INTERNATIONAL STANDARD

ISO 23932-1

First edition
2018-09

Fire safety engineering — General principles —

Part 1: General

Ingénierie de la sécurité incendie — Principes généraux —

Partie 1: Généralités

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Reference number
ISO 23932-1:2018(E)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 documents 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: 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 first edition of ISO 23932-1 cancels and replaces ISO 23932:2009, which has been technically revised.

The main changes compared to the previous edition are as follows:

— a clarification of the FSE process (Figure 1) has been added and the document has been restructured subsequently in accordance with the performed changes;

— an expanded discussion of the types of risk analysis approaches commonly used for FSE has been added;

— references to relevant FSE standards have been added;

— examples to illustrate the FSE process have been added.

A list of all parts in the ISO 23932 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.

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Introduction

Fire safety designs often rely on prescriptive specifications set in national, regional or local regulations. It is possible that various engineering approaches also be allowed by these regulations. In addition to prescriptive design, regulations can also allow the use of performance-based design, i.e. the reliance on engineering methods to determine whether a given design meets stated performance objectives. Fire safety can be evaluated through engineering approaches based on the quantification of the behaviour of fire and people, and based on the knowledge of the consequences of such behaviour on life, property, operations, environment and heritage.

Fire safety engineering (FSE) is used in support of performance-based fire safety design. The FSE process not only involves fire safety design, but also extends to the implementation of fire safety design plans and fire safety management.

The difference between prescriptive and performance-based fire safety design is highlighted in this document by requiring fire safety objectives (FSO), functional requirements (FR) and performance criteria (PC) to be explicitly stated in performance-based fire safety design.

This document sets forth the general principles and requirements for a performance-based fire safety design and the implementation of fire safety design plans and fire safety management. Hence, it is important that this document be viewed as an outline of the FSE process, and not as a detailed design methodology. This document provides the process (necessary steps) and essential elements that are needed to design, implement and maintain a robust performance-based fire safety programme.

A set of ISO documents on FSE is available, which provides methods and data supporting the steps in a FSE design, as defined in the ISO 23932 series. This coherent set of ISO documents ensures an effective and correct application of FSE, which includes performance-based fire safety design, implementation of fire safety design plans and fire safety management.

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Fire safety engineering — General principles —

Part 1: General

1 Scope

This document provides general principles and requirements for FSE, and is intended to be used by professionals involved in

1) performance-based fire safety design (of both new and existing built environments),

2) implementation for fire safety design plans, and

3) fire safety management.

This document is not intended as a detailed technical design guide, but does provide the key elements necessary for addressing the different steps and their linkages in the fire safety design process. This document also provides key elements linked to the implementation of fire safety design plans and fire safety management. This document is intended not only to be used on its own, but also in conjunction with a consistent set of FSE documents covering methods in performance-based fire safety design, implementation and management.

FSOs covered by this document include:

— safety of life;

— property protection;

— continuity of operations;

— protection of the environment;

— preservation of heritage.

The general principles and requirements of FSE can be applied to all configurations of the built environment, i.e. buildings or other structures (e.g. off-shore platforms; civil engineering works, such as tunnels, bridges and mines; and means of transportation, such as motor vehicles and marine vessels), but may not be applicable for construction sites.

Because prescriptive regulations covering fire safety design commonly co-exist with performance-based design, this document acknowledges that fire safety designs conforming to prescriptive regulations can become the basis for comparison of engineered designs of built environments.

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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*

3 Terms and definitions

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

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

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

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

3.1
affected party
party that is impacted by a fire safety design, including property owners and other property stakeholders, or authority having jurisdiction or in charge of public safety, health and welfare

3.2
deterministic analysis
risk analysis approach (3.10) in which the fire safety design is evaluated using a set of worst credible case scenarios

3.3
engineering judgement
process exercised by a professional or a team of professionals who is qualified by way of education, experience and recognized skills to complement, supplement, accept or reject elements of an engineering analysis

3.4
fire safety engineering
FSE
application of engineering methods based on scientific principles to the development or assessment of designs in the built environment through the analysis of specific fire scenarios or through the quantification of risk for a group of fire scenarios

3.5
fire safety strategy
specification of design functions used in achieving fire-safety objectives that forms the basis for the design

3.6
functional requirement
FR
statement of the means to achieve specified FSO, taking into account the features of a built environment

Note 1 to entry: Mandatory functional requirements are required, explicitly or implicitly, by national regulations or building codes; voluntary functional requirements are expressed by other affected parties.

3.7
mandatory objective
FSO, such as life safety and protection of the environment, which is required by national regulations or building codes

3.8
performance criterium
PC
threshold of performance that forms an agreed basis for assessing the safety of a built environment design

3.9
probabilistic analysis
risk analysis approach (3.10) in which the fire safety design is evaluated using the full range of representative scenarios

3.10
risk analysis approach
method for comparing estimated risk and tolerable risk using some form of risk measure, which includes *qualitative analysis* (3.18), *deterministic analysis* (3.2) and *probabilistic analysis* (3.9)

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3.11
safety factor
multiplicative adjustment applied to calculated values to compensate for *uncertainty* (3.14) in methods, calculations, input data and assumptions

3.12
safety margin
additive adjustment applied to calculated values to compensate for *uncertainty* (3.14) in methods, calculations, input data and assumptions

3.13
trial fire safety design
design chosen for the purpose of making a *fire safety engineering* (3.4) analysis and evaluation

3.14
uncertainty
quantification of the systematic and random error in data, variables, parameters or mathematical relationships, or of a failure to include a relevant element

3.15
validation
process of determining the degree to which a calculation method is an accurate representation of the real world from the perspective of the intended uses of the calculation method, such as confirming the correct assumptions and governing equations implemented in a model when applied to the entire class of problems addressed by the model

3.16
verification
process of determining that a calculation method implementation accurately represents the developer's conceptual description of the calculation method and the solution to the calculation method

Note 1 to entry: The fundamental strategy of verification of computational models is the identification and quantification of error in the computational model and its solution.

3.17
voluntary objective
FSO that is required by *affected parties* (3.1) beyond *mandatory objectives* (3.7)

3.18
qualitative analysis
risk analysis approach (3.10) in which areas of increased risk are identified

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4 Overview of the FSE process

The FSE process shall be initiated at the earliest stage of a project (that can include, for example, architectural concept design, structural, ventilation, plumbing, electrical designs) for a new built environment, to modify or refurbish an existing built environment or to evaluate compliance with updated regulations. Fire safety design shall be integrated fully with all other engineering design specialities throughout such a project. This is necessary when considering, for example, how the result of acoustic or thermal engineering (introduction of flammable sound/heat absorbing materials) or enhancement of security (limitation of methods of egress) can introduce unintended fire safety design problems.

Figure 1 shows an outline of the FSE process of a built environment, with references to Clauses of this document and references to additional ISO documents which explain the process in more detail. The process involves performance-based fire safety design, implementation of fire safety design plan and fire safety management. In Figure 1, the performance-based fire safety design begins with setting the analysis scope and ends with documentation in final report.

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As shown in Figure 1, the FSE process is iterative. When following the process, the fire safety designer shall explore the answers to key questions posed in decision nodes. The answers to these questions can require that steps of the process be repeated. This procedure is illustrated by the decision nodes (rhombi) and the associated iterative loops (Yes/No arrows) in Figure 1.

The boundaries of the analysis shall be clearly defined in the first part of the FSE process. First, the overall project scope shall be documented. This can include factors such as new building, renovation, expansion, and so forth. Secondly, the scope of the FSE project, within the context of the overall project, shall be identified, agreed and documented. The FSE project scope statement shall contain a description of project relevant information, e.g. characteristics of the built environment, affected parties and external environmental factors, but also a clear definition of what shall be analysed with the performance-based fire safety design.

In subsequent steps, the FSOs and FRs shall be identified. This shall be followed by the selection of the type of risk analysis approach and the subsequent identification of PCs, which are dependent on the chosen risk analysis approach.

The identification of FSOs, FRs and PCs is an essential part of the FSE process. Objectives describe the desired outcome of fires, i.e. they identify what is essential to protect. The FSO for a project should be clearly defined. It should also be documented as to which objectives are to be met by the fire safety analysis and which may be deemed to be met by compliance with prescribed (deemed to satisfy) regulatory measures. FRs translate objectives into required functionality of the fire safety design. Finally, FRs are quantified in terms of PCs, which are used for determining whether or not the FSOs are achieved given the selected risk analysis approach. The risk analysis approach is selected based on the required treatment of uncertainty in the design (see Clause 8). An FSO can be represented by one or more FRs. Similarly, an FR can be quantified by one or more PCs.

The following questions illustrate the relationship between FSOs, FRs and PCs:

— FSOs (see Clause 6): What are the required/desired outcomes of all foreseeable fires?

— FRs (see Clause 7): How will these outcomes be achieved by design functionality?

— PCs (see Clause 9): How will the adequacy of the design be measured in engineering terms?

When the boundaries of the analysis are set, a trial fire safety design plan shall be created. This design plan shall then be evaluated using design scenarios and engineering methods. The evaluation shall be performed in relation to the identified PCs. If the criteria are met, the trial design can be considered to have met the objectives. If not, revision of the trial fire safety design is required. It is possible to have more than one trial design that fulfils the objectives.

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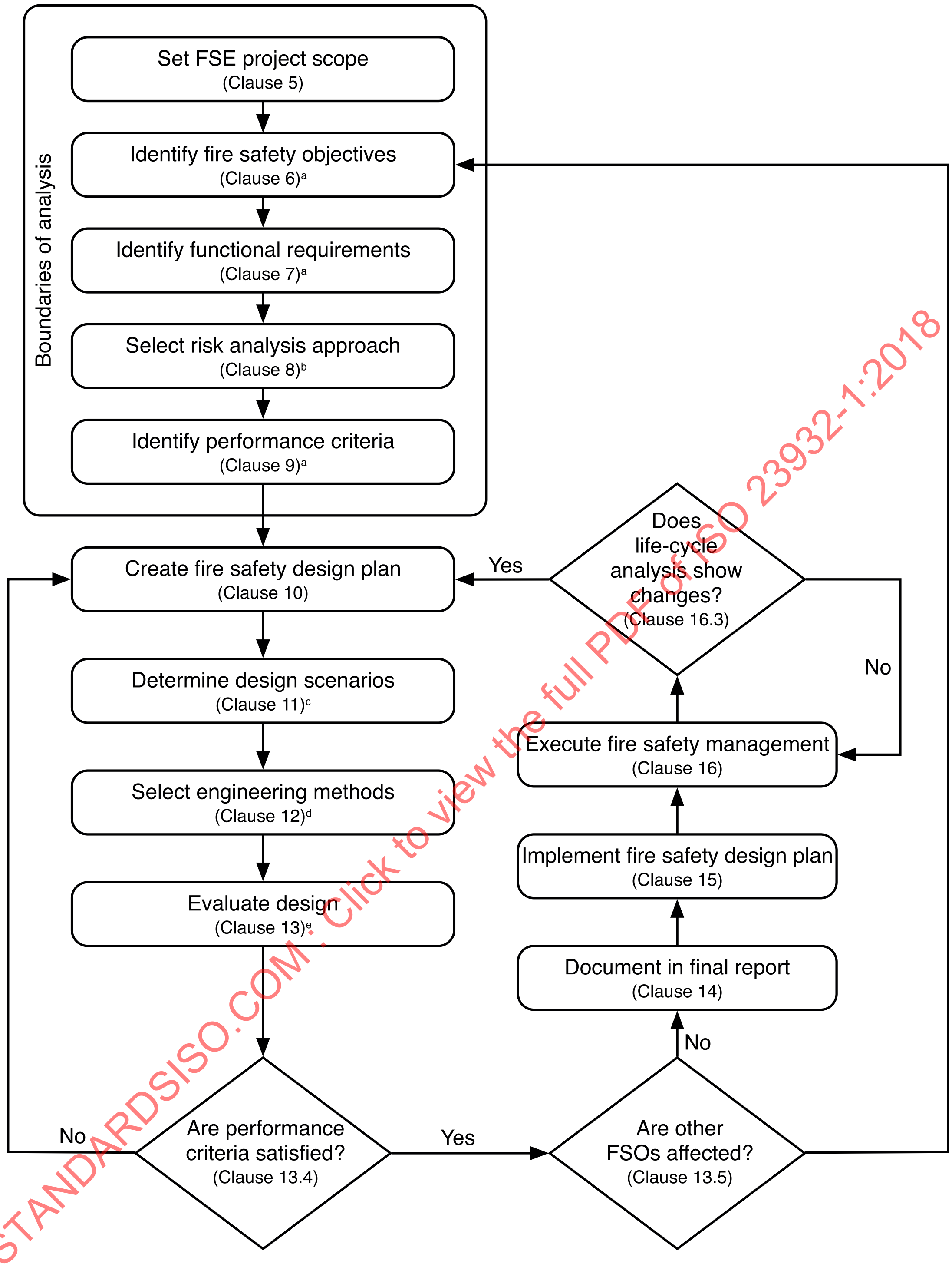

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a See also ISO/TR 16576 (Examples).

b See also ISO 16732-1, ISO 16733-1, ISO/TS 29761.

c See also ISO 16732-1, ISO 16733-1, ISO/TS 29761.

d See also ISO/TS 13447, ISO 16730-1, ISO/TR 16730-2 to 5 (Examples), ISO 16734, ISO 16735, ISO 16736, ISO 16737, ISO/TR 16738, ISO 24678-6.

e See also ISO/TR 16738, ISO 16733-1.

NOTE Documents linked to large parts of the FSE process: ISO 16732-1, ISO 16733-1, ISO/TS 24679, ISO/TS 29761, ISO/TR 16732-2 to 3 (Examples), ISO/TR 24679-2 to 4 and 6 (Examples).

Figure 1 — FSE process — Design, implementation and management

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Once a trial fire safety design plan has been evaluated and shown to meet the FSOs of concern to the analysis, the fire safety designer shall assess whether the trial fire safety design plan has negatively affected any prescribed FSOs. Once a set of appropriately justified fire safety trial designs are obtained, the fire safety designer may provide the set of options to the client, or apply cost-benefit analysis or other measures to identify a final fire safety design solution.

Documentation of the fire safety design solution shall be provided in the form of a report in the final step of the performance-based fire safety design. The fire safety design is then, when relevant, accepted by the appropriate authority and implemented, e.g. construction of the built environment and subsequent inspections. Once the build environment is in use, management activities shall be conducted to monitor if the fire safety design plan is respected. Changes to the use or design of the built environment shall require revision of the fire design plan according to the performance-based fire safety design process.

Figure 1 is strictly applicable to deterministic analysis (see 8.4) and probabilistic analysis (see 8.5). For qualitative analysis (see 8.3), the procedure can be used in a reduced manner appropriate to the analysis.

NOTE Significant parts of the FSE process are described in ISO 16732-1, ISO 16733-1, ISO/TS 24679 and ISO/TS 29761. In addition, examples of application of the FSE process are provided in ISO/TR 16732-2 to 3 and ISO/TR 24679-2 to 4 and 6.

5 Set FSE project scope

A clear FSE project scope shall be set in the initial phase of the FSE process. In order to achieve this, the contractual and organizational context of the design work shall be clearly defined, including the functions and duties of each member of the design team.

The FSE project scope statement shall contain project-related information that is relevant for the performance-based fire safety design. This can include, but is not limited to:

— characteristics of the project;

— characteristics of the site;

— characteristics of the built environment;

— affected parties;

— external factors;

— extent of FSE application and non-FSE regulatory compliance.

An essential part of the project characteristics is whether the planned project involves refurbishment, expansion or change in the use of an existing built environment, or is solely the construction of a new built environment.

The characteristics of the site, i.e. the location where the building or other structure is to be built, include such aspects as fire service access, extinguishment water supply and characteristics of the surrounding built environment.

The characteristics of the built environment, i.e. building or other structure, include such aspects as the type of built environment, type of construction technique and planned use.

Affected parties can include authorities having jurisdiction, owners, developers, employees and other prospective occupants, emergency responders, insurers and neighbours. All parties directly or indirectly influenced by the planned project should be identified.

External factors can include environmental and manmade conditions external to the built environment that can influence fire safety. For example, the potential for natural disasters, e.g. earthquakes, forest fires, flooding, etc., shall be considered. Potential manmade conditions, e.g. the fire safety of neighbouring built environments, transportation of dangerous goods, etc., shall also be taken into

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account. External factors can also include requirements or restrictions imposed by national, regional or local government, which can dictate which types of buildings/projects that are allowed.

In the FSE project scope, it shall be clear to what extent an FSE approach will be applied, e.g. for the entire built environment or only part of it, or for all or selected fire safety areas (see Clause 6), and which regulations apply. For example, there may be parts of the built environment that are designed in ways that do not conform to prescriptive requirements. These parts can then be designed using performance-based fire safety design, provided that all the FSOs for the built environment are fulfilled.

EXAMPLE 1 A hotel building contains floors with hotel rooms, an open lobby area and a restaurant, which are all separated with appropriate fire barriers and have separate means of escape. The hotel floors and the restaurant follow the prescriptive requirements in the codes and regulations. However, due to its design (e.g. size, number of floors, etc) the open lobby area does not conform to prescriptive requirements. Performance-based fire safety design can therefore be performed for the lobby area of the hotel building. However, it needs to be ensured that deviations from prescriptive requirements in the lobby area does not lead to increased risks in the parts of the building, in which case performance-based fire design would need to be applied to all parts of the building.

EXAMPLE 2 In a planned building, all prescriptive requirements related to the life safety of rescue service personnel are followed. However, some prescriptive requirements related to the life safety of occupants are not followed, namely the prescribed maximum distance to emergency exits is exceeded. Performance-based fire safety design can be performed for the life safety of occupants to address the deviation from the prescriptive requirements, namely to show that the extended distance to emergency exits is addressed by other safety improving measures. However, it needs to be ensured that deviations from the prescriptive requirements related to the life safety of occupants do not influence the life safety of rescue service personnel. There can also be other FSOs that are influenced by the proposed deviations. In this specific case, an extended maximum distance to emergency exits influences (among other things) the ease of access to the fire for the rescue service personnel.

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6 Identify FSOs

6.1 General

FSOs are either voluntary or mandatory. Voluntary objectives can be added by the building owner, who can consult affected parties. Mandatory objectives are stated in codes or regulations. These mandatory objectives shall always be met.

When dealing with predominantly prescriptive regulations, it is possible that the FSOs are not clearly identified in the regulations. In such cases, the fire safety designer can provide an interpretation of the FSOs in a form that is understood by affected parties, and an agreement on the objectives should be obtained and documented, as these are the basis for demonstrating compliance with the prescriptive regulations. This can sometimes be accomplished by stating the interpretation of the intent of the regulatory provisions, or how equivalent safety is intended to be achieved. A regulatory interpretation of FSOs is, in some cases, provided by authorities having jurisdiction.

In addition to required regulatory objectives, i.e. mandatory objectives, there can be some other objectives that are voluntary, e.g. minimizing of business interruption. In this case, engineering analysis can lead to the addition of objectives.

Objective statements typically address one or more of the fire safety areas in 6.2 to 6.6.

NOTE Examples of FSOs are provided in ISO/TR 16576.

6.2 Life safety

Life safety objectives typically seek to reduce or avoid harm to occupants and other affected people within and outside the built environment. To avoid injuries that can occur before an occupant can reasonably react to fire and begin evacuation, the objective is typically stated in terms of requirements on equipment or other products to reduce the likelihood of fire occurrence.

EXAMPLE 1 An example of a life safety objective for building occupants is: the fire safety design shall be such that fire related injuries to occupants (away from the immediate areas of fire origin) are minimized (FSO1).

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EXAMPLE 2 An example of a life safety objective for rescue service personnel is: the fire safety design shall be such that the rescue service personnel are given opportunities for safe operations for a reasonable period of time in case of fire (FSO2).

6.3 Property protection

The property protection FSOs can relate both to one's own property and the property of others. Objectives typically seek to reduce or avoid both damage to the built environment and to its contents, such as equipment.

EXAMPLE 1 An example of a property protection objective for the protection of a building is: the fire safety design shall be such that property losses caused by fire are limited (FSO3).

EXAMPLE 2 An example of a property protection objective for the protection of neighbouring buildings is: the fire safety design shall be such that neighbouring property losses are limited (FSO4).

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6.4 Continuity of operations

The business or operations continuity objectives typically seek to reduce the length of time that operations are interrupted, but can also be stated in terms of the economic cost of such interruptions (including market share and lost employment opportunities) or the functional continuity required for the safety of a specific process.

EXAMPLE 1 An example of a business and operations continuity objective for a production facility is: the fire safety design shall be such that business operations are not interrupted for a significant time as a result of a fire (FSO5).

EXAMPLE 2 An example of an operations continuity objective for a community is: the fire safety design shall be such that transportation, power, information, health care and other infrastructure necessary for the functioning of the community/region/country are not interrupted for a significant time as a result of a fire (FSO6).

6.5 Protection of the environment

The environmental protection objectives typically seek to reduce or avoid the immediate and long-term effects of a fire on the quality of the natural environment, which can include animals, soil, ground water, etc. If there are national, regional or local requirements for environmental quality, it is possible to state the minimum environment protection objectives in terms of compliance with those requirements.

EXAMPLE An example of an environmental protection objective for a ground water is: the fire safety design shall be such that the ground water quality is unlikely to be compromised outside of the immediate area of a fire (FSO7).

6.6 Protection of heritage

The heritage protection objectives typically seek to avoid the loss or alteration of objects for which the value at stake is not primarily economic. These irreplaceable objects are generally both old and unique, having cultural or other symbolic significance.

EXAMPLE 1 An example of a heritage protection objective for museum artefacts is: the fire safety design shall be such that damage to artefacts as a result of a fire is limited (FSO8).

EXAMPLE 2 An example of a heritage protection objective for a culturally important building is: the fire safety design shall be such that damage to the structure and external façade as a result of a fire is limited" (FSO9).

7 Identify FRs

Each FSO shall be associated with one or more FRs that are necessary to satisfy by the fire safety design. An FR is a statement of a condition necessary to achieve the FSO. That is, the means to achieve an objective are specified as the requirements for the functions, which are elements subject to control through fire safety design, such as the structure, compartments or other defined spaces, materials and

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products used in the construction of the built environment or fire protection systems. While objectives are stated in terms of non-quantifiable outcomes of fires, FRs are stated in terms of the function of the fire safety design that is deemed necessary to achieve the stated objectives. FRs are still qualitative, but they apply at the level of the design elements and are more meaningful and directly useable for engineering.

EXAMPLE 1 Examples of FRs linked to the achievement of FSO1 stated above are: FSO1 is achieved if (1) occupants are not exposed to untenable conditions due to elevated temperatures, radiation, toxic species, irritant species or reduced visibility while moving along the paths of egress (FR1.1), and (2) occupants are not exposed to falling debris or failing building parts while moving along the paths of egress (FR1.2).

EXAMPLE 2 An example of an FR linked to the achievement of FSO2 stated above is: FSO2 is achieved if fire does not result in permanent structural damage during the time required for rescue operations (FR2.1)

EXAMPLE 3 An example of an FR linked to the achievement of FSO3 stated above is: FSO3 is achieved if fire does not spread beyond the compartment of fire origin (FR3.1).

EXAMPLE 4 An example of an FR linked to the achievement of FSO4 stated above is: FSO4 is achieved if fire does not spread to neighbouring properties (FR4.1).

EXAMPLE 5 An example of an FR linked to the achievement of FSO5 stated above is: FSO5 is achieved if machines that are essential for production, but not directly involved in the fire, are not damaged by elevated temperatures or radiation (FR5.1).

EXAMPLE 6 Examples of FRs linked to the achievement of FSO6 stated above are: FSO6 is achieved if (1) major road transportation routes are not blocked by smoke or fire (FR6.1), and (2) essential transformer stations are not affected by fire (FR6.2).

EXAMPLE 7 An example of an FR linked to the achievement of FSO7 stated above is: FSO7 is achieved if waste extinguishment water does not spread significant amounts of contaminants to the ground water (FR7.1).

EXAMPLE 8 An example of an FR linked to the achievement of FSO8 stated above is: FSO8 is achieved if any damage to artefacts as a result of the fire is reparable (FR8.1).

EXAMPLE 9 Examples of an FR linked to the achievement of FSO9 stated above are: FSO9 is achieved if (1) no major structural collapse of the building occurs for the entire duration of the fire (FR9.1), and (2) the façade can be repaired using time typical building techniques (FR9.2).

NOTE Examples of FRs are provided in ISO/TR 16576.

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8 Select risk analysis approach

8.1 General

Once the FSO and connected FRs have been decided, a risk analysis approach shall be selected. A common feature of risk analyses is that a comparison between estimated risk and tolerable risk is made using some form of risk measure, i.e. PCs. The tolerable risk can be either explicitly stated, i.e. absolute, or implicitly derived, i.e. comparative (see 8.2). The tolerable risk in prescriptive regulations is implicitly defined by the regulatory provisions. The tolerable risk in performance-based designs should be explicitly stated. Risk needs not be expressed numerically.

Risk analysis approaches can be categorized in terms of the level of treatment of uncertainty in the risk analysis (see Figure 2). The lowest level of treatment of uncertainty is achieved by the qualitative analysis, in which deviations from the tolerable risk are identified. The intent of the qualitative analysis is to identify areas of increased risk, which means that uncertainty is partially handled by identifying and subsequently addressing all negative impacts. Addressing negative impacts can include introduction of compensating measures to reduce the impact of a deviation or simple estimates to show that a deviation has a negligible impact.

An intermediate level of treatment of uncertainty is achieved by the deterministic analysis, in which a set of worst credible case scenarios are evaluated. The intent of the deterministic analysis is to expose the design to a severe challenge, which means that uncertainty is partially addressed by assuming

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worse than average exposure. These are sometimes characterized as consequence analyses, compared against some tolerable risk criterion.

The highest level of treatment of uncertainty is achieved by the probabilistic analysis, in which the full range of representative scenarios are identified and evaluated. The intent of the probabilistic analysis is to sufficiently quantify the entire scenario space, which means that uncertainty is directly addressed in the analysis. Both the frequency and consequence for each scenario need to be quantified in the probabilistic analysis. Quantification of frequency and consequence can be expressed as specific values or distributions.

The choice of risk analysis approach depends on the level of treatment of uncertainty required in the analysis. For relatively well-known deviations, for which the designer can reasonably predict the impact of the deviations, only basic treatment of uncertainty is typically needed and a qualitative analysis can suffice. However, when the uncertainties are greater, i.e. when the designer cannot predict the impact of the design, a more in-depth treatment of uncertainty is required and a deterministic or probabilistic analysis is needed.

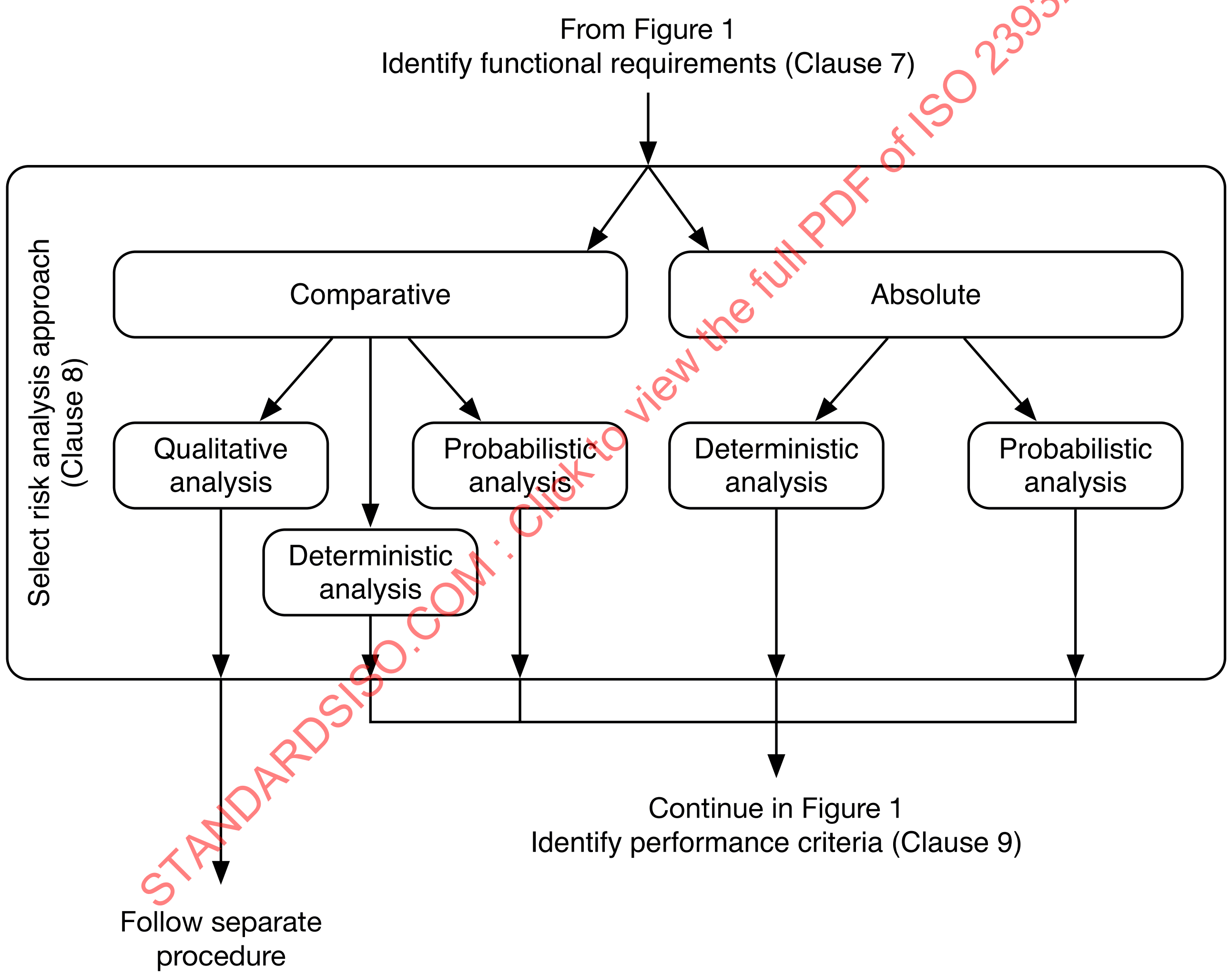

Figure 2 — Different types of analyses in the FSE process

In a comparative analysis, tolerable risk is implicitly derived from a benchmark design for a defined set of tolerable conditions. The risk analysis approach can be qualitative, deterministic, or probabilistic analysis (see Figure 2). Only the factors associated with the deviation need to be analysed and the outcome is a comparison with the benchmark, i.e. “higher” or “lower”. The chosen risk analysis method determines the measures used for the comparison.

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In an absolute analysis, risk is estimated, and tolerability of the risk is judged, based on a defined level of tolerable risk (however quantified). The risk analysis approach can be deterministic or probabilistic analysis (see Figure 2).

NOTE The different risk analysis approaches are described in ISO 16732-1, ISO 16733-1 and ISO/TS 29761.

8.2 Comparative versus absolute approach

A performance-based fire safety design can employ a comparative or absolute approach. In the comparative approach, the risk level of the design built environment, i.e. building or other structure, is compared with the risk level of a benchmark built environment. The benchmark shall be designed exclusively according to the prescriptive regulations, which implicitly defines a risk level for comparison. If the risk level of the design built environment is equal to or lower than the risk of the benchmark, the fire safety design shall be considered to provide a sufficient level of safety. The comparative approach requires that minor and relatively well-established changes are made from the prescriptive requirements to ensure a valid comparison between the level of risk of the design built environment and the benchmark built environment.

In some cases, a comparative approach is not possible or desirable, in which case an absolute approach shall be employed. For example, it can be impossible to design a benchmark built environment according to prescriptive regulations, i.e. if the regulations require a performance-based approach. Authorities having jurisdiction can also require an absolute approach for performance-based fire safety design. The risk level shall be explicitly stated if an absolute approach is employed. A risk level can be stated in the regulation, or may need to be derived using statistics or other estimates.

For both the comparative and absolute approach, the risk level can often be expressed in terms of PCs.

EXAMPLE 1 The regulations in an example country specify that a specific building type, namely a two-storey school building, can be designed prescriptively, but perhaps for only a specific material type, such as concrete. However, deviations from the prescriptive requirements are envisioned, such as the use of lightweight timber construction, and a performance-based fire safety design will therefore be employed. As a benchmark building exists, i.e. an equivalent prescriptively designed building, a comparative approach can be applied.

EXAMPLE 2 The regulations in an example country only allow prescriptive design of buildings up to 16 floors in height. The design building has a height of 32 floors and therefore needs to be designed using a performance-based approach. As there is no benchmark building, i.e. a prescriptively designed 32-floor building is not allowed, an absolute approach is applied.

8.3 Qualitative analysis

Qualitative analysis can be performed in cases where minor deviations from the prescriptive requirements are made. Because qualitative analysis belongs to the comparative approach, comparisons can be made to a benchmark. The qualitative analysis aims to identify deviations from the benchmark design that lead to increased risk compared to the benchmark, which means that uncertainty is partially addressed by identifying all negative impacts. If possible, comparison can be made based on sections or individual paragraphs in the prescriptive regulations.

The qualitative analysis leads to a separate procedure compared to the deterministic and probabilistic analyses (see Figure 2). Once the deviations leading to increased risk have been identified, they are directly addressed for every identified deviation in order to get a lower risk level than the benchmark design. However, it shall be ensured that any risk-reducing measures taken in response to a specific deviation also covers all possible areas of increased risk.

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The qualitative analysis is often based on logical reasoning, but can also involve simple calculations as input.

EXAMPLE Regulations in an example country state that the maximum walking distance to the closest emergency exit shall not exceed 30 m for a specific type of building. However, the maximum walking distance in the design building is set to 35 m, which exceeds the requirement in the prescriptive regulations. The designer identifies the deviation, concludes that it contributes to an increased risk for the safety of evacuees, and attempts to address the increased risk by introducing a more sensitive smoke detector than the prescriptive regulations require. These detectors provide a quicker detection and subsequent alarm, which allow evacuees more time to escape. However, the designer fails to recognize that an increased maximum walking distance to the closest emergency exit also means that the rescue services need to travel longer distances inside the building to reach a fire. The designer has hence failed to identify all possible areas of increased risk connected to the deviation.

8.4 Deterministic analysis

Deterministic analysis involves the evaluation of a set of worst credible case scenarios, i.e. scenarios that represent a severe but not unlikely challenge for the design. It is based on the estimation of the seriousness of the consequences of each design scenario, which is compared with threshold values expressed as PCs. Deterministic analysis includes quantitative analyses of the consequences of a fire, but the frequency of occurrence of the scenarios is not explicitly considered. However, other probabilistic considerations, such as reliability, may be evaluated separately.

NOTE Deterministic analysis is described in ISO 16733-1 and ISO/TS 29761.

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8.5 Probabilistic analysis

8.5.1 General

Probabilistic analysis explicitly considers both the frequency of occurrence and consequence of the scenarios evaluated. Depending on the desired level of detail and the form of risk expression, two levels of risk-based analysis are available; semi-quantitative risk analysis and quantitative risk analysis.

NOTE Probabilistic analysis is described in ISO 16732-1. In addition, examples of application of probabilistic analysis are provided in ISO/TR 16732-2 to 3.

8.5.2 Semi-quantitative risk analysis

Semi-quantitative risk analysis involves quantification of scenarios partially or fully in the form of point scales or categories with predefined broader ranges. Often, either frequency of occurrence or consequence is quantified using statistical data, and other components of risk are described qualitatively. Sub-components, be it frequency of occurrence or consequence, can be assigned weights, depending on their importance or contribution to the overall risk. Semi-quantitative analysis can be sufficient to prove the acceptability of risk when an absolute approach is employed.

8.5.3 Quantitative risk analysis

Quantitative risk analysis consists of an analysis of the risks as a quantified combination, for all scenarios, of the frequency of occurrence and consequence that are predicted. Engineering calculations are commonly used in quantitative risk analysis, but require good quality and case-specific input data. Quantitative risk analysis allows for determination of expected loss of life, property damage, cost of interruptions, environmental impact and heritage losses associated with the design. There are various methods available, ranging from predictions based on statistical data analysis to advanced computer modelling with random input sampling. Quantitative risk analysis is appropriate for both comparative and absolute approaches.

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9 Identify PCs

PCs shall be formulated. They are engineering metrics that are expressed in deterministic or probabilistic form and determine whether each FR has been satisfied by the fire safety design. For each FR, there shall be one or more PCs.

The exact formulation of PCs depends on the selected risk analysis approach. For the comparative approach, where tolerable risk is implicitly derived from a benchmark design, PCs shall be chosen to enable valid comparison to the benchmark. PCs can therefore be expressed both as conservative estimates, i.e. values corresponding to less than critical exposure given average susceptibility, or as representative estimates, i.e. values corresponding to critical exposure given average susceptibility.

For the absolute approach, where comparison is made with a defined level of tolerable risk, PCs are dependent on whether the analysis is deterministic or probabilistic. In the case of deterministic analysis, where the design is exposed to a severe challenge (worst credible case scenarios), PCs shall be expressed as conservative estimates to account for the low level of treatment of uncertainty in the analysis. In the case of probabilistic analysis, PCs can be expressed both as conservative and representative estimates. However, conservative and representative estimates are not associated with the same frequency of occurrence as the severity of the exposure is different.

EXAMPLE 1 In an example project, an absolute approach is applied and the chosen risk analysis method is the deterministic analysis. PCs corresponding to conservative estimates are chosen for FR1.1, i.e. levels of exposure to elevated temperatures (< 353 K), radiation (< 2,5 kW/m^2), toxic species (CO < 2 000 ppm, CO_2 < 5 %, O_2 > 15 %), irritant species (Fractional Effective Concentration < 0,3, as defined in ISO 13571:2012) and reduced visibility (< 10 m). These PCs would allow the majority of the population to escape safely in case of a real fire, but are chosen deliberately in the analysis to account for the fact that uncertainty is not treated to a high level of detail.

EXAMPLE 2 In an example project, an absolute approach is applied and the chosen risk analysis method is the probabilistic analysis, namely a quantitative risk analysis. Example regulations state that the frequency of occurrence of a building occupant being exposed to toxic species (CO < 2 000 ppm, CO_2 < 5 %, O_2 > 15 %) cannot exceed 10^{-6} per year. The toxicity levels would allow the majority of the population to escape safely in case of a real fire, i.e. it is a conservative estimate of dangerous exposure. The design team wants to instead use a realistic estimate of dangerous exposure (Fractional Effective Dose < 1, as defined in ISO 13571:2012 and meaning incapacitation for half of the population) together with the frequency of occurrence from the regulation (10^{-6} per year). However, this is not an equivalent expression of PCs as the exposure is more severe, i.e. the tolerable risk would be higher. The criteria in this example relates only to individual risk and a proper analysis would require also the inclusion of a societal risk measure.

NOTE Examples of PCs are provided in ISO/TR 16576.

10 Create fire safety design plan

The trial fire safety design plan is an elaboration of the fire safety strategy and consists of a set of fire safety design elements. In relation to the trial fire safety design, it is useful to organize functions and design elements into the following categories:

— initiation of fire and effluent production;

— spread of fire and propagation of effluents;

— compartmentalization and structural stability;

— detection, activation and suppression;

— human behaviour and evacuation;

— fire-fighter intervention (if relevant).

The fire safety design plan should be described and documented in a fire safety design report (see Clause 12).

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11 Determine design scenarios

11.1 General

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

— design fire scenarios (for fire behaviour);

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

Scenario development is typically proceeded by the identification of hazards, which guides the scenario selection process.

The selection of design scenarios shall be documented in the fire safety design report (see Clause 12).

11.2 Hazard identification

It is necessary that hazard identification be conducted in a methodical and organized manner to ensure that there are no omissions. Fire incident data applying to similar types of built environment or environmental conditions may be used in the hazard identification. Hazard can be internal or external.

a) Internal hazards should consider at least the following:

  — occupancy type and associated utilization of the built environment;

  — type of activities or uses;

  — construction products and goods;

  — equipment for normal use and fire safety.

b) External hazards should consider at least the following:

  — neighbouring activities;

  — natural environmental hazards.

11.3 Design fire scenarios

A fire scenario shall be described in terms of the fire development in either qualitative terms (for qualitative risk analysis) or quantitative terms (for deterministic analysis and quantitative risk analysis). A quantitative description of a fire scenario can include the incipient phase, growth phase, fully developed phase, decay phase and extinction depending on the FSO being evaluated. A fire scenario can also include the effect of measures or actions influencing the development of the fire.

EXAMPLE 1 It is possible that a design fire for the life safety of building occupants (e.g. FSO1–FR1.1) only needs to include the first three phases of the fire development, i.e. incipient phase, growth phase, fully developed phase, if the fire is estimated to not reach the decay phase until after evacuation is completed.

EXAMPLE 2 It is possible that a design fire for the protection of neighbouring buildings (e.g. FSO4–FR4.1) only needs to include the fully developed phases, if the likelihood of spread to neighbouring buildings is significantly lower for all other phases of the fire.

A standardized method shall be used to identify a manageable group of design fire scenarios for analysis. Different methods are applicable depending on the risk analysis approach. Consultation with affected parties shall be made to ensure that all relevant scenarios are considered.

For probabilistic analyses, sufficient number of design fire scenarios shall be chosen to ensure adequate representation of the scenario space. For deterministic analyses, design fire scenarios shall be chosen to represent worst credible cases. This requires thorough consideration of specific safety challenges

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of the built environment, for example, conflicts between smoke spread and exit choice of evacuees. In order to deliver acceptable safety, design fire scenarios for deterministic analysis also need to cover the risk associated with scenarios not explicitly included in the analysis.

EXAMPLE 3 A design team has decided to use a probabilistic analysis for life safety (e.g. FSO1–FR1.1). They have chosen a handful (3 to 5) of design fire scenarios to represent the entire scenario space of the specific building, which is a relatively complex building. However, it is very unlikely that all possible scenarios, i.e. the scenario space, can be represented by a handful scenarios, and the design team needs to perform a thorough review of possible fires that can occur in the building.

EXAMPLE 4 A design team has decided to use a deterministic analysis for life safety (e.g. FSO1–FR1.1). One of the chosen design fire scenarios is a small, but frequently occurring, fire with limited consequences, e.g. a fire in a small item. However, this scenario is not appropriate for the deterministic analysis as it does not represent a severe exposure, i.e., it is not a worst credible case.

EXAMPLE 5 A design team has decided to use a deterministic analysis for life safety (e.g. FSO1–FR1.1). One of the chosen design fire scenarios is the biggest fire that can credibly occur in the building. However, this fire is located in a large compartment and is not likely to influence the safety of occupants. It is recommended that the design team instead choose a slightly smaller fire in a critical location, e.g. a fire blocking the main path of egress. This fire can better address the specific safety challenges of the building.

NOTE The selection of design fire scenarios for probabilistic analysis is described in ISO 16732-1. The selection of design fire scenarios for deterministic analysis is described in ISO 16733-1.

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11.4 Design occupant behavioural scenarios

When life safety is the objective being considered, the evaluation of a design requires an assessment as to whether occupants are protected for the period of time from after fire ignition until they reach a place of safety.

The location of occupants within a built environment at any time and the way the location of occupants changes with time during normal use and emergency situations depend on the interaction of a variety of parameters related to the characteristics of the built environment and the occupants, the fire-safety management system proposed and the developing fire scenario.

In order to account for the likelihood and consequence of potential fire scenarios, it is necessary to define the classes of occupants who can be present. The response of occupants to a fire condition is influenced by a whole range of variables related to the characterization of the occupants in terms of:

— their number;

— their distribution within the built environment at different times;

— their familiarity with the built environment;

— their abilities and disabilities;

— their reaction to smoke and any physiological effects the fire effluent can have on them;

— their behaviours and other attributes;

— the characterization of the built environment, including its use, layout and services;

— the provision of warnings, means of escape and emergency-management strategy;

— the interaction of all these features with the developing fire scenario and provisions for emergency intervention (rescue service and rescue facilities).

These attributes make up the occupant behavioural scenarios for consideration in evaluating the design. Design behavioural scenarios can represent the conditions in a single enclosure or a group of similar enclosures within a built environment. Any structure can contain a variety of different behavioural scenarios to consider during a fire evacuation. A small number of design behavioural scenarios can be

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used to represent the conditions in different enclosures in a wide variety of structures, although the individual scenarios can vary somewhat in particular cases.

It is impossible to analyse all scenarios, even with the aid of the most sophisticated computing resources. It is necessary to reduce this infinite set of possibilities to a manageably small set of scenarios that are amenable to analysis and that collectively represent the range of combinations of occupant characteristics that can be present.

NOTE The selection of design occupant behaviour scenarios for deterministic analysis is described in ISO/TS 29761.

12 Select engineering methods

12.1 General

It is necessary to select engineering methods to assess whether the trial fire safety design plan meets the FSOs. This selection process involves the determination of which engineering methods, as mentioned below, have acceptable accuracy and efficiency in demonstrating that PCs are satisfied as the result of one or more design fire scenarios.

There are several possible engineering models that can be used in performance-based fire safety design, and 12.2 to 12.7 below only highlight a selection of methods.

It is necessary that the selection of engineering methods used for evaluation are documented in a fire safety design report. This report shall present enough detailed information to allow its evaluation in terms of meeting the FSOs when assessed against design scenarios using selected engineering methods. In order to achieve this, the report shall include the selected FSE project scope (see Clause 5), FSOs (see Clause 6), FRs (see Clause 7), chosen risk analysis approach (see Clause 8), PCs (see Clause 9), trial fire safety design plan (see Clause 10), design scenarios (see Clause 11) and engineering methods (see Clause 12).

The fire safety design report shall receive the agreement of the affected parties, especially the authorities having jurisdiction when dealing with regulatory objectives (if relevant). Following comments received by affected parties, it can be necessary to change one or more of the items contained in the report.

The fire safety design report should be developed continuously throughout the design process. The report is therefore typically updated with new information in the different phases of the design, but is made final upon agreement of the affected parties at the stage of selection of engineering methods.

12.2 Fire models

Performance-based fire safety design often requires the use of models, either algebraic equations, calculation methods or computer simulation software, to estimate the consequences of design fire scenarios. These models can relate to a specific fire phenomena, e.g. fire plumes, ceiling jet flows, smoke layers or vent flows, or describe fire and smoke spread at a more holistic level, e.g. zone models or Computational Fluid Dynamics (CFD) models. It is important that the appropriate model is chosen based on the problem at hand.

NOTE Models of specific fire phenomena are described in ISO 16734 (fire plumes), ISO 16735 (smoke layers), ISO 16736 (ceiling jet flows), ISO 16737 (vent flows), and ISO 24678-6 (flashover). Furthermore, guidance on the use of zone models is provided in ISO/TS 13447.

12.3 Evacuation models

When the life safety of occupants (and possibly rescue service personnel) is considered, the use of models that are able to simulate evacuation processes are needed. These models can be either simple hand calculation methods or more advanced computer simulation software. The complexity of evacuation models can vary, and models can be categorized in different ways. One possible categorization is based on how the built environment is represented, i.e. as nodes and arcs (coarse network models), as a grid

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(fine network models) or as a continuum (continuous models). Other categorizations include the level of treatment of human behaviour. Different types of evacuation models have different types of strengths and weaknesses, and it is important that the appropriate model is chosen based on the situation that is to be simulated.

NOTE Guidance on models for evaluating behaviour and movement of people is provided in ISO/TR 16738.

12.4 Validation and verification

Validation and verification of calculation methods shall be conducted for assessing whether a given calculation method is appropriate for given applications.

Fire can have multiple impacts on the built environment, its occupants and the environment. It is necessary to use validated equations and models to predict these impacts.

For those calculation methods that consist of algebraic equations and computer models applicable to specific fire phenomena (e.g. fire plume, ceiling jet, smoke layer, vent flow or fire growth), a distinction can be made between equations developed for which validation is needed and equations/models that have already been validated, particularly those that have been published as International Standards or Technical Specifications. It is necessary that any equation or model be used only within its field of validity, otherwise it is necessary to provide justifications.

NOTE The process of validation and verification is described in ISO 16730-1 and exemplified for different types of models in ISO/TR 16730-2 (fire zone model), ISO/TR 16730-3 (CFD model), ISO/TR 16730-4 (structural model) and ISO/TR 16730-5 (egress model).

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12.5 Data from test methods and surveys

Data from test methods or experiments/surveys are typically used as input to various types of engineering methods. It should be shown that the data from a test method or experiments/surveys meets the specific requirements of the relevant engineering method used, and is suitable and adequate for the design under consideration. It should also be shown that the data from a test method or experiments/surveys meets specific reliability (e.g. as measured by repeatability and reproducibility) and accuracy requirements that are documented in the test method or survey standards.

12.6 Analysis of results from reference fire scenario test

Where calculation methods are not available or are not valid due to the complexity of the phenomena involved, a design may be evaluated through the analysis of results from fire tests having a characteristic scale comparable (based on engineering judgement) to the largest dimension of the built environment that can influence the outcomes. It is necessary that such tests, that are designed to reproduce all important features of fire behaviour for the situation of interest, be denoted as reference fire scenario tests. Results from this type of fire test should be analysed to show that the conclusions drawn are applicable to the relevant design situation and that such conclusions do not represent an unwarranted extrapolation from test data. Such a test is limited to simple configurations of the built environment or parts thereof.

12.7 Engineering judgement

When calculation methods and/or data are not available (or not fully appropriate) and the performance of reference-scale tests are not possible due to limited resources, it can be necessary to utilize engineering judgement to agree on the data being used or to determine if certain parts of a fire safety design meet objectives by satisfying the PCs. It is desirable that this be a team effort involving individuals with relevant areas of expertise and experience.

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13 Evaluate design

13.1 General

The trial fire safety design plan should be evaluated by carrying out an engineering analysis using selected engineering methods to determine whether the PCs are achieved for the design fire scenarios. This evaluation quantifies the performance of the trial fire safety design. Depending on whether the PCs are expressed in a deterministic or a probabilistic manner, the evaluation can involve specific calculations for each design fire scenario or a probabilistic representation of calculations applying to a range of design fire scenarios.

13.2 Quantification of design scenarios

13.2.1 Input data

Data is required to determine, with sufficient accuracy, input parameters for all the design scenarios. Data can be obtained from tests and/or surveys, or from literature. For design fire scenarios, there is a specific need to quantify the design fire associated to each design fire scenario and to estimate the effects of these design fire scenarios.

It is necessary to check carefully the data derived from tests and surveys regarding:

— the validity of the methodology by which data was obtained;

— the range of application of the testing and survey results;

— the uncertainty attached to them.

In the majority of cases, it is recommended to control the set of data by using it when comparing the results of a calculation method with valid experimental or statistical results. For data taken from the literature, the same checks as for data from tests and surveys is necessary.

An assessment of the uncertainty of the input data for calculation methods used in the analysis should be made.

NOTE Guidance related to input data for design fires is provided in ISO 16733-1. Guidance related to input data for occupant behaviour is provided in ISO/TR 16738.

13.2.2 Estimation of consequence

It is necessary to determine the consequences of each design fire scenario taking into account the performance (such as effectiveness, level of confidence, response time) of the fire protection systems and any influence of the fire protection systems on the fire severity.

When dealing with life safety, behavioural scenarios shall be taken into account.

These analyses consider:

a) determination of fire behaviour. The evaluation of design fire scenarios through a deterministic analysis or the evaluation of all representative fire scenarios in a probabilistic analysis should include the following aspects of fire behaviour:

   — design fire growth in the built environment;

   — movement of effluents caused by the design fire in the built environment;

   — functioning and reliability of active fire-protection systems;

   — functioning and reliability of passive fire systems;

   — effects of the fire-safety management.

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b) determination of fire impact. The evaluation of fire behaviour should be made to identify the impacts on the relevant fire safely objectives.

13.2.3 Estimation of frequency of occurrence

In the case of probabilistic analysis, it is necessary to undertake an appropriate and detailed evaluation of the frequency of occurrence of each design scenario. For the deterministic analysis, design scenarios are chosen to represent a severe exposure, i.e. a worst credible case approach. Quantification of the frequency of occurrence is therefore mainly applicable for the probabilistic analysis.

13.3 Uncertainty

In evaluating a fire safety design plan, as with any engineering evaluation, there are many sources of uncertainty. These can include uncertainties associated with:

a) the choice and definition of the scenario(s);

b) the functioning of fire protection measures;

c) the selection of appropriate engineering methods for a chosen scenario;

d) the validity of the selected engineering method;

e) the value of input data and chosen parameters;

f) assumptions made as part of the analysis.

The magnitude of uncertainty associated with each component of the evaluation shall be considered and then combined to establish an overall level of uncertainty. This overall level provides the basis for the choice of method for addressing uncertainty.

The chosen risk analysis approach is inherently linked to the level of treatment of uncertainty in the risk analysis (see Clause 8). Depending on the approach chosen, i.e. qualitative analysis, deterministic analysis or probabilistic analysis, the uncertainty needs to be handled in different ways.

In the qualitative analysis, uncertainties are addressed by identifying areas of increased risk compared to a benchmark built environment. This means that uncertainty is partially handled by identifying and subsequently addressing all negative impacts.

The deterministic analysis attempts to handle uncertainties by applying a worst credible case approach. However, some uncertainties, such as uncertainties related to failure of fire protection systems, need to be specifically handled in the deterministic analysis. One way to address the reliability of technical systems is to assign a less serious fire scenario or to accept more severe exposure for the less probable case of technical system failure. The basic idea is that if a technical system fails, a reasonable safety level shall still be achieved, bearing in mind that this situation is less likely for a well-maintained system. If the same fire scenario would have been considered for the two cases, e.g. functioning versus failing sprinkler system, there would be no added benefit of installing the system if the same objectives were to be fulfilled. Another way to address uncertainties in the deterministic analysis is a systematically performed sensitivity analysis where one variable at a time is varied to study the influence of the variation.

In the probabilistic analysis, some uncertainties can be explicitly quantified by, for example, assigning distributions to input values. Care shall be taken to choose distributions that adequately represent the underlying uncertainties.

Any safety factors or safety margins incorporated in a proposed solution involve a degree of expert judgement by the designer and, consequently, also by those responsible for assessing and approving the solution. Wherever possible, this judgement should be informed by an understanding of the basis and limitations of the chosen scenarios, models and data, and should be made explicit in the reporting and presentation of the final design.

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For the important practical case where a design is based on a single analytical expression, methods have been developed in structural and other engineering areas to derive safety factors (partial coefficients) corresponding to a pre-determined level of risk or failure. The method is usually termed as a “reliability-based design” and assumes that relevant uncertainties are quantified in statistical terms.

It is not yet possible to quantify levels of uncertainty for all stages of the design process, nor is there yet a generally accepted methodology for combining them.

13.4 Comparison with PCs

It is necessary to compare the results of the evaluations of the fire safety design for each design scenario with the PCs for the relevant FSOs. If the comparison is unsatisfactory for one or several of the objectives or design scenarios, the following responses are possible.

— The trial design should be modified, to meet any PCs that are not met by the original trial design. Any changes made in the fire safety design plan due to actions from Clause 13 should result in a repeat of the procedures outlined in Clauses 10 to 13.

— When the objective under consideration is voluntary, it can be possible to change the PCs with the informed agreement of the affected parties. This will result in a repeat of the procedures outlined in Clauses 9 to 13.

— For some situations, it can be necessary to review the scope of the project. In this case, the process should return to Clause 5.

13.5 Identify other affected FSOs

Once a trial fire safety design plan has been shown to meet the FSOs of concern, the fire safety designer shall assess whether the design has negatively affected any prescribed FSOs not already considered in the analysis. This is particularly relevant in cases where a comparative approach has been applied and where FSOs are not explicit in the regulations. In these cases, it is possible that changes have been made compared to the prescriptive regulations without realizing the influence on other FSOs. If other affected FSOs are identified, the process described in Clause 5 to 13 should be performed for the newly identified objectives.

EXAMPLE Regulations in an example country state that the maximum walking distance to the closest emergency exit shall not exceed 30 m for a specific type of building. The design team want to extent this distance to 35 m. Due to the introduction of a number of fire safety features, a trial fire safety design plan is shown to provide equivalent life safety for building occupants compared to a prescriptively designed building with a maximum walking distance of 30 m. Although the requirement of 30 m in the prescriptive regulations is stated as a requirement for evacuation routes, it can have an impact on other FSOs, e.g. the life safety of rescue service personnel. The design team therefore needs to identity other FSOs affected by the change of maximum walking distance to the closest emergency exit. The FSE process then needs to be repeated (in full or reduced form) for these identified objectives.

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14 Document in final report

14.1 General

All of the information which was involved in developing the fire safety design, from FSE project scope to final design and ongoing operations and maintenance of the facility, should be documented. The following reflects the types of information which should be reported.

14.2 FSE assessment

The FSE assessment shall clearly and completely explain the basis of the assessment (including all assumptions) and can include at least the following:

— reasons for choosing performance-based design;

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- description of the boundaries of the analysis (FSE project scope, FSOs, FRs, chosen risk analysis approach and PCs);
- presentation of the fire safety design plan;
- presentation of the engineering methods and input data used for the assessments and justification for the choices made;
- various steps of the evaluation of the trial design for the design fire scenarios and results;
- comparison of the results with PCs;
- summary conclusion;
- description of quality assurance work.

14.3 Conditions of use of the built environment

The conditions of use of the built environment, consistent with assumptions made in the design, shall be documented. This serves as information for the owner/manager of the built environment throughout its lifetime. The documentation shall include at least the following:

a) a description of the built environment and its activity, such as the following for the case of a building:
   - number of stories and floor area of each storey;
   - location of the building relative to property lines and streets;
   - use of the built environment;
   - purpose/function and dimensions of each part of the built environment;
   - description of the location of all fixtures, furnishings, decorations, equipment and combustible products;
   - for industrial installations, a description and analysis of the processes;
   - occupancy of each space;
   - access of fire service intervention;
   - location and features of the final refuge;
   - evacuation routes to the final refuge.

b) a list of assumptions made in the assessment which need to be followed, such as:
   - upper limit and location of fire load;
   - upper limit and location of occupants;
   - active fire protection measures (including in-house fire-fighters);
   - passive fire protection measures;
   - egress trials;
   - inspection and maintenance.

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