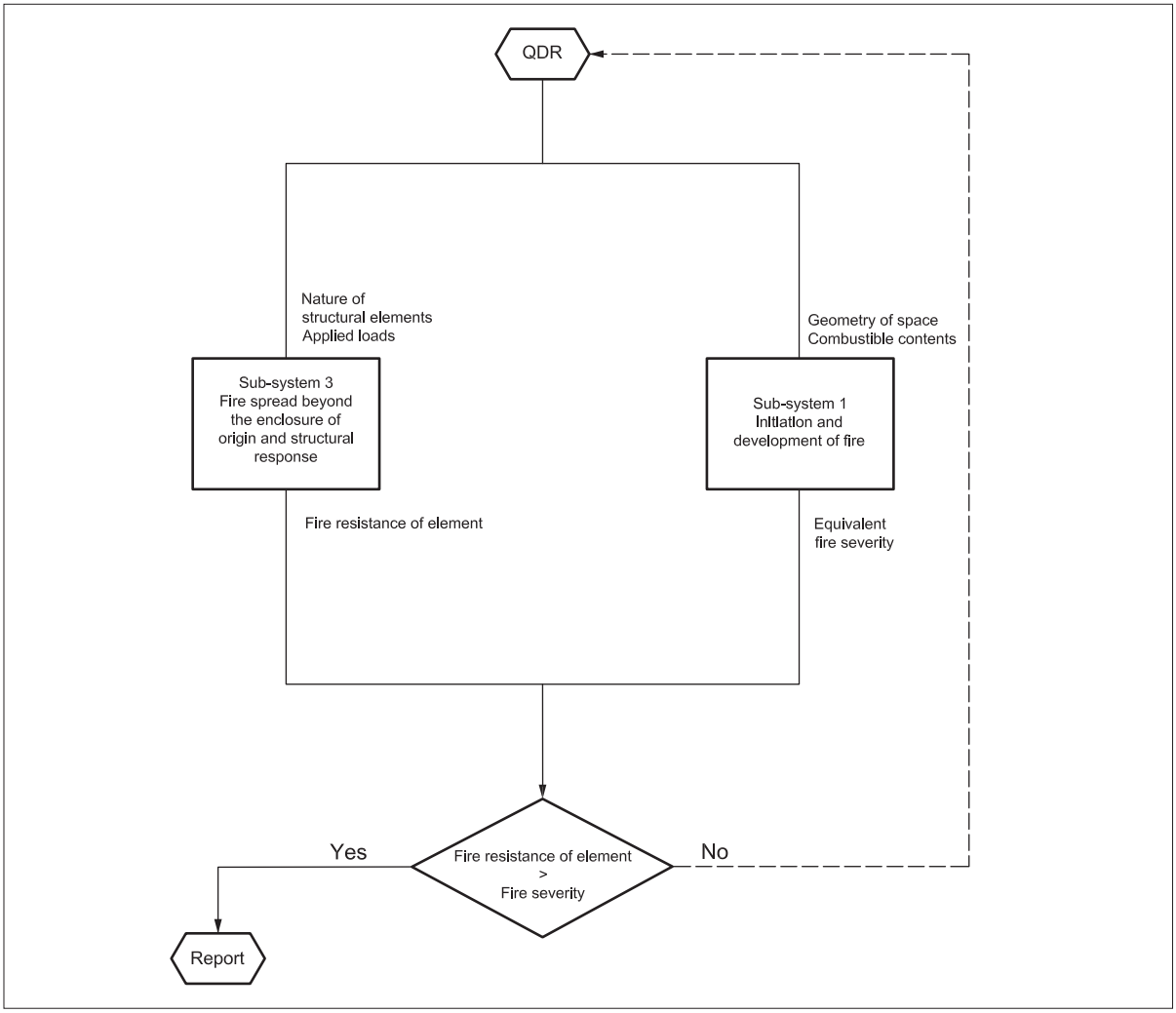


Figure 3 — *Example of how the sub-system procedures can be simplified to assess the adequacy of means of escape from the room of fire origin*



NOTE For further information on ASET (available safe escape time) and RSET (required safe escape time), see 7.4.1.

Figure 4 — *Example of how the sub-system procedures can be utilized to assess the ability of a building structure to resist a compartment burnout*



0.3 PD 7974-7 — Probabilistic risk assessment

In addition to PD 7974-1 to PD 7974-6 that cover the sub-systems, PD 7974-7 addresses another aspect of FSE, that of probabilistic risk assessment.

PD 7974-7 provides guidance on how to analyse the risk to a building and its contents, occupants and fire control systems with the intention of determining the frequency and consequences of certain fire scenarios and the possible need for extra measures required to reduce any unacceptable risks.

0.4 Background

0.4.1 General

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

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

a) life safety;

b) property protection;

c) protection of the environment;

d) cost-effective fire protection; and

e) operational requirements.

The design code 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, design 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 design codes are summarized in Table 1.

Table 1 — *Examples of advantages and disadvantages of design 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
Familiarity to stakeholders and authorities having jurisdiction	Unresponsive to changes in construction methods, technology and materials
	Might result in compliance taking precedence over wider safety considerations

0.4.2 Benefits of fire safety engineering

A fire safety engineering (FSE) 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.

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 FSE compared to the more traditional design code approach are summarized below in Table 2.

Table 2 — *Examples of advantages and disadvantages of FSE approach*

Advantages	Disadvantages
Fire safety measures tailored to risk and specified functional 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 reduced without compromising safety.	Lack of data in some fields.
Provides a framework to translate research into practice.	Might be restrictive unless future flexibility of use is explicitly considered as a functional objective.
Enables alternative fire safety strategies to be compared on cost and operational grounds.	Potentially unfamiliar to stakeholders and authorities having jurisdiction.
Enables cost and benefits of loss control measures to be assessed.	Might require additional analyses/fire testing as part of verification of the design package.
Increased opportunity to use modern and innovative technology.	
Requires design team and operator to explicitly consider fire safety.	

1 Scope

This British Standard provides a framework for an engineering approach to fire safety in buildings by giving recommendations and guidance on the application of scientific and engineering principles to the protection of people, property and the environment from fire. It is applicable to the design of new buildings and the appraisal of existing buildings.

The general approach to fire safety engineering (FSE) described in this British Standard can 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 necessitate special consideration which is beyond the scope of BS 7974 and its supporting documents.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purpose of this British Standard, the following terms and definitions apply.

3.1 approvals body

organization responsible for approving the fire safety aspects of a building

NOTE Examples of approvals bodies are the local authority building control, approved inspectors, and the fire authority.

3.2 authority having jurisdiction

organization, office or individual responsible for enforcing the requirements of legislation or standards, or for approving equipment, materials, an installation, or a procedure

