International Standard

# ISO 16733-1

Second edition
2024-10

# Fire safety engineering — Selection of design fire scenarios and design fires —

## Part 1: Selection of design fire scenarios

*Ingénierie de la sécurité incendie — Sélection de scénarios d'incendie et de feux de dimensionnement —*

*Partie 1: Sélection de scénarios d'incendie de dimensionnement*



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# Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 4, *Fire safety engineering*.

This second edition cancels and replaces the first edition (ISO 16733-1:2015), which has been technically revised.

The main changes are as follows:

— Annex C has been removed as the content is now included in ISO/TS 16733-2;

— revised to reference updated content in ISO 23932-1.

A list of all parts in the ISO 16733 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

# Introduction

Selection of the fire scenarios requiring analysis is critical in fire-safety engineering. The number of possible fire scenarios in any built environment (a building or other structure) can be very large and it is not always possible to quantify them all. In order for these fire scenarios to be made amenable to analysis, they are reduced from this large set of possibilities to a small set of design fire scenarios.

The characterization of a fire scenario comprises a description of fire initiation, the growth phase, the fully-developed phase, decay and extinction, together with the likely smoke and fire spread routes. This includes a description of the interaction with the proposed fire protection features for the built environment. The possible consequences of each fire scenario should be considered.

This document introduces a methodology for the selection of design fire scenarios that is tailored to the fire-safety design objectives. Several fire-safety objectives can be addressed, including safety of life (for occupants and rescue personnel), conservation of property, protection of the environment and preservation of heritage. A different set of design fire scenarios can be required to assess the adequacy of a proposed design for each objective.

Following selection of the design fire scenarios, a description of the assumed characteristics of the fire on which the scenario quantification is based is needed. These assumed fire characteristics are referred to as "the design fire". The design fire should be appropriate to the objectives of the fire-safety engineering analysis and result in a design solution that is commensurate with credible worst case scenarios.

Users of this document should be appropriately qualified and competent in the fields of fire-safety engineering and risk assessment. Users need to understand the parameters within which specific methodologies can be used.

ISO 23932-1 provides a performance-based methodology for engineers to assess the level of fire safety for new or existing built environments. Fire safety is evaluated through an engineered approach which is based on the quantification of the behaviour of fire and on knowledge of the consequences of such behaviour on life, property, heritage and the environment. ISO 23932-1 provides the process (necessary steps) and essential elements to design a robust, performance-based fire-safety programme.

ISO 23932-1 is supported by a set of fire-safety engineering standards on the methods and data needed for the steps in a fire-safety engineering design. It is summarized in ISO 23932-1:2018, Clause 4 and shown in Figure 1.

The following International Standards on fire-safety engineering are tied to the steps in the fire safety engineering design process outlined in ISO 23932-1: ISO 16730-1, ISO 16732-1, ISO 20414, ISO 20710-1, ISO 24678-1, ISO 24678-2, ISO 24678-3, ISO 24678-4, ISO 24678-5, ISO 24678-6, ISO 24678-7, ISO 24678-9 and ISO 24679-1.

# Fire safety engineering — Selection of design fire scenarios and design fires —

# Part 1: Selection of design fire scenarios

## 1 Scope

This document describes a methodology for the selection of design fire scenarios for use in fire-safety engineering analyses of any built environment, including

— buildings,

— structures, and

— transportation systems.

This document specifies procedures for selecting a manageable number of design fire scenarios using a qualitative or semi-quantitative approach.

NOTE See ISO 16732-1 for a full quantitative approach using risk assessment.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13943, *Fire safety — Vocabulary*

ISO 16730-1, *Fire safety engineering — Procedures and requirements for verification and validation of calculation methods — Part 1: General*

ISO 16732-1, *Fire safety engineering — Fire risk assessment — Part 1: General*

ISO 23932-1, *Fire safety engineering — General principles — Part 1: General*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

**3.1**
**design fire**
quantitative description of assumed fire characteristics within the *design fire scenario* (3.2)

Note 1 to entry: A design fire is, typically, an idealized description of the variation with time of important fire variables such as the heat release rate, flame spread rate, smoke production rate, toxic gas yields and temperature.

**3.2**
**design fire scenario**
specific *fire scenario* (3.4) on which an analysis will be conducted

**3.3**
**exposed**

**3.3.1**
**exposed person**
person intended to be protected either from the effects of fire and fire effluents (e.g. smoke and corrosive gas) or from fire suppression effluents, or both

**3.3.2**
**exposed object**
object intended to be protected either from the effects of fire and fire effluents (e.g. smoke and corrosive gas) or from fire suppression effluents, or both

**3.3.3**
**exposed environment**
environment intended to be protected either from the effects of fire and fire effluents (e.g. smoke and corrosive gas) or from fire suppression effluents, or both

**3.4**
**fire scenario**
qualitative description of the course of a fire with respect to time, identifying key events that characterize the studied fire and differentiate it from other possible fires

Note 1 to entry: See *fire scenario cluster* (3.6) and *representative fire scenario* (3.5).

Note 2 to entry: It typically defines the ignition and fire growth processes, the fully developed fire stage, the fire decay stage, and the environment and systems that will impact on the course of the fire.

Note 3 to entry: Unlike deterministic fire analysis, where fire scenarios are individually selected and used as *design fire scenarios* (3.2), in *fire risk assessment*, fire scenarios are used as representative fire scenarios within fire scenario clusters.

**3.5**
**representative fire scenario**
specific *fire scenario* (3.4) selected from a *fire scenario cluster* (3.6) from which the consequence can be used as a reasonable estimate of the average consequence of scenarios in the *fire scenario cluster*

**3.6**
**fire scenario cluster**
subset of *fire scenarios* (3.4) usually defined as part of a complete partitioning of the universe of possible fire scenarios

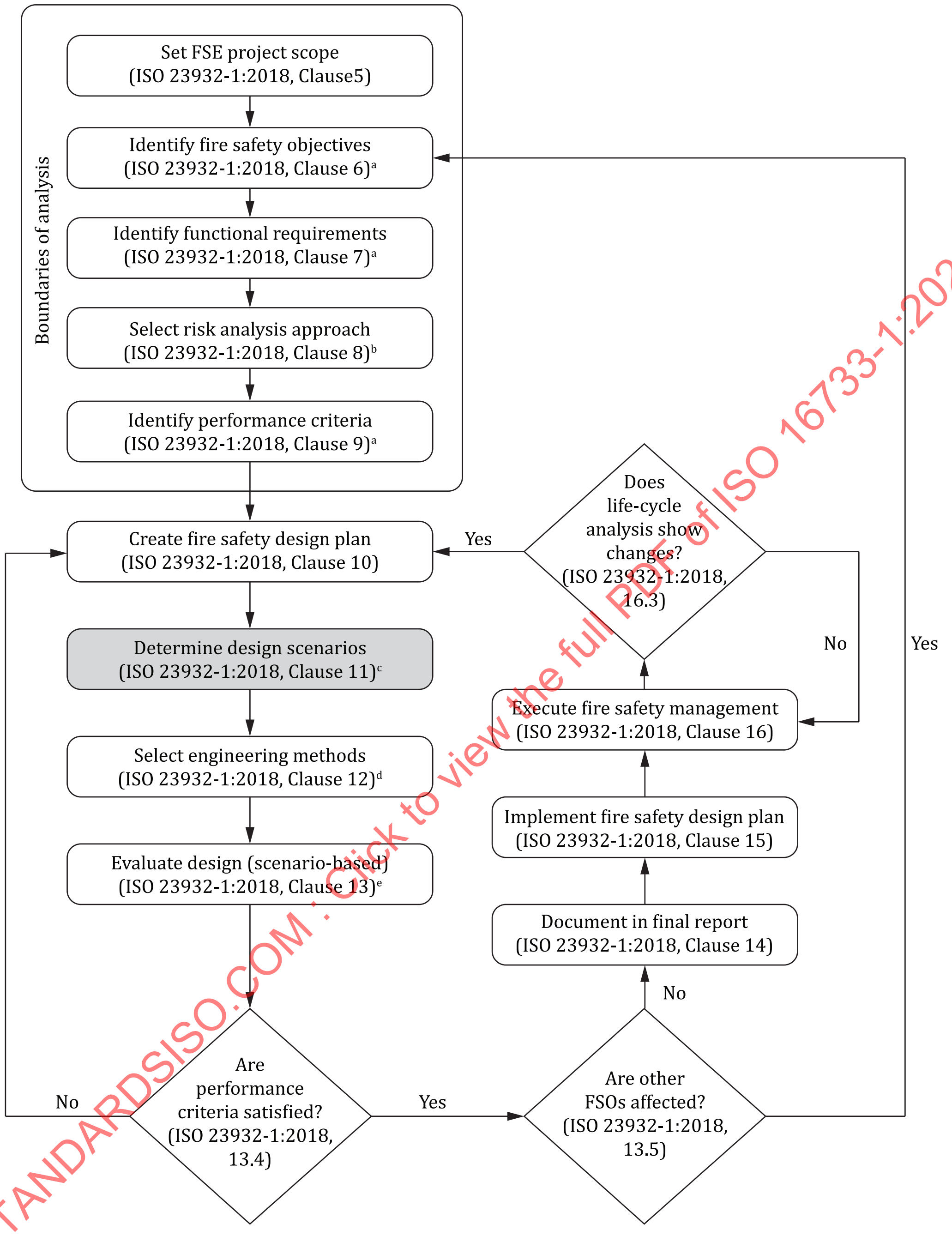
Note 1 to entry: This subset is usually defined so that the calculation of fire risk as the sum over all fire scenario clusters of fire scenario cluster frequency multiplied by *representative fire scenario* (3.5) consequence does not impose an undue calculation burden.

# 4 Fire safety engineering applications

## 4.1 Fire safety engineering process

ISO 23932-1 provides a performance-based methodology for engineers to assess the level of fire safety for new or existing built environments. Fire safety is evaluated through an engineered approach based on the quantification of the behaviour of fire and based on knowledge of the consequences of such behaviour on life, property, heritage and the environment.

ISO 23932-1 specifies the process, including the necessary steps and essential elements, to design a robust, performance-based fire-safety programme. This document specifies how to develop design fire scenarios in accordance with ISO 23932-1:2018, Clause 11. This step in the fire-safety engineering process is shown as a shaded box in Figure 1.




[a] Refer to ISO/TR 16576 for examples.

[b] Refer to ISO 16732-1, ISO 16733-1 (this document), ISO/TS 16733-2, ISO/TS 29761.

[c] Refer to ISO 16732-1, ISO 16733-1, ISO/TS 16733-2, ISO/TS 29761.

[d] Refer to ISO/TS 13447, ISO 16730-1, ISO/TR 16730-2 to ISO/TR 16730-5 for examples, ISO/TR 16738, ISO 24678-1, ISO 24678-2, ISO 24678-3, ISO 24678-4, ISO 24678-5, ISO 24678-6, ISO 24678-7 and ISO 24678-9.

[e] Refer to ISO/TR 16738 and ISO/TS 16733-2.

NOTE Figure 1 adapted from ISO 23932-1:2018.

**Figure 1 — Fire-safety engineering process**

### 4.1.1 Establish project scope

The project scope shall describe the purpose and function of each part of the design, as well as the fixtures, furnishings, decorations, equipment and combustible products that are to be installed, stored or used in the built environment. Where this information is not available, assumptions shall be made. The validity of each assumption shall be checked and confirmed both during and after the project. The scope of the design work shall be defined, including the extent to which an FSE approach will be applied.

ISO 23932-1:2018, Clause 5 shall be followed.

### 4.1.2 Identify fire safety objectives

There can be several fire-safety objectives which shall be taken into account when they apply.

— Safety of life (for occupants and rescue personnel).

— Conservation of property.

— Protection of the environment.

— Preservation of heritage.

It shall be taken into account that a different set of design fire scenarios can be required to assess the adequacy of the proposed design for each objective.

ISO 23932-1:2018, Clause 6 shall be followed.

### 4.1.3 Determine functional requirements

A functional requirement is a statement of a condition necessary to achieve the fire-safety objective, e.g. spaces used for evacuation shall be free from harmful fire effects. All functional requirements shall be identified, so that the potential of any possible fire scenarios to threaten the fulfilment of the functional requirement can be assessed. If a fire scenario does not threaten the achievement of a functional requirement, then it is not relevant. An example of a functional requirement for life safety can be: “ensure that the structure does not fail and protect the paths of egress from harmful fire effects until evacuation is completed”.

ISO 23932-1:2018, Clause 7 shall be followed.

### 4.1.4 Select risk analysis approach

The choice of which risk analysis approach to take depends on the level of treatment of uncertainty required in the analysis. The relevant risk analysis approach enables a comparison between estimated and tolerable risk using some form of risk measure or performance criteria.

The risk analysis approach can be qualitative, deterministic, or probabilistic analysis. In general, it is not necessary and is often either impractical or cost-prohibitive or both, to conduct a full, quantitative fire risk assessment on an entire built environment. The complexity of the relevant method determines the level of effort required and it should reflect the level of detail necessary for informed decision making.

ISO 23932-1:2018, Clause 8 shall be followed.

### 4.1.5 Identify performance criteria

The type of analysis (deterministic, probabilistic) and the performance criteria used shall be selected. Performance criteria are the engineering metrics that are expressed in deterministic or probabilistic (e.g. measures of fire risk) form to determine if each functional requirement has been satisfied by the fire-safety design. Performance criteria shall be developed for a life safety functional requirement. For example, setting the maximum concentration or dose of carbon monoxide that an occupant can be exposed to.

ISO 23932-1:2018, Clause 9 shall be followed.

### 4.1.6 Fire safety design plan

The trial fire-safety design plan shall include a detailed fire-safety strategy. It shall be documented in a fire design report, with enough detailed information provided to evaluate whether it meets the fire-safety objectives when assessed against the design fire scenarios. The fire-safety design plan shall include descriptions of the functions of different parts of the built environment and their contribution to satisfying the fire-safety strategy. Figure 1 illustrates the fire-safety design process specified in ISO 23932-1.

ISO 23932-1:2018, Clause 10 shall be followed.

### 4.1.7 Determine design scenarios

Design scenarios can be divided into the following two categories of sub-scenarios:

— design fire scenarios (for fire behaviour);

— design behavioural scenarios (for human behaviour, either of occupants or rescue service personnel), addressing both life safety and potential impact on the fire development related to some aspects of fire scenarios.

Also ISO/TS 29761 should be referred to for details of a methodology for the selection of design occupant behavioural scenarios and ISO 23932-1:2018, Clause 11 shall be followed.

### 4.1.8 Select engineering methods

Engineering methods shall be selected in order to assess whether the trial fire-safety design plan meets the fire-safety objectives. This selection process involves determining which engineering methods have acceptable accuracy and efficiency in demonstrating that the relevant performance criteria are satisfied as the result of one or more design fire scenarios.

ISO 23932-1:2018, Clause 12 shall be followed.

### 4.1.9 Evaluate design

The trial fire-safety design plan shall be evaluated by carrying out an engineering analysis using select engineering methods to determine whether the relevant performance criteria are achieved for the design fire scenarios.

ISO 23932-1:2018, Clause 13 shall be followed.

### 4.1.10 Document in final report

All of the information used in developing the fire-safety design shall be documented, from FSE project scope to final design and shall include details regarding the ongoing operations and maintenance of the facility.

ISO 23932-1:2018, Clause 14 shall be followed.

### 4.1.11 Implement fire-safety design plan

When deviations from the final fire-safety design plan are necessary, they shall be documented in a report. Evidence that products used in construction or components used in manufacturing conform with any assumptions made in the fire-safety assessment shall be documented in a conformity assessment report.

ISO 23932-1:2018, Clause 15 shall be followed.

### 4.1.12 Execute fire-safety management

Once a fire-safety design is implemented in the built environment, fire-safety management and inspection shall be conducted throughout the lifetime of the built environment. The management and inspection processes shall ensure that the design scenarios used by fire-safety designers are relevant.

ISO 23932-1:2018, Clause 16 shall be followed.

## 4.2 The role of design fire scenarios in fire-safety design

Design fire scenarios are the foundation of fire-safety engineering assessments. Such assessments entail analysing design fire scenarios and drawing inferences from the results with regard to the adequacy of the proposed design to meet the performance criteria that have been set. Identification of the appropriate scenarios requiring analysis is crucial to the attainment of a built environment that fulfils the fire-safety objectives.

The number of possible fire scenarios in most built environments is large. It is impossible to analyse all scenarios, even with the aid of the most sophisticated computing resources. The possible fire scenarios shall be reduced to a manageable set of design fire scenarios that is amenable to analysis. This set of design fire scenarios shall represent the range of fires that can challenge the engineering design that is the subject of the analysis.

Each design fire scenario shall be representative of a risk-significant cluster of fire scenarios. The risk associated with a cluster is characterized in terms of the combination of probability (or likelihood) of occurrence of the risk and the resultant consequence. For the purposes of this International Standard, when a deterministic assessment is envisioned, a qualitative estimation of the likelihood and consequence suffices. For a full quantitative risk assessment, ISO 16732-1, shall be followed.

Once design fire scenarios are selected, the design of the built environment shall be modified, if necessary, until the analysis demonstrates the performance criteria associated with the relevant fire-safety objective(s) are met and the risk associated with the design is acceptably low.

The design fire scenarios in the fire-safety design report described in ISO 23932-1:2018 11.1 shall be identified and reviewed by the affected parties. During this process, scenarios that are of such low risk that they cannot, individually or collectively, affect the overall evaluation of the design shall be eliminated. It is important to remember that low consequence combined with high likelihood or high consequence combined with low likelihood can be high or low risk, depending on whether the consequence or the probability dominates. Neither probability nor consequence can be used completely in isolation for risk screening.

The characterization of a design fire scenario for analysis purposes involves a description of the initiation, growth, decay and extinction of fire, together with the likely smoke and fire spread routes under a defined set of conditions. The impacts of smoke and fire on people, property, structure and environment are relevant consequences of a design fire scenario. They are part of the characterization of that scenario when those consequences are relevant to the specified fire-safety objectives. The characterization of fire growth, fire and smoke spread, fire extinction, as well as fire and smoke impact, all involve a temporal sequence of events. Some events are predictable through the use of fire-safety science and the characterization of the event sequence in the scenario shall be consistent with the science. These characteristics should not be used as arguments to reduce the severity of the fire.

## 4.3 The role of design fires in fire-safety design

Following identification of the design fire scenarios, the assumed characteristics of the fire on which the scenario quantification will be based shall be described. These assumed fire characteristics and the further associated fire development are referred to as the “design fire”.

A complete description of the design fire, from ignition to decay may be estimated using the specified initial conditions and a series of calculations to estimate parameters such as

— sprinkler activation time,

— transition to flashover, and

— duration of fully developed burning.

Alternatively, the design fire can be a combination of quantified initial conditions and subsequent fire development determined iteratively or by calculation using more complex models that account for phenomena such as

— transient effects of changing ventilation on smoke production, and

— thermal feedback effects from a hot layer to the fuel surface.

As with the design fire scenario, the design fire shall be appropriate to the relevant fire-safety objectives. For example, if safety of life is an objective, a design fire that affects the means of escape can be selected. If the severity of the design fire is underestimated, the application of engineering methods to predict the effects of the fire elsewhere can produce results that do not accurately reflect the true impact of fire and underestimate the hazard. Conversely, if the severity is overestimated, it can result in unnecessary expense.

Also refer to ISO/TS 16733-2 for guidance on characterizing design fires.



# 5 Design fire scenarios

## 5.1 Characteristics of fire scenarios

Each fire scenario is differentiated by a unique occurrence of events and circumstances associated with the nature of the facility and the sources of fire, as well as a particular set of circumstances associated with the fire safety measures. The fire safety measures are defined by the fire-safety design, while the nature of the facility and sources of fire are required to be specified to characterize the scenario. Accordingly, a fire scenario can be characterized with the following factors:

— In relation to the facility or built environment:

  — ventilation conditions including location and size of potential openings that could provide a source of air/oxygen during the course of the fire;

  — ambient environmental conditions;

  — interconnections between spaces or compartments providing potential routes of fire and smoke spread;

  — materials and methods of construction and the size of the compartments;

  — status and performance of each of the fire-safety measures, including active systems and passive features;

  — detection, alarm and fire suppression systems by automatic or non-automatic means (e.g. dedicated fire safety personnel);

  — self-closing doors or other discretionary elements of compartmentalization;

  — building air handling system or smoke management system;

  — reliability of each of the fire-safety measures.

— In relation to the source(s) of fires:

  — location of initial ignition, specifying whether it is an occupied or an unoccupied space, whether it is filled with valuable content or if it is mostly empty space, and whether the fire is close enough to expose structural elements or not;

  NOTE 1 Each of these binary sorts can also be specified as a matter of degree, e.g. densely occupied, lightly occupied, occasionally occupied, or inherently unoccupied.

  — whether the initial state is smouldering or flaming;

  NOTE 2 This depends, firstly, on the first item ignited and, secondly, on the igniting heat source.

— whether the combustion environment of the initial ignition and the availability of fuel is or is not sufficient to support fire growth to flashover;

NOTE 3 More detailed specifications regarding contents and furnishings, fuel load per unit area, or room linings and such, can be derived from field surveys that provide probabilities of high-density vs low-density, high-combustibility vs low-combustibility spaces directly. Alternatively, these can be set up as one of a few rooms designed and selected to represent all spaces that are or are not capable of going to flashover, where the probabilities are taken from fire statistics based on what percentage of fires in the design properties have historically gone to flashover or not.

## 5.2 Identification of fire scenarios

### 5.2.1 General

A systematic approach to the identification of design fire scenarios for analysis is required in order to identify important scenarios and to provide a consistent approach. When performance criteria are given in a deterministic form, the design fire scenarios shall be chosen so that a design shown to meet the performance criteria for these scenarios can be relied upon to ensure safety for all the scenarios that were not analysed. Alternatively, when performance criteria are in a probabilistic form, the design fire scenarios shall be chosen so that calculations based on them will produce an estimate of the fire risk. In this case, ISO 16732-1 for probabilistic risk assessment procedures shall be followed.

It is important that the design fire scenarios be appropriate to the objectives of the fire-safety engineering task. For example, for a life safety objective, the design fire scenarios should represent a threat to people (see also ISO/TS 29761). While for a structural objective, the design fire scenarios should represent a threat to the structural system of the building.

There are several possible approaches to identifying design fire scenarios that may be used, including the following:

a) Identifying a list of prescribed scenarios relevant to the specific built environment. These scenarios may be listed in a national code or standard wherein the regulator can require that they are considered at a minimum. While this approach, if available, is the simplest and easiest to apply, some potentially important scenarios related to an individual built environment can be overlooked if only these scenarios are used. An example of prescribed scenarios is given in Annex B.

b) Applying a qualitative or semi-quantitative systematic approach to determine a set of credible design fire scenarios for deterministic analysis.

c) Selecting a comprehensive set of scenarios of known likelihood and consequence, structured using techniques such as event trees to enable a quantitative fire risk assessment to be undertaken. This approach works best when historical fire incident data, or other statistical data relevant to the particular built environment, is available. Particular caution shall be used when assigning likelihoods based on statistics of rare events.

This document is mainly concerned with the approach in b). For prescribed scenarios, the relevant regulatory document shall be consulted. For a fully quantitative risk assessment approach, ISO 16732-1 shall be followed. Overall, the intent is to ensure that the selected design fire scenarios encompass all credible scenarios and that the scenarios not selected pose only an acceptable risk.

The following nine steps describe a systematic procedure for identifying design fire scenarios:

— Step 1 —Specific safety challenges.

— Step 2 — Location of fire.

— Step 3 — Type (characteristics) of fire.

— Step 4 — Potential complicating hazards leading to other fire scenarios.

— Step 5 — Systems and features impacting on fire.

— Step 6 — Occupant actions impacting on fire.

— Step 7 —Design fire scenarios.

— Step 8 —Scenario selection based on system availability and reliability.

— Step 9 — Final selection and documentation.

### 5.2.2 Step 1 —Specific safety challenges

#### 5.2.2.1 Identify the built environment use

Step 1 involves identifying the use or uses of the built environment, as relevant to the fire-safety objective, in order to ensure that all people in the building are accounted for. This is particularly important for buildings that are multi-functional, e.g. shopping malls, airports, transport terminals and conference centres.

EXAMPLE 1 An airport can accommodate functions such as check-in counters, parking garages, shops and air-side baggage handling. With a life safety objective in mind, each of these functions or uses is associated with distinctly different airport users. Therefore, fire scenarios that challenge the evacuation strategies applying to different functional areas of the building will be of interest.

EXAMPLE 2 A manufacturing plant can accommodate functions such as receiving and processing of inwards goods, storage of combustible materials, office and administration support, and manufacturing processes. A safety objective to protect a piece of business-critical equipment requires fire scenarios that potentially expose that equipment to damaging concentrations of smoke or heat.



#### 5.2.2.2 Identify the exposed person, object or environment to be protected

The exposed person, exposed object or exposed environment to be protected depend on the fire-safety objective. For life safety, the occupants or users of the built environment are the relevant exposed. Depending on the building use or function, there can be different groups of users (e.g. staff, visitors, fire-fighters). For an environmental objective, it can be a nearby stream, while for a property protection objective, it can be a valuable commodity stored in the built environment or the building structure itself. When selecting a design fire scenario both the fire-safety objectives and the relevant exposed person, object or environment shall be considered.

#### 5.2.2.3 Identify the important characteristics of the exposed person, object or environment

The important characteristics are those that most determine the threat to the exposed person, exposed object or exposed environment that is posed by the fire. Where the exposed person are users of the built environment, characteristics of interest can include the following:

— users' tendencies when selecting an egress route;

— users' level of training in undertaking manual fire-fighting;

— users' familiarisation with evacuation procedures;

— the layout of the built environment.

Characteristics of interest can also include the vulnerability of occupants within the built environment and whether they are more susceptible to the effects of fire and smoke.

Similarly, the sensitivity of a piece of equipment to elevated temperature, smoke or combustion gases can assist in identifying the most vulnerable objects in the built environment and, therefore, which fire scenarios are more likely to challenge or pose a threat to the exposed object.

#### 5.2.2.4 Determine the safety challenges

Because the aim of the deterministic analysis is to test the fire-safety design using a selection of severe but credible scenarios, issues or conflicts than can, in combination with fire, potentially lead to the failure of the design shall be identified. These issues and conflicts are referred to in this document as safety challenges.

For a life safety objective, these issues are often occupant characteristics that lead to non-optimal response or movement in emergency situations. Conflicts often involve a discrepancy, either between built environment uses and users or between users and built environment layout.

A typical life safety challenge involving a conflict in built environment use, is a person's tendency to use familiar exits. This tendency means that people will try to move towards the main entrance or exit, which can potentially cause a major evacuation bottleneck in case of fire. A fire that quickly renders the main entrance unusable is therefore a scenario that severely challenges the fire-safety design.

A challenge for property protection is when an item of machinery that is sensitive to elevated temperature or to contamination by specific types of combustion products.

### 5.2.3 Step 2 — Location of fire

Step 2 typically involves characterization of the space in which the fire begins, as well as characterization of the specific location within the space. The specific safety challenges identified in the preceding step shall be taken into account in the characterization of the space.

Identification of the most likely locations can be done using fire statistics. Alternatively, if statistics are not available, an assessment can be based on the presence of heat sources, fuel packages and occupants. While the most likely locations are of interest, they are not necessarily representative of challenging or credible worst case fire scenarios.

Identification of the most adverse or challenging locations may be done using fire statistics for injury or monetary loss. It can also require engineering judgement where statistical data are lacking. Challenging locations are those where special circumstances and events can adversely impact on achieving the applicable fire-safety objectives.

Examples include the following:

— fires in assembly areas, clean rooms or other spaces with a high density of vulnerable users or highly vulnerable property either close to the fire's point of origin or with access to exposed structural members, in each case such that there can be insufficient time and space for fire-safety measures to act effectively;

— fires that are blocking entry to or that are within the egress system, which can delay or prevent safe evacuation;

— fires in rooms or spaces, including concealed spaces and exterior surfaces, that are outside the coverage of fire-safety systems.

Other examples of locations for which fire scenarios are possibly needed include the following:

a) internal:

   1) construction products (e.g. involving sandwich panels where sudden collapse can occur, threatening firefighters);

   2) rooms where the fire location can potentially enhance flame spread and rate of fire growth (e.g. a fire located in a room corner can lead to fire spread across combustible ceiling and wall materials, potentially challenging the egress design);

   3) stairwells required to be used for evacuation;

   4) cable trays or ducts (e.g. a fire develops in a hidden or unoccupied area and spreads via the ducting to other parts of the built environment, threatening occupant escape);

5) roof space (e.g. a fire located under the roof);

6) cavity spaces (e.g. fires in wall cavities, facades, or plenums);

b) external:

1) neighbouring built environment or nearby vegetation;

2) roofs (e.g. a fire located on the upper surface of the roof);

3) exterior cladding (e.g. if a combustible cladding is used, external vertical fire spread can lead to ignitions at various elevations in a building, challenging the design of any fire sprinkler system).

Design fire scenarios for other locations shall be agreed upon with the affected parties and design team for special situations. It can be necessary to consider possible changes that can occur over the life of the built environment, for example where energy efficiency measures have resulted in changes to the materials within the external envelope, therefore leading to changes in their expected fire behaviour.

The location of the exposed person, exposed object or exposed environment that are to be protected should also be considered. Fires that will not develop, spread into, or lead to damaging conditions where the person, object or environment are located, are not likely to be design fire scenarios.

See Annex A for guidance regarding source data for frequencies by fire location.

### 5.2.4 Step 3 — Type of fire

The type of fire is characterized by a series of stages, including ignition, fire growth, full development, decay and extinction. Of particular importance in defining the type of fire that will challenge the design and the fire-safety systems, are the initial intensity and rate of growth of the fire. The initial intensity and rate of growth are determined by some combination of the following:

— initial heat source;

— the first item ignited;

— the first large item ignited;

— any other items ignited prior to ignition of the first large item.

Therefore Step 3 typically involves two steps; characterization of the initial ignition and characterization of the early-stage fire when it is well established. If the first item ignited is also a large item, these two steps can be treated as the same. However, many fires begin with very small initial fuel items, such as:

— spilled food on a stove;

— trash in a trash can;

— deposited soot in a chimney;

— accumulated lint in a clothes-dryer.

For such fires, the initial ignition does not occur within the same time and does not closely resemble the early-stage of a well-established fire.

Fire incident statistics provide an appropriate basis for identification of the initial ignition conditions for fire scenarios, together with frequencies for alternative initial ignition conditions. The goal of this systematic approach is to screen possible fire scenarios by relative risk. A practical way to do this using fire incident statistics and engineering judgement is to identify:

— one set of fire scenarios with high likelihood and minimal consequence;

— one set of fire scenarios with high consequence and minimal likelihood.

Identification of the initial ignition conditions can also be determined by risk analysis using, for example, fault tree methods, engineering judgement, or tests.

Using fire incident statistics appropriate for the built environment and occupancy under consideration, rank the combinations of the initial heat sources and the initial fuel items by frequency and consequence-related criteria. Examples include:

— the most likely fires;

— fires of a certain minimum size;

— flame extent beyond room of origin;

— fire size greater than a specific area;

— likelihood of five or more deaths;

— consequences of more than a defined monetary threshold indicating a large loss, such as the minimum loss associated with the costliest 1 % of fires.

In the absence of sufficiently detailed fire incident data, fires accounting for the largest share of fire injuries or fire fatalities, or fires accounting for the largest share of property damage measured in monetary terms, can also be considered. The types of fires that will challenge the built environment and features shall be identified, taking into account the fire-safety objectives.

Appropriate statistics can be available on a national basis, a state or provincial basis, or for properties similar to the built environment being designed. If appropriate national statistics are not available, information from other countries with similar fire experience may be utilized. Care in applying fire incident statistics should be exercised, in order to ensure that the data are appropriate for the built environment under consideration, particularly when using data from other countries since the differences may be in orders of magnitude.

Fire scenarios for other types of fires may be selected during the development of the trial fire-safety design plan for special situations.

For objectives such as the safety of sleeping occupants, the smouldering phase of fire development should be taken into account. However, it is less likely that fire incident statistics are readily available for smouldering fires compared to flaming fires, since some of these fires transition to flaming fires before being included in fire incident databases. If any flaming fire scenarios involving ignition of very small initial fuel items rank high on a consequence-weighted ranking, these fires must have involved at least one additional fuel item of substantial size. Engineering judgement is usually sufficient to estimate what large fuel item(s) are close enough to a small fire of the defined type to be the subsequent item ignited that creates a well-established fire.

See Annex A for guidance regarding source data by fire type.

### 5.2.5 Step 4 — Potential complicating hazards leading to other fire scenarios

Fire scenarios that can arise from the potential hazards associated with the intended use of the property or the design that are identified while developing the trial fire safety design plan shall be considered. Other critical high-consequence scenarios, excluding high-hazard locations which are specified in Step 2, shall also be included.

Examples of critical high-consequence scenarios include the following:

— vulnerability to events such as earthquakes or terrorism, which have the potential to initiate multiple fires or lead to multiple fire-safety measures becoming disabled simultaneously;

— vulnerability to non-fire events that can weaken the built environment structure and lower the threshold of fire severity needed to produce structural collapse;

— use of high hazard materials that are susceptible to spontaneous ignition, rapid fire spread, explosion, unusually intense fire, unusually toxic smoke, embedded oxygen that can feed fire separately from ambient air, unusual difficulty or danger if fire is fought by conventional means (such as pool chemicals), unusual environmental hazards in products of combustion or contaminated fire-fighting media, or other unusually severe fire conditions;

— presence of high-hazard operations, including the use of open flame(s) near easily ignited materials;

— special hazards present during the construction phase or during maintenance operations.

If any of these scenarios are more severe and as likely as those identified in the previous steps, they shall be included in the set for analysis. They may replace less hazardous scenarios that are similar in nature.

### 5.2.6 Step 5 — Systems and features impacting on fire

The fire-safety systems and features which, if they fail, are likely to impact the achievement of the fire-safety objective shall be identified. Less than perfect system reliability is addressed in Clause 5.4 (Step 8).

Typical systems and features for consideration include the following:

a) passive systems and features:

   1) control of contents, furnishings or materials (perhaps with fire retardant treatments, or otherwise subject to flammability control);

   2) doors and other openings in the enclosure of fire origin and other relevant compartmentation, such as windows, wall and ceiling/floor assemblies, as well as any penetration systems, fire resistance ratings and flammability properties;

   3) structural members, including their means of protection and fire resistance ratings;

b) active systems and features:

   1) active suppression system, such as sprinklers, gas flooding, etc.;

   2) smoke management system, with either natural or mechanical ventilation,;

   3) fire detection system, which can smoke, or heat, etc.;

   4) warning and communication system;

   5) egress system, including hold-open devices on doors;

   6) fire-safety management;

   7) fire fighter operations.

### 5.2.7 Step 6 — Occupant actions impacting on fire

The actions that building users take can have a significant impact, favourable or otherwise, on the course of a fire or on the movement of smoke. Such possible actions shall be identified in this step. Acts of arson or of carelessness which cause fires to start are likely to have been captured in the fire incident data employed in Step 3 and need not be considered during Step 3 again. Rather, it is necessary to consider the actions that follow ignition.

Depending on the nature of the built environment, trained staff or an in-house fire brigade can reduce the impact of a fire in the early stages of development, for example if staff close doors upon detection of the fire. The actions of municipal fire fighters may also be considered, particularly for objectives related to property protection or business continuity.

On the other hand, poorly trained staff or casual visitors can leave doors open, allowing rapid fire development and smoke transport. The characteristics of a fire and its emissions can also prevent people from intervening in the fire.

It should be considered that occupants can influence the course of the fire, and there may be some scenarios in a risk assessment approach that include occupant actions, e.g. a scenario where a door is left open by an occupant, and another scenario where the door is closed. On the other hand, for a deterministic approach, it is necessary to select design fire scenarios representing a credible worse case.

## 5.3 Step 7 — Design fire scenarios

### 5.3.1 General

In Steps 1 through 6, a large number of potential fire scenarios have been identified. From the fire scenarios identified, scenario clusters and a set of design fire scenarios shall be selected by following the Steps 1 through 6.

### 5.3.2 Combining scenarios into scenario clusters

The characterization of scenarios specified in 5.2 shall be refined into a concise, parametric description of possible scenarios at this stage. Models and other calculation procedures may be used to evaluate the effect that the fire-safety systems and features identified in Step 5 have on the course of the fire. ISO 24678-4 for smoke layers or ISO 24678-5 for vent flows can be applied for example. The limits of application of the models and procedures used shall be taken into account. ISO 16730-1 shall be followed in respect of relevant procedures to use for verification and validation of calculation methods and ISO/TS 13447 contains further guidance on the application of fire zone models.

The process of combining scenarios into scenario clusters involves identifying common parameters and fire characteristics. For example, the types of rooms can include normally occupied rooms, normally unoccupied rooms, means of egress, concealed spaces, and exterior locations. Ranges for the rate of increase in fire severity can include, for example, linear growth corresponding to smouldering fire and ranges for the alpha parameter in a t-squared fire representation, corresponding to flaming and fast flaming. By selecting a type or range from each parameter, the user defines a specific scenario cluster, which combines more fully specified scenarios (e.g. each of the specific points of origin in each of the rooms that fit a particular room type). Each scenario cluster is represented by a single representative design fire scenario, the consequence of which will be used to characterize the consequence for all scenarios in the cluster.

With respect to both the location of the point of origin and the initial rate of fire growth (such as smouldering, flaming, fast flaming or explosion), it is likely that some locations or rates of fire growth will challenge some fire protection systems or features, while other locations or rates will challenge other fire protection systems. This can necessitate the use of multiple representative scenarios for a single scenario cluster or be addressed by selecting representative scenario characteristics to challenge a design system or feature in one area, while selecting characteristics to challenge a different system or feature in another area.



### 5.3.3 Caution on exclusion of scenarios believed to have negligible risk

Because there are a very large number of possible fire scenarios, the process of combining scenarios into a comprehensive collective set of scenario clusters can be simplified if some scenarios are excluded at the outset based on negligible risk. If this step is taken, it shall be justified explicitly and quantitatively. It shall only be taken if there is strong evidence that the facts support a judgement of negligible risk. It is particularly dangerous to use this step to exclude low-frequency, high-consequence scenarios. Scenarios that have low frequency individually are possibly not low frequency when considered as a group.

### 5.3.4 Demonstrating that the scenario structure is complete

The universe of potential scenarios shall be mapped into scenario clusters either selected for analysis or specifically excluded, as specified in 5.3.2 and 5.3.3. This confirms that all scenarios have been considered and that their treatments were explicitly chosen, completing the scenario structure.

If two or more candidate designs are compared to each other rather than to specified acceptability criteria, then in some cases, scenario clusters can be excluded even if they involve significant risk. For example, if the two designs can be expected to have similar or identical risk in those scenarios. In this case, "similar" means that the expected difference in risk for the scenarios proposed for exclusion is substantially less than the expected difference in risk for the scenarios proposed for explicit analysis. These expectations should be based on engineering judgement. However, since engineering judgement can reflect a shared misperception of the true risk, such exclusions should be limited.

### 5.3.5 Scenario selection procedure based on level of analysis

There are two levels of analysis that can apply:

— qualitative analysis, based on engineering judgement and simple risk screening;

— semi-quantitative analysis, using generic data from similar built environments for scenario frequency assessment and deterministic calculations.

Where a full quantitative fire risk assessment procedure is envisaged using data specific for built environments as well as the determination of scenario probability and consequence, a risk-ranking process as specified in ISO 16732-1 is an appropriate basis for the final selection of design fire scenarios.

Where a simplified approach (qualitative or semi-quantitative) to design fire scenario selection is needed (e.g. where less detailed scenario frequency data is available), the procedures described in 5.3.6 shall be taken into account.

### 5.3.6 Selection of design fire scenarios for deterministic analysis

The process described in this subclause aims to find the worst credible cases, i.e. design scenarios that challenge the achievement of the fire-safety objectives. For this purpose, Steps 1 to 6 described in 5.2 can be simplified for different locations and types of fire, by identifying the following:

a) the aspects and characteristics of the exposed person, exposed object or exposed environment and the fire that present challenges because they increase the risk of unacceptable harm;

b) the aspects and characteristics of the exposed person, exposed object or exposed environment and the fire that are challenging because they increase the risk of unacceptable harm or damage through characteristics of the fire;

c) the aspects and characteristics of the fire-safety systems or features present challenges because they reduce the operability or effectiveness of the system or feature.

Where the built environment has been compartmented to prevent fire spread, the location(s) within each compartment shall be considered to ensure that all parts of the built environment are evaluated. A manageable set of challenging design scenarios shall be compiled based on the identified characteristics of the exposed person, exposed object or exposed environment, the fire development, and the fire-safety systems or features present.

For a qualitative or semi-quantitative selection process, the frequency of each design fire scenario does not require explicit evaluation since all representative scenarios shall be taken into account and not combined with other scenarios. Fire scenarios can be evaluated for use as representative design fire scenarios by considering whether the scenario is capable of producing conditions that would exceed the performance criteria, or whether they can be replaced by other representative scenarios of greater severity.

For example, for semi-quantitative screening, separate risk matrices can be developed for each type of consequence. An example of a risk ranking matrix is shown in Figure 2. In this example, the scenario frequency appears in each column and the scenario consequence in each row. Therefore, the scenarios with the highest risk appear in the top right of the matrix (darkest shading) while the lower risk scenarios appear in the bottom left of the matrix (lightest or no shading). Refer to References [17], [22] and [23] for further guidance in using risk ranking matrices.

EXAMPLE 1 For a life safety objective, a high-risk scenario can be when fatalities or life-threatening injuries are expected (high consequence) as a result of a fire scenario that can occur several times over the life of the built environment (anticipated event).

EXAMPLE 2 For a business interruption objective, a low-risk scenario can be when downtime is expected to cause damage that is repairable (low consequence) as a result of a fire scenario that will probably not occur over the life of the built environment (unlikely event).

Where the fire-safety objective is life safety, refer to ISO/TS 29761 regarding the selection of design occupant behavioural scenarios and design behaviours and how they relate to the design fire scenario.

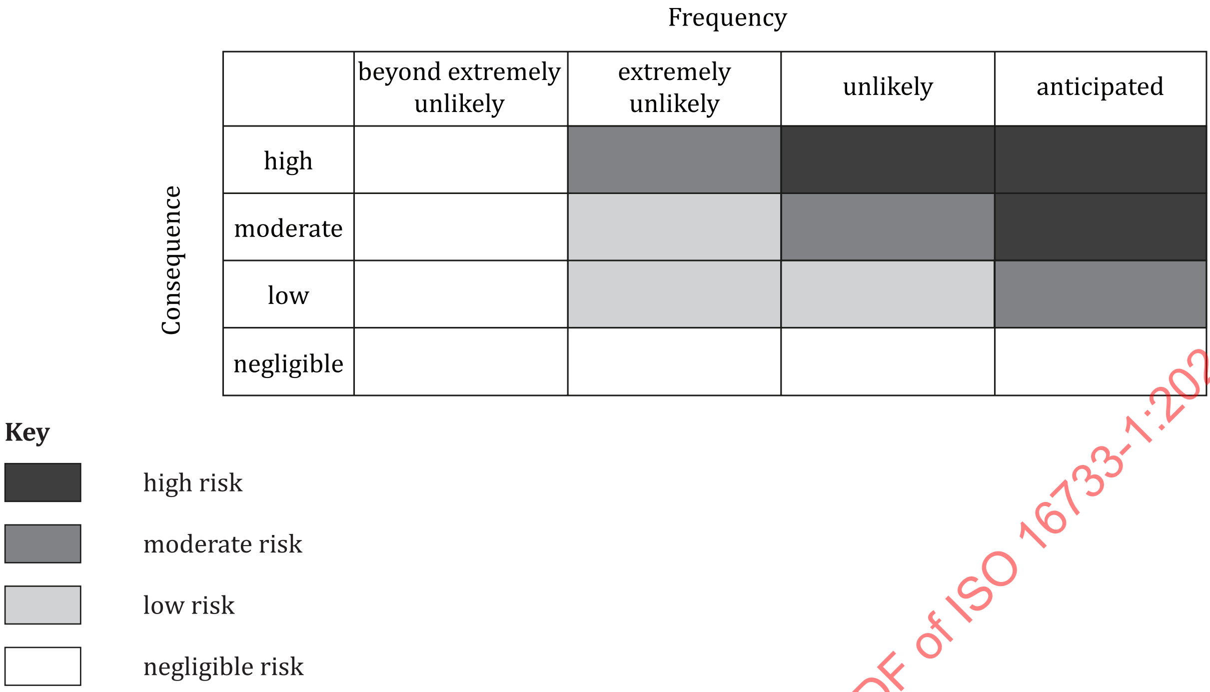



**Figure 2 — Risk ranking matrix**

## 5.4 Step 8 —Scenario selection based on system availability and reliability

When the ability of the fire to grow arises from less than perfect system reliability or a fire-safety feature not performing as intended, it is not possible for any design, however redundant, to fully achieve the fire-safety goals and objectives normally set for a project where systems are all fully functional and operating as designed.

The possibility that each system (as identified in Step 5) is not operational (due to routine maintenance, deterioration with age, or human action or inaction, etc.) shall be considered. In this case, it is acceptable to include the scenario for analysis but the design fire or the performance criteria to be achieved under a system failure condition need to be modified, such that a greater hazard can be considered tolerable.

If the possibility of a system or feature not performing as intended has not been allowed for in the preceding design fire scenarios, then the probability of failure should be considered and either

— the affected parties and design team determine that the probability of failure is sufficiently low that the risk is acceptable and the scenario is not a credible one for analysis, or

— the affected parties and design team include the scenario as a design fire scenario and determine either what design fire characteristics or performance criteria, or both, will be applied in the analysis. These need not be the same as for other scenarios where the system or feature perform as intended.

Justification of design fire size modifications shall be provided whenever limited performance of the system or feature is being considered.

EXAMPLE 1 For the design of a smoke extract system for a sprinklered building that uses a deterministic approach, a scenario where the sprinklers fail to operate is also considered depending upon the acceptable resulting risk and objectives. The design of the smoke extraction system for the scenario where sprinklers are assumed to fail to operate may accept a lesser smoke layer height or greater smoke density as performance criteria. It can also be assumed that the smoke extraction system capacity is not adversely influenced in case of sprinkler failure.

EXAMPLE 2 For the design of a smoke extract system, a scenario wherein a single smoke extract fan fails to operate is considered. The design minimum smoke layer height above floor level can be reduced compared to the scenario where all smoke extract fans operate as intended.

## 5.5 Step 9 — Final selection and documentation

For each fire-safety objective, the highest ranked fire scenarios shall be selected for analysis. The selected scenarios should represent the major portion of the cumulative risk (the sum of the risk of all scenarios). Input from the affected parties into this selection process is recommended. The fire scenarios selected for analysis shall be documented, these become the “design fire scenarios”. The fire scenarios not selected for analysis and the reasons for their exclusion should also be documented.

When making final selections, the following common errors or biases should be taken into consideration.

— If multiple, high-consequence but unlikely scenarios are eliminated from consideration, it is important to be careful that the eliminated scenarios do not have a moderate or high likelihood collectively. Where possible, it is better to combine similar scenarios, so that more scenarios are directly represented and analysed, than to eliminate scenarios.

— It is not appropriate at this stage to eliminate a scenario, despite its substantial contribution to risk, due to the cost of eliminating or reducing that risk. Any decision to accept the risk of a particular scenario because of the high cost of eliminating or reducing that risk, should be made at a later stage, after more detailed analysis and with the full involvement of the affected parties.

— It can be appropriate to eliminate a scenario, despite its substantial contribution to risk, because no identifiable design choice can reduce or eliminate that risk. For example, unless design choices include the selection of clothing and managing occupant activity, risks to persons who are intimate with the starting point of a fire or who are incapable of acts of self-preservation can be examples of the bases for scenarios that can legitimately be eliminated at this stage. Elimination of such scenarios, however, should be documented, stating why it is not possible to protect the person or eliminate the hazard by any means. It would not be appropriate to eliminate a scenario if the conditions of the occupants can be expected (for example, intoxicated customers in a nightclub). In such a case, additional protection would be an appropriate design decision.

# Annex A
(informative)

# Data for development of design fire scenarios

Table A.1 is intended provide guidance regarding the type and source of data typically required in applying document. In some cases, the data required for a specific scenario is not available, necessitating the use of engineering judgement. In this case, alternative sources of data from individuals with field observation knowledge based on lengthy work experience can be used. Delphi panels comprising groups of experts are also sometimes used to try and eliminate bias in the grouping of opinions into an expert estimate. Refer to ISO 16732-1 for guidance on the use of engineering judgement and on estimating frequency and probability.

**Table A.1 — Data for development of design fire scenarios**

| Data element | Value and/or source | Relevant subclauses in this document |
|---|---|---|
| Frequencies by fire location | If fire statistics are available by area of origin, then they should be used. If fire statistics are not available, separate areas into the following groups:<br>a) normally occupied spaces;<br>b) occupiable but not normally occupied spaces (e.g. closets);<br>c) means of egress;<br>d) rooms and areas containing identified major hazards;<br>e) concealed spaces and exterior locations.<br>Treat each of these area groups as a group to be represented by at least one of the areas chosen for a design fire scenario. Specific locations within a chosen space also need to be selected, but can be inferred from the choice of first burning item by using engineering judgement.<br><br>**Limitations**<br>Fire incident data collected by fire departments is not always complete, as not all fire departments contribute data to a wider jurisdiction. Many countries do not require systematic fire data collection. International compatibility of fire statistics can be significantly limited in some cases, resulting in differences of orders of magnitude. | 5.2.3 |
| Frequencies by fire type (with type defined by initial ignition conditions or initial burning rate) | First, a typology of fires based on the ranges of the initial burning rates should be created. The contents of each fire type should be included, with lists of either the items first ignited, the types of materials first ignited, or of the igniting heat sources (e.g. lighted tobacco product, open flame, radiant or convective heat), or all three.<br>Based on the composition of this item, the arrangement of other (secondary) combustible items and the availability of oxygen, engineering judgement can be used to infer an initial burning rate, which can be extended to the initial smouldering, a generic free-burning rate or a flash fire or explosion initiation. Transition to multiple burning items can involve estimations of room layouts and ventilation conditions, as well as the use of algebraic expressions to estimate when and whether a second item will ignite. Transition to full room involvement can involve estimations of room fuel loads and ventilation, as well as the use of algebraic expressions to estimate when and whether flashover will occur. Room linings can be relevant to flame spread past the first room to adjacent spaces. The existence, characteristics and status of barriers can be relevant to the calculation of fire spread to sections of a floor or to additional floors.<br>If the designations of the items first ignited, the first ignited materials, and the heat sources match the available fire incident databases, then fire statistics can be used directly to estimate the needed frequencies.<br>If the match is not exact, engineering judgement should be used in combination with fire statistics to produce the needed estimates.<br>**Limitations**<br>Fire incident data collected by fire departments is not always complete as not all fire departments contribute data to a wider jurisdiction. | 5.2.4 |