



BSI Standards Publication

Application of fire safety engineering principles to the design of buildings

Part 6: Human factors: Life safety strategies - Occupant evacuation, behaviour and condition (Sub-system 6)

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Summary of pages

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Foreword

Publishing information

This Published Document 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This Published Document supersedes PD 7974-6:2004, which is withdrawn.

Relationship with other publications

The parts of PD 7974 are structured as follows:

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

This series of Published Documents are intended to be used in support of BS 7974, but do not represent the only means of satisfying the recommendations of the code of practice.

Information about this document

This Published Document can be used to set specific acceptance criteria and undertake detailed analysis for escape and tenability. It can be used to identify and define one or more fire safety design issues to be addressed using fire safety engineering.

This is a full revision of the Published Document, and introduces the following principal changes.

- The principal guidance and bibliography have been updated in line with recent developments and publications since 2004.
- The data tables in the annexes have been expanded to include more recently published data and bibliography.
- A full set of expressions has been provided for fractional effective dose calculations with worked examples to illustrate the calculation methods.

Use of this document

This publication is not to be regarded as a British Standard.

As a guide, this Published Document takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

It has been assumed in the preparation of this Published Document 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 guidance in this Published Document is presented in roman (i.e. upright) type. Any 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.

Particular attention is drawn to Approved Document B of the Building Regulations 2010 [[1](#)].

Introduction

This Published Document provides information regarding engineering methods currently available for the evaluation and management of occupant behaviour, particularly escape behaviour, during a fire emergency and for the evaluation of occupant condition, especially in relation to exposure to fire effluent and heat.

Most cases of fire involve evacuation of the occupants. A basic principle of a performance-based (fire safety engineering) building design is that the available safe escape time (ASET) is greater than the required safe escape time (RSET) by an appropriate margin of safety. An appropriate margin of safety takes account of the risks associated with different potential fire scenarios and the uncertainties in the prediction of ASET and RSET for particular design scenarios (see Purser, 2003 [2]). Uncertainties for specific ASET and RSET parameters are considered in this Published Document. Assessment of overall safety margin for a design is considered in BS 7974.

An ideal fire safety design ensures that building occupants are able to reach a place of relative or ultimate safety without ever coming into contact with or even being aware of fire effluent and/or heat. This is the main design criterion for the safety of the majority of occupants in multi-compartment buildings (see BS 7974 and BS ISO/TR 13387-8). A major design criterion is therefore the estimation of the time required for escape in situations where occupants are not directly affected by fire effluent or heat.

There will inevitably be some potential scenarios when some occupants become aware of or are exposed to fire effluent, particularly when the occupants are in the enclosure of fire origin. This can vary between seeing fire or smoke or exposure to slight smoke contamination, common in many accidental fires, to life threatening exposures such as in major fire disasters. For all of these types of scenarios, it is important to be able to assess the likely effects of such exposures, either as part of the main design or as part of a risk assessment.

To achieve these evaluations, detailed input information is required in four main areas:

- a) the building design and emergency life safety management strategy;
- b) the occupant characteristics including human behaviour;
- c) the fire simulation dynamics; and
- d) intervention effects.

The response of occupants to a fire condition is influenced by a range of variables in these four categories, related to the characterization of the occupants in terms of their number, distribution within the building at different times, their familiarity with the building, their abilities, behaviours and other attributes; the characterization of the building including its use, layout and services; the provision for warnings, means of escape and emergency management strategy; the interaction of all these features with the developing fire scenario; and provisions for emergency intervention (by fire and rescue services).

Guidance is provided on the evaluation of escape and evacuation times from buildings:

- in the absence of fire and where occupants are not directly affected by a fire – for example in building locations remote from the fire compartment;
- when the escape behaviour of occupants and therefore RSET is influenced by fire, specifically by fire effluents and heat; and
- the evaluation of ASET in relation to tenability limits due to fire effluents and heat.

The time required for escape depends upon a series of processes consisting of:

- 1) time from ignition of fuel resulting in a fire to detection;
- 2) time from detection of a fire to the provision of a general evacuation warning to occupants; and
- 3) evacuation time, which has two major components:
 - pre-travel time – this consists of the time required after a warning to recognize the emergency and then respond by carrying out a range of activities before travelling to exits; and
 - travel time (the time required for occupants to travel to a place of safety).

NOTE 1 See Purser, 2003 [3] for further information.

For detection, warning and pre-travel recognition and response times, research regarding human behaviour in the event of fire has been essentially qualitative, describing the psychological, behavioural and physiological factors affecting detection and recognition of fires and the wide range of pre-travel behaviours engaged in by groups of occupants. Some studies have included measurements of the times for which these behaviours were engaged in, which can be used as input to evacuation time calculations.

NOTE 2 For further information, see BS ISO/TR 13387-8; Purser, 2003 [2]; Canter, 1990 [4]; Sime, 1988 [5]; Sime, 1998 [6]; Purser and Bensilum, 2001 [7]; Proulx and Fahy, 1997 [8]; Bryan, 2002 [9]; and Bryan, 1977 [10].

The results of this work have provided an understanding of the complexities of human behaviour during fire emergencies and escape from occupied buildings and the profound effects of the behavioural activities engaged in before the travel phase of evacuation on escape and evacuation times. In many situations, these pre-travel processes and activities comprise the greatest part of the time required for escape, while for evacuation engineering calculations most attention has historically been directed to the travel phase.

NOTE 3 See Purser, 2003 [2]; Purser, 2003 [3]; Canter, 1990 [4]; Sime, 1988 [5]; Sime, 1998 [6]; Purser and Bensilum, 2001 [7]; Proulx and Fahy, 1997 [8]; Bryan, 2002 [9]; and Bryan, 1977 [10].

Previous methodologies have attempted to provide qualitative evaluation based upon different occupancy criteria to inform designers regarding aspects that are likely to affect evacuation timing and efficiency; however, since they were not linked with quantitative performance data they could not be used to develop engineering analytical calculations to evaluate escape time (see Sime, 1998 [6]). Current methods presented in this Published Document make use of published quantitative data on escape and evacuation parameters for application to escape and evacuation time calculations.

In an earlier draft version of the design guidance (DD 240-1), attempts were made to relate pre-travel time solely to the type of warning system used (sounder, recorded voice message or direct personal address message). Although the type of warning system has been found to be one important parameter, subsequent research has shown that in many situations additional features, especially the fire safety management system and occupant characteristics, are more important aspects influencing escape parameters, especially warning and pre-travel times. Guidance on these aspects was included in the 2004 edition of this Published Document, but the available data were limited at that time. Work in this area has expanded considerably in recent years, which is reflected in the updated guidance in this edition.

References to specific sources of information are cited throughout this Published Document. Two sources of information and guidance for evaluating aspects of occupant escape behaviour and condition (effects of exposure to heat, smoke and toxic gases) from the Society of Fire Protection Engineers (SFPE) are particularly recommended. The behaviour and condition chapters in the *SFPE Handbook of Fire Protection Engineering* [11] have been considerably expanded in the 5th Edition,

with references to specific chapters included in this Published Document. In addition, the SFPE has also published a second edition of the *Guide to Human Behaviour in Fire* [12] which contains useful information on the evaluation of behaviour and condition.

NOTE 4 For further information, see BS ISO/TR 13387-8; Purser, 2003 [2]; Canter, 1990 [4]; Sime, 1988 [5]; Sime, 1998 [6]; and Purser and Bensilum, 2001 [7].

At the time of publication the only method available for the quantification of these behavioural phenomena is by observation, measurement or analysis of actual incidents or simulated emergency experiments. For these data to be of value for application to RSET calculations they are assigned to specified behavioural scenarios, designated in terms of features influencing behaviour, including occupancy type, occupant characteristics, fire safety management strategy and warning system (see Nilsson and Fahy, 2016 [13]). A number of data sets are now available for a range of occupancy types, which are summarized in [Clause 6](#). These have been used to develop guidance for pre-travel times for different design behavioural scenarios.

NOTE 5 See Purser and Bensilum, 2001 [7]; Proulx and Fahy, 1997 [8]; Proulx and Sime [14]; and Gwynne and Boyce, 2016 [15].

Travel to and through exits and escape routes involves physically-based processes more amenable to relatively simple calculation methods for design purposes (see references [2], [16], [17], [18], [19], [20], [21]). However, travel times can be affected by behaviours such as wayfinding and exit choice (see references [2], [4], [6] and [7]) and certain physical phenomena such as merging flow, for which calculation parameters have not been fully solved (see references [3], [22], [23] and [24]).

There is considerable interaction between the various aspects of pre-travel and travel times in the determination of total evacuation times for groups of building occupants. This has important implications for design performance evaluations (see references [2], [7], [16] and [22]). A range of human behaviours can be involved to a greater or lesser extent in all these phases of escape time.

The guidance in this Published Document on evaluation of occupant behaviour and condition is intended to be considered with the guidance from the other documents in the 7974 series as part of an overall performance-based design as set out in BS 7974.

1 Scope

This Published Document is intended to provide guidance to designers, regulators and fire safety professionals on the engineering methods available for the evaluation of life safety aspects of a fire safety engineering design in relation to escape and tenability strategies.

The objective of the fire safety engineering strategy is to ensure exposure to the effects of fire does not impede the safe escape of occupants or cause exposure to conditions leading to adverse health effects.

Guidance is presented regarding the evaluation and management of occupant behaviour during a fire emergency and for the evaluation of occupant condition related to exposure to fire effluent and heat.

This Published Document addresses the parameters that underlie the basic principles of designing for life safety and provides guidance on the processes, assessments and calculations necessary to determine the location and condition of the occupants of the building, with respect to time. This is achieved using the information presented on the evaluation, quantification and management of occupant behaviour, particularly escape behaviour, during a fire emergency.

This Published Document also provides a framework for reviewing the suitability of an engineering method for assessing the life safety potential of a building for its occupants.