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Fire safety engineering — Selection of design occupant behavioural scenarios

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National foreword

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Fire safety engineering — Selection of design occupant behavioural scenarios

Ingénierie de la sécurité incendie — Sélection de scénarios de dimensionnement du comportement des occupants

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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 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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 92, *Fire safety*, Subcommittee SC 4, *Fire safety engineering*.

Introduction

In a fire safety engineering assessment, the ability of occupants to escape safely or find a designated place of refuge is evaluated for each design fire scenario, taking account of the occupants expected to be present in the building or other structure.

The purpose of this Technical Specification is to outline a general methodology for selecting design fire scenarios for the specific fire safety objective of life safety of the occupants, and then developing the occupant behavioural scenarios for which those design fire scenarios will be tested. ISO 16733-1 provides general guidance on the selection of design fire scenarios.

Since each design fire scenario might require several different occupant behavioural scenarios, the number of possible design occupant behavioural scenarios in any built environment (a building, structure or transportation vehicle) can be very large, and it is not possible to quantify them all. This large set of possibilities needs to be reduced to a manageably small set of occupant behavioural scenarios that are amenable to analysis. In a deterministic assessment, which is implicitly envisioned in this Technical Specification, a manageable number of design occupant behavioural scenarios is selected. For a full quantitative risk assessment, see ISO 16732-1.

The characterization of an occupant behavioural scenario involves a description of the initial occupant distribution and the number and other characteristics of the population, including their reaction and response capabilities. The occupant behavioural scenarios will be specifically determined for each design fire scenario, which itself includes the interaction with the proposed fire protection features for the built environment. The possible consequences of each fire scenario for each occupant behavioural scenario need to be considered.

Following selection of the design occupant behavioural scenarios, it is necessary to describe the assumed characteristics of the occupant behaviour on which the scenario quantification will be based. These assumed occupant behaviour characteristics are referred to as “the design occupant behaviour”. Design occupant behaviours are usually characterised in terms of pre-travel activity delay times (response and reaction times) and occupant movement speeds. The design occupant behaviour needs to be appropriate to the life safety objective of the fire safety engineering analysis and has to result in a design solution that is conservative.

Fire safety engineering — Selection of design occupant behavioural scenarios

1 Scope

This Technical Specification describes a methodology for the selection of design occupant behavioural scenarios that are severe but credible for use in deterministic fire safety engineering analyses of any built environment including buildings, structures, or transportation vehicles.

Occupant behavioural scenarios are linked to design fire scenarios. Guidance on the selection of design fire scenarios and design fires is covered in ISO 16733-1. The steps in ISO 16733-1 are followed in this Technical Specification with life safety of the occupants as the single fire safety objective under consideration.

ISO/TR 16738 provides information on methods for the quantification of the different aspects of human evacuation behaviour in a design context. One part of that process involves the selection of occupant behavioural scenarios. This Technical Specification provides guidance for that aspect of the evaluation of an egress design.

This Technical Specification addresses behaviours that occur after fire ignition and does not deal with behaviours that influence fire ignition.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13571:2012, *Life-threatening components of fire — Guidelines for the estimation of time to compromised tenability in fires*

ISO 13943, *Fire safety — Vocabulary*

ISO 16733-1:2015, *Fire safety engineering — Selection of design fire scenarios and design fires — Part 1: Selection of design fire scenarios*

ISO/TR 16738, *Fire-safety engineering — Technical information on methods for evaluating behaviour and movement of people.*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943, ISO/TR 16738 and the following apply.

NOTE Some of the definitions have been updated to reflect the current understanding of the terms as employed in fire safety engineering. Some are duplicated here for the convenience of users of this document.

3.1
ASET
available safe escape time

for an individual occupant, the calculated time interval between the time of ignition and the time at which conditions become such that the occupant is estimated to be incapacitated, i.e. unable to take effective action to escape to a safe refuge or place of safety

Note 1 to entry: The time of ignition may be known, e.g. in the case of a fire model or a fire test, or it may be assumed, e.g. it may be based upon an estimate working back from the time of detection. The basis on which the time of ignition is determined needs to be stated.

Note 2 to entry: This definition equates incapacitation with failure to escape. Other criteria for ASET are possible. If an alternate criterion is selected, it needs to be stated.

Note 3 to entry: Each occupant can have a different value of ASET, depending on that occupant's personal characteristics.

[SOURCE: ISO 13943:2008, 4.20, modified]

3.2
built environment

building or other structure

EXAMPLE Off-shore platforms; civil engineering works, such as tunnels, bridges, and mines; and means of transportation, such as motor vehicles and marine vessels.

Note 1 to entry: ISO 6707-1 contains a number of terms and definitions for concepts related to the built environment.

[SOURCE: ISO 13943:2008, 4.26]

3.3
design fire

quantitative description of assumed fire characteristics within the *design fire scenario* (3.4)

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

[SOURCE: ISO 13943:2008, 4.64]

3.4
design fire scenario

specific *fire scenario* (3.7) on which a deterministic fire safety engineering analysis is conducted

Note 1 to entry: As the number of possible fire scenarios can be very large, it is necessary to select the most important scenarios (the design fire scenarios) for analysis. The selection of design fire scenarios is tailored to the fire-safety design objectives and accounts for the likelihood and consequences of potential scenarios.

[SOURCE: ISO 13943:2008, 4.65]

3.5
design occupant behaviour

quantitative description of occupant behavioural characteristics within the *design occupant behavioural scenario* (3.6)

Note 1 to entry: It is, typically, an idealized description of the time needed for evacuation or refuge, comprising components for recognition, response, and travel. The actual variables include delay time, travel distance, and travel speed.

EXAMPLE Young, intoxicated people in a stadium might delay longer before beginning to evacuate than those who are not intoxicated; older people in a nursing home may travel more slowly than other mobile adults would; intoxicated people may have more difficulty with decision-making and, as a result, might take more time to make exit choices.

3.6
design occupant behavioural scenario

specific occupant behavioural scenario on which a deterministic fire safety engineering analysis will be conducted

3.7
fire scenario

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

Note 1 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 impact on the course of the fire.

[SOURCE: ISO 13943:2008, 4.129]

3.8
occupant behavioural scenario

qualitative description of occupant behaviour and response over time, including the number of occupants and the physical and cognitive characteristics that affect their decision-making and actions in response to fire cues, identifying key characteristics that differentiate members from other occupants

Note 1 to entry: It typically describes the number and other characteristics and capabilities of group members that would impact the decision-making and behavioural processes (i.e. elderly occupants might be less likely to hear an alarm and may move more slowly than younger occupants; staff may recognize and react to an alarm more quickly and engage in rescue activities before evacuating themselves).

3.9
pre-travel activity time

PTAT

for an individual occupant, the interval between the time at which a warning of a fire is given and the time at which the first move is made by that occupant towards an exit

Note 1 to entry: This consists of two components: *recognition time* (3.10) and *response time* (3.11).

Note 2 to entry: For groups of occupants, the following two phases can be recognized:

— pre-travel activity time of the first occupants to move;

— pre-travel activity time distribution between the first and last occupants to move.

[SOURCE: ISO/TR 16738:2009, 3.9]

3.10
recognition time

interval between the time at which a warning of a fire is given and the first response to the warning

[SOURCE: ISO/TR 16738:2009, 3.10]

Note 1 to entry: This concept is thoroughly discussed in ISO/TR 16738:2009, Annex B.

3.11
response time

interval between the time at which the first response to the event occurs and the time at which travel begins to a *safe location* (3.13)

[SOURCE: ISO/TR 16738:2009, 3.11]

Note 1 to entry: This concept is thoroughly discussed ISO/TR 16738:2009, Annex B.

3.12
RSET
required safe escape time
calculated time period required for an individual occupant to travel from their location at the time of ignition to a safe refuge or place of safety

[SOURCE: ISO 13943:2008, 4.277]

3.13
safe location
location remote or separated from the effects of a fire so that such effects no longer pose a threat

Note 1 to entry: The safe location may be inside or outside the building depending upon the evacuation strategy.

[SOURCE: ISO/TR 16738:2009, 3.12]

3.14
travel time
time needed, once movement towards an exit has begun, for an occupant of a specified part of a building to reach a *safe location* (3.13)

[SOURCE: ISO/TR 16738:2009, 3.14]

4 Fire safety engineering applications

4.1 The role of occupant behaviour scenarios in fire safety design

When a built environment is designed, it has expected (planned) uses and users. In order to complete an evaluation of an engineered design, design fire scenarios are developed to demonstrate that the design will meet its fire safety design objectives. This process is outlined in ISO 16733-1.

When life safety is one of the design objectives, the evaluation demonstrates the extent to which occupants are protected from the fire and its effects. The evaluation should include: the users and/or occupants of the building, their roles, needs, and anticipated abilities, and, if and how the occupants will react and respond to a fire. These factors enable determining the degree of life safety provided by the design.

Just as the fire safety evaluation requires fire scenarios appropriate to the building's design and intended use, the evaluation also requires scenarios of occupant behaviour that reflect the expected population and their characteristics, as described in this Technical Specification.

4.2 The role of design occupant behavioural scenarios in fire safety design

The evaluation of the life safety provided by an engineered design requires an assessment as to whether occupants are protected for the period of time, after fire ignition, until they reach a designated place of safety.

The location of occupants within a building, at any one time, and the way occupant location changes with time during normal use and emergency situations depends on the interaction of a variety of parameters related to the characteristics of the building and the occupants, the fire safety management system proposed for the building and the developing fire scenario. There are essentially five categories of information required to determine the location (and condition) of occupants during a fire:

a) the building characteristics;

b) fire safety management strategy/procedure;

c) the occupant characteristics;

d) the fire dynamics, including smoke transport;

e) intervention effects;

f) the acute effects of the fire effluent on the individual occupants to the extent that there is quantitative knowledge on which to base the evaluation.

Long-term effects of exposure to the fire effluent should also be considered, to the extent that there is quantitative knowledge on which to base the evaluation.

Changes in occupant location during an incident depend on pre-travel activity processes (including recognition and response) and movement processes. Each of these processes occurs over a period of time: recognition time, response time, and movement or travel time. These times can be estimated for each individual, for groups of people in the same location, or a distribution of times can be estimated for the building population. The calculation of these times is an essential task in evaluating an engineered design.

In evaluating a design option, one would:

- take a building, as designed, including its evacuation plan and fire safety management plan;
- determine the various types of potential occupants to consider (e.g. staff vs. visitors, disabled vs. able-bodied, etc.);
- determine the relevant design fire scenarios given the identified occupant population;
- for each design fire scenario, evaluate the predicted outcome for each type of occupant;
- compare the available and required escape times for relevant parts of the building (i.e. estimate the harm done to people by the range of fires that can occur in the building if it is designed as proposed, and compare that harm to levels of acceptable harm as set by the stakeholders for the project);
- at each step of the calculations, provide for estimation of uncertainty, as that will be important in the final evaluation.

In order to do this, one would:

1) determine design occupant behavioural scenarios, including initial input, as well as response data (if necessary);

2) choose an appropriate evacuation calculation method;

3) model the fire and apply the evacuation calculation method;

4) compare the results to the guidance on estimating time available for escape, given in ISO 13571.

There may be several fire safety objectives to be evaluated for a particular design. When life safety is the objective being considered, occupant behavioural scenarios are constructed. They may be relevant for other fire safety objectives.

It would be impossible to analyse all scenarios even with the aid of the most sophisticated computing resources. This infinite set of possibilities needs to be reduced to a smaller, manageable set of groupings or clusters of scenarios that are amenable to analysis and that collectively represent the range of combinations of occupant numbers and other characteristics that could be present.

Once occupant behavioural scenarios are selected and evaluated, the design of the built environment is modified until analysis demonstrates that the estimated fire risk associated with the design is acceptably low and meets the performance criteria associated with the specified fire safety objective(s).

The characterisation of a design occupant behavioural scenario for analysis purposes involves a description of such things as the number of occupants, their locations throughout the built environment, and their ability or inability to recognize and respond to fire cues, and their ability or inability to move through the available escape routes. The impacts of smoke and fire on people are part of potentially relevant consequences of a design occupant behavioural scenario and are part of the characterisation of that scenario when those consequences are relevant to the life safety objective. The characterisation or quantification of occupant recognition and response and movement belong to the “design occupant behaviour". Some later events will be predictable from earlier events through the use of fire safety science, and the characterisation of the event sequence in the scenario shall be consistent with such science.

5 Focusing the steps of ISO 16733-1 for a life safety objective

5.1 Overview of the procedure

In the first part of this three-part procedure, follow the first six steps described in ISO 16733-1 for design fire scenario selection as they would be followed for the fire safety objective of life safety of the occupants. The remainder of this Clause provides guidance for these steps.

Second, select the relevant scenarios following ISO 16733-1, steps 7 to 9.

Third, evaluate the design using occupant behavioural scenarios created and selected as outlined in Clauses 6 and 7.

5.2 Step 1 — Identify the specific safety challenges

At this step, the expected uses of the building are considered, and for every expected use, the variation in potential users shall be considered. This step informs the process that determines which characteristics of the structure, the fire, and any safety systems are relevant for evaluating life safety.

The building users will ultimately be specified in terms of the following:

- number of users;
- permanent/transitory;
- trained in evacuation procedures/untrained;
- potential age ranges;
- potential vulnerabilities;
- awake/asleep/unconscious/impaired;
- social groupings or not;
- variability in composition of occupant groups (e.g. will it always be the same kinds of users?).

It is not necessary at this stage to specify the different occupant groups that would be expected, but rather to be cognizant of the variations that could exist and will have to be considered while going through steps 2 to 6.

Because the aim of the deterministic analysis is to test the fire safety design using a selection of severe but credible scenarios, it is imperative to identify issues or conflicts that, in combination with fire, could potentially lead to the failure of the design. These issues and conflicts are referred to here as *life safety challenges*. Issues can be occupant characteristics that lead to non-optimal response or movement in emergency situations. Conflicts can involve a mismatch between building uses and users or between users and building layout.

5.3 Step 2 — Location of fire

This step focuses on locations most likely to threaten occupants, based on the challenge they present to the objective of life safety. The challenge could be related to the fire's proximity to occupied spaces or escape routes, or its potential for spreading smoke and toxic products into occupied areas or escape routes. The challenge could be related to difficulties in decision making that would face some occupants if a fire impacted their escape routes. Fires that will not spread flames into, spread effluent into, or otherwise damage areas where occupants will be located can be ignored.

5.4 Step 3 — Type of fire

Fires begin and grow in stages. These stages are: smouldering, oxidative pyrolysis, anaerobic pyrolysis, well-ventilated flaming, underventilated flaming in a poorly ventilated compartment, and postflashover flaming (see ISO 19706). Not all fires manifest all stages.

The threats to people from fires are due to the presence of the fire itself, the fire effluent (toxicity, irritancy, elevated temperature, and reduced visibility), and to the thermal radiation from the effluent and the heated surfaces of the compartment.

NOTE 1 The presence of the fire can change occupants' actions by effectively blocking passages, actuating fire alarms or fire suppression devices, etc.

NOTE 2 Exposure to dilute fire effluent has behavioural effects on occupants' actions, slowing movement and enhancing the potential for indecision or faulty decisions. It reduces the visibility of doors and exit signs.

NOTE 3 Longer exposure to or more concentrated effluent can lead to incapacitation: the inability of an occupant to effect his or her own escape. These are described in ISO 13571 and ISO 27368.

NOTE 4 The effluent from a smouldering fire or from anaerobic pyrolysis is only a threat to a person who is very close to the combustible. While such fires can generate high concentrations of toxic and irritant gases, the mass loss rates are small, and the dilution of these gases occurs before the effluent spreads far from the source. As this dilution occurs, the temperature diminishes, reducing the thermal threat.

Since the nature and concentrations of the effluent components change during the course of a fire, depending on the burning items and the access of fresh air to the fire, the effect on each occupant changes with occupant location, the effluent flow pattern, and the cumulative exposure of the occupant to the effluent.

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

ISO 16733-1 lists several hazards that should be considered in this step, including earthquakes and terrorist events that can result in multiple fires or disable multiple safety systems simultaneously, non-fire events that can impair structural stability, and presence of high-hazard materials and operations that can initiate fires or complicate their suppression.

These hazards should be considered here as they relate to occupant safety or evacuation. For example, an earthquake or terrorist attack could completely change the evacuation from what is expected. That is, the physical environment is changed and things not included in an ordinary evacuation would have to be considered, such as debris in travel paths or routes eliminated due to broken stairwells or jammed doors.

5.6 Step 5 — Systems and features impacting fire

This step identifies the fire safety systems and features that are likely to have a significant impact on the course of the fire or the development of untenable conditions, including in the characterization of each scenario the initial status of the system or feature. Impacting fire includes impacting fire outcomes, and outcomes can be affected by systems and features that impact behaviour (such as notification systems).

This step shall address how occupants can use or misuse the fire safety systems that are in place, how those actions can impact the growth and spread of the fire, or how systems and features can affect evacuation and life safety.

Among the passive systems and features that shall be considered are doors, windows, structural elements, contents and furnishings, and size of compartment. The type (use) of the building and the composition of the occupant population can influence the likelihood that a door will be closed or left open. If open, a door can allow fire and smoke to spread into occupied areas and evacuation routes. If closed, the scenario might be eliminated in a life safety analysis because it will protect occupants on the other side. Another consideration can be that if occupants will have to move through a closed door, there could be difficulties presented by the latching mechanism or handle, or by the opening force required by the door.

Active systems to be considered include smoke control systems, suppression systems, stairwell pressurization systems, detection, warning, and communication systems, fire safety management, and firefighting operations.

NOTE 1 A stairwell pressurization system might only function properly if a limited number of doors are open simultaneously. During a fire, if occupants prop open many such doors, the fire effluent might enter the stairwell and other occupied areas. Fire safety management systems have a role in the effective operation of safety systems and features and in minimizing the likelihood of unsafe practices in the ordinary use of a building.

NOTE 2 Away from the fire and outside the fire room, the air may be stratified, with a hot, smoky upper layer and a lower layer that poses a far lower threat to life safety. Actuation of an automatic sprinkler system can prevent a small fire from becoming an uncontrolled fire, but the increased interlayer mixing may result in reduced visibility in travel paths. The designer will have to factor in the effect that this mixing will have on the evacuation time and the enhanced smoke exposure to vulnerable occupants.

NOTE 3 Other systems that might influence the consequences of a specific fire scenario, such as notification and egress systems, are important to consider even if they do not directly affect fire or the smoke spread. Notification systems can alert and guide occupants in their evacuation. Determining the effectiveness of the system will have to take into consideration the abilities and disabilities of expected occupant population. For example, how will people with different sensory impairments, e.g. hearing or vision, be alerted?

Egress systems, such as emergency evacuation elevators, will impact the evacuation, as will a fire safety management plan that will establish the likelihood of trained staff present, quality of any training provided, and overall planning and preparation for emergencies.

5.7 Step 6 — Occupant actions impacting fire

When the objective is life safety, this step is handled as described in ISO 16733-1, and focuses on the actions of building occupants following ignition that impact fire growth and development.

In this step, consideration is given to the presence, or lack, of staff trained in evacuation procedures or in-house fire brigade, as well as actions covered under step 5. For this step, it is particularly essential that the potential uses and users of the building have been defined.

NOTE 1 Occupants may bring into the building some goods that might be discarded during the evacuation process, adding to, or changing the configuration of, the fire load or interfering with evacuation. For example, luggage left behind at an airport while escaping may be left in egress paths, creating both a hazard to occupant movement and possibly providing additional fuel to a spreading fire.

NOTE 2 Trained occupants might begin warning or suppression activities. Occupants might change the conditions in ways that affect the evacuation or exposure to fire and smoke, in positive or negative ways, such as opening a manual smoke hatch (if trained to do this correctly), or inadvertently opening too many doors in a pressurized stairwell, for example. Opening too many doors might influence the functioning of the pressurization system. The mobility of the expected population will affect the likelihood of many doors being open for a long time. A fire management plan, e.g. a phased evacuation, and training could minimize the likelihood of this happening.

5.8 Steps 7 to 9 — Scenario selection

The final three steps in the process of selecting design fire scenarios are described in ISO 16733-1. These steps discuss methods to reduce the large number of potential fire scenarios to the manageable number that will be included in the evaluation of the design. The description of these steps is not repeated here but the focus is on finding worst credible cases, i.e. design scenarios that challenge the achievement of the life safety objectives.

6 Design occupant behavioural scenarios

6.1 Characteristics of occupant behavioural scenarios

Design fire scenarios will have been selected with consideration for the occupants who will be impacted or who might impact the fire's growth and development, based on the expected uses of the structure. At this point, a group of occupant behavioural scenarios will be associated with each design fire scenario. An occupant behavioural scenario represents a particular combination of events and circumstances associated with non-design factors such as the following:

a) building use/activities (intended use), which can vary by time of day, month, season, etc.;

b) number and distribution of occupants to be expected for the intended use;

c) initial occupant-based information (e.g. roles, demographics, knowledge and training, etc.);

d) susceptibility of the occupants to the components of the fire effluent;

e) recognition, response, and movement abilities of those occupants;

f) external environmental conditions (e.g. weather).

Other factors are part of the fire safety design or could vary throughout the lifespan of the building or in the different uses of the building, such as the following:

- egress paths (egress design);
- whether the paths are isolated from the fire effluent;
- staff (presence and/or training);
- signage;
- alarm system characteristics;
- management plan.

Other factors are always treated as elements of design, such as the following:

- performance of each of the fire safety measures;
- reliability of each of the fire safety measures.

The design fire scenarios that are associated with the design occupant behavioural scenario will provide information on the location and spread of fire and smoke effects. It is important to note that while every fire scenario will have a set of design occupant behavioural scenarios associated with it, the same occupant behavioural scenarios will not necessarily be used for every fire scenario.

6.2 Identification of occupant behavioural scenarios

6.2.1 General

The design fire scenarios have been selected with consideration of the uses and users of the building. In creating the associated occupant behavioural scenarios, specific choices shall be made to describe those occupants impacted by the design fire scenarios.

As with design fire scenarios, the number of possible occupant behavioural scenarios in any built environment can be very large, and it is not possible to quantify them all. This large set of possibilities needs to be reduced to a manageable set of scenarios that are amenable to analysis.

Occupant behavioural scenarios are needed to determine initial conditions so that changes in occupant location, any resulting toxic exposures and total evacuation time can be calculated. Any change in occupant location during an incident depends on pre-travel activity processes and movement processes. Pre-travel activity processes have two components: recognition and response. Each of these components occurs over a period of time: recognition time, response time, and movement (or travel) time. These times can be estimated for each individual, for a group of individuals in the same location, or a distribution of times can be estimated for the building population. The calculation of these times is an essential task in evaluating an engineered design.

For each design fire scenario, the relevant occupant behavioural scenarios shall be defined. For each scenario, then, users select or calculate appropriate times.

The following attributes are defined for the design, and do not vary throughout the entire evaluation:

a) type of occupancy;

b) geometry of the spaces;

c) egress design (including exit route options and lighting);

d) fire safety management plan;

e) detection and alarm systems (other than their functionality, which might be the issue for a particular design fire scenario).

The following attributes are defined for each design fire scenario and are the same for each occupant behavioural scenario to be evaluated for that type of fire:

— functionality of the detection and alarm systems;

— usability of the egress system;

— location of the fire;

— spread of fire and smoke;

— nature/severity of the fire effluent.

The first four steps outlined below provide a systematic approach towards identifying occupant behavioural scenarios. Every step shall be followed for the results to be valid.

Appropriate statistics to support the selection of occupant behavioural scenarios may be available on a national basis, a state or provincial basis, or for like properties sharing ownership with the structure being designed. If appropriate national statistics are not available, then information from other countries with similar fire or other evacuation experience may be utilized, keeping in mind, however, that there might be important differences between countries and cultures in terms of reactions and responses. It is essential to exercise care in applying incident statistics and it may be necessary to demonstrate that the data is appropriate for the built environment under consideration. For example, occupant recognition time could vary greatly between countries that have vastly different familiarity with central fire alarm systems and that could make the application of data from one country inappropriate in another.

6.2.2 Step A — Number of occupants and distribution of occupants

In this step, the estimate of the number of occupants and their locations is refined in more detail than in step 2. Consider the number of occupants and their locations throughout the occupancy being evaluated. The occupant behavioural scenarios are related to the design fire scenario under consideration, so the fire scenario will provide guidance as to the expected number of occupants and their initial locations throughout the structure under consideration. For example, if high density was considered a concern in step 1, the number occupants would be specified here.

When considering crowded conditions, the occupant load can be based on the densities specified in national codes, when those specified densities reflect the maximum allowable load. In some national codes, the densities in the code may simply define the scope of application of the code and are not meant to be taken as reasonable numbers of occupants for an evacuation scenario. The occupant load can be obtained from statistics or surveys of similar occupancies. Identification of the most adverse or challenging locations can involve engineering judgment. Challenging locations and challenging occupant loads will be those where special circumstances could adversely affect the performance of fire safety measures. For an international comparison for assembly occupancies, see Reference [9].

NOTE High and low occupant densities can present different challenges. High densities can result in longer delay times due to crowded conditions, while with low occupant densities, there might be no crowd for an occupant to follow and possibly few people available to spread warning messages.

6.2.3 Step B — Characteristics of the occupant population

Define the occupant population in terms of their physical and cognitive attributes. These characteristics or attributes can affect their ability to perceive cues, interpret these cues, respond to these cues, and move to a safe location. Any difficulties in this regard can be due to age, physical condition, health status, disabilities or impairments. Any expected combinations of these factors should be reflected in the occupant behavioural scenario.

The behavioural attributes can vary depending on an occupant's role in the structure. An occupant could be a resident, a visitor, or a member of staff. A visitor could have no knowledge at all about the building. A resident would be a frequent user of a building, but might not have responsibility for dealing with emergencies. A member of staff would also be a frequent user of a structure and may or may not have a role to play in facilitating an evacuation. For example, the resident of a high-rise apartment building may have a certain familiarity with the building but might not know anything more than the path from the front door to the elevator; much less about the building, in fact, than the resident of a single-family dwelling would know about that structure. A member of staff in a museum might have responsibility to assist visitors, but an office worker might have no responsibility other than self-rescue in an emergency situation.

The occupant population should be appropriate for the design fire scenarios under consideration. The following is a list of attributes that can be used as a guide, as it is not possible to make it all-inclusive:

- gender;
- age;
- physical capabilities;
- susceptibility to smoke, heat, and toxic gases;
- sensory capabilities;
- familiarity with the building;
- past experience and knowledge of fire emergencies;
- social and cultural roles;
- presence of others;
- commitment to activities.

6.2.4 Step C — Activities of occupants

Define the activities of the occupants. The initial activities in which occupants are engaged can affect their ability to perceive cues, and the time it will take them to respond and react to cues. The degree to which they are committed to an activity, or the degree to which an activity holds their focus, can delay their awareness of cues and can result in an unwillingness to respond promptly to information provided by the cues.

NOTE One of the most obvious activities that will have an impact is sleeping versus being awake.

6.2.5 Step D — Presence and training of staff

Occupant behavioural scenarios shall include any combinations of staff/coordinator presence and effectiveness expected to be present. Determine the combinations of staff and non-staff who will be present for the fire scenario under consideration, and if staff are present, their expected level of training and effectiveness.

NOTE The effectiveness of the occupants' response in an emergency can be influenced by staff or individuals/occupants with fire safety roles, if any are present. If staff or coordinators are present, their training and the effectiveness of their response will influence behaviour of the occupants.

6.3 Selection of design occupant behavioural scenarios

6.3.1 General

In steps A through D, a large number of potential occupant behavioural scenarios will have been identified. From this large number, a set of design occupant behavioural scenarios is to be selected. There will be clusters of scenarios that share some characteristics. From these clusters, one scenario can be selected to be representative of those in the cluster.

NOTE 1 For example, a scenario might involve a staff member in a hotel gift shop whereas a scenario cluster might be specified as an awake person familiar with the environment in an occupied space in the hotel lobby.

NOTE 2 An example of a characteristic common to a group of behavioural scenarios might be occupants of a hotel room. Within a cluster, variations on this characteristic might be whether the people are awake or asleep, the age of the people, and their familial (or non-familial) relationships.

Since this Technical Specification describes a deterministic approach, this process would not necessarily involve the construction of an event tree. Engineering judgement, readily available data, and order-of-magnitude estimates of likelihood and consequences can be used; however, the justification for decisions shall be documented. Another way to sort the possible combinations of factors that make up an occupant behavioural scenario is through the use of a matrix.

6.3.2 Step E — Occupant characteristics matrix

6.3.2.1 General

Develop a matrix of occupant characteristics. An occupant characteristics matrix presents alternative combinations of occupant characteristics that make up the occupant behavioural scenarios. Initially, all combinations of characteristics are to be considered, although some will be readily omitted from further consideration (e.g. all occupants in a restaurant can be assumed to be awake). An example is presented in Table 1.

Table 1 — Sample occupant characteristics matrix for a hotel

Characteristic	Hotel guests	Restaurant patrons	Hotel employees
Familiarity	transitory	transitory	permanent
Training	none	none	yes
Ages	adults and children	adults; children possible	adults
Disabilities	wide range possible	wide range possible	small range possible
Vulnerabilities	possible	possible	possible
Level of intoxication	intoxication possible	intoxication possible	conscious
Awake/Asleep	awake or asleep	awake	awake
Social groupings	individuals, couples, families	individuals, couples, families, groups	individuals, co-workers
Role	guest (expects assistance)	guest (expects assistance)	manager/subordinate
Source: SFPE Handbook of Fire Protection Engineering.[10]			

6.3.3 Considerations on selecting scenarios

When narrowing the set of behavioural scenarios, consider the breadth of possibilities that this reduced set covers, as well as the statistical likelihood of those scenarios occurring. The scenarios are then listed or ranked in order of relative risk, in a qualitative sense.

The likelihood of occurrence of each combination should be considered, using available data and/or engineering judgement as recommended in ISO 16732-1:2012, 6.3.

The consequence of each scenario should be considered, using available loss data and/or engineering judgement, as recommended in ISO 16732-1:2012, 6.4. For this purpose, the “consequence” for each path would be the reaction, response, and movement times relevant for that combination of occupant characteristics, given the fire and smoke development detailed in the associated design fire scenario.

Since the aim of this exercise is to estimate life loss or injuries due to fire, care should be taken to ensure that data employed in the process are relevant to the built environment under consideration. Guidance on how occupant behaviour can depend upon the nature of the built environment can be found in ISO/TR 16738.

6.3.4 Final selection and documentation

Select the highest ranked representative scenarios for quantitative analysis. These will become the “design occupant behavioural scenarios”. The selected scenarios should represent the major portion of the cumulative risk. Input from the stakeholders into this selection process is recommended. The justification for including or not including each representative scenario shall be documented.

In constructing the set of design occupant behavioural scenarios, certain common errors and biases are to be avoided.

— If multiple high-consequence, low-likelihood scenarios are eliminated from consideration, it is important to be careful that the eliminated scenarios do not have a moderate or high collective likelihood.

— Where possible, it is better to combine like 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 consequence, because the only design choices capable of producing an acceptable outcome for that scenario are very expensive. A decision to accept the consequence of a particular scenario because of the high cost of eliminating or reducing that consequence should be made at a later stage, after more detailed analysis and only with the full involvement of the stakeholders.

— It can be appropriate to eliminate a scenario, despite its substantial consequence, because no identifiable design choice can reduce or eliminate that risk. Elimination of such scenarios, however, shall be documented, stating why it is not possible to protect the person or eliminate the hazard by any means.

EXAMPLE Risks to persons who are intimate with the starting point of a fire or who are incapable of acts of self-preservation (because of consumption of alcohol or drugs in their own home) may be examples of the bases for scenarios that can legitimately be eliminated at this stage. It is not appropriate to eliminate a scenario if the conditions of the occupants should be expected (for example, intoxicated customers in a nightclub). In such a case, additional protection would be an appropriate design decision to deal with occupants with diminished capability for self-protection.

6.3.5 Sensitivity analysis of parameters affecting life safety objectives

The life safety consequences of the selection of the set of design occupant behavioural scenarios should not be excessively sensitive to small changes in a single variable. A sensitivity analysis, i.e. the process of changing different variables one at a time within reasonable limits,[11] is one way to test the robustness of the fire safety design given uncertainty in the input variables. A finding of acute sensitivity to small change in one or more variables warrants modifying the set of design occupant behavioural scenarios or refinements to the fire safety management plan for the building.

As the deterministic analysis involves a selection of a manageable subset of all the endless number of possible scenarios, i.e. the worst credible cases, it is important to investigate the effect of reasonable changes of different variables on the end result. If a small change of one variable, e.g. the proportion of people in wheelchairs, leads to the life safety objective not being achieved, the designer should question the level of safety.

A sensitivity analysis shall involve all relevant fire- and occupant-related variables. The fire-related variables are those presented in ISO 16733-1:2015, steps 2 to 5.

NOTE 1 The process for assessing the impact of varying safety system availability and reliability is addressed in ISO 16733-1:2015, step 8.

The selection of occupant-related variables for the sensitivity analysis can be based on the occupant and evacuation-related variables such as the following:

a) number of occupants and their location;

b) combination of occupant characteristics;

c) initial response of occupants;

d) initial route choice of occupants.

In relation to the combination of occupant characteristics, these can include the following:

- permanent/transitory;
- trained/untrained;
- potential age ranges;
- cognitive, sensory or mobility issues;
- potential vulnerabilities;
- awake/asleep/unconscious/intoxicated;
- social groupings or not;
- role.

NOTE 2 These characteristics are mainly concerned with the ability of building occupants to mitigate or cope with a fire event. All these variables can be varied with regards to their magnitude, e.g. the degree of familiarity with the building, and frequency, e.g. the number of guests who are very unfamiliar with the building. It might also be relevant to vary the initial behaviour and the initial route choice in the sensitivity analysis.

For example, in a hotel fire scenario, it might be assumed that the occupants are asleep, but not intoxicated. The sensitivity analysis would assume some percentage of occupants were intoxicated, with the resulting additional delays in waking and possibly more difficulty in decision making and way-finding. Similarly, the sensitivity analysis can test the effect of varying the ages of the occupants.

7 Design occupant behaviour

7.1 General

Design occupant behaviour is defined in terms of the design occupant behavioural scenario. It may, for example, be defined in terms of pre-travel activity delay times and initial travel speeds. However, design behaviour characteristics may be subsequently modified based upon the outcome of the analysis. For example, if conditions develop such that counterflows may occur, the design occupant behaviour shall be modified to reflect the effects of competing flows sharing one route or path. Similarly, events such as developing smoke conditions that block egress paths can impact the design occupant behaviour. It is necessary to ensure, however, that the design occupant behaviour is appropriate to the objectives of the fire safety engineering analysis and results in a design solution that is conservative.

A particular design occupant behavioural scenario is likely to have more than one design occupant behaviour associated with it. For example, occupants who originally occupy spaces by themselves (e.g. in hotel rooms) will have different travel speeds when they begin to crowd into common spaces, such as stairwells, and new occupant behaviour (in terms of travel speeds) may be required.

If using a computational model for analysis, the model may include assumptions about some of the points being discussed here, and the user should be aware that some assumptions may not be realistic or appropriate for the given application. Users should check the assumptions for appropriateness and consider the use of sensitivity analysis to address any assumptions that do not appear realistic.

Design occupant behavioural scenarios reflect an idealized representation of the abilities of the occupants to recognize fire cues, respond to those cues, and move to safety, in qualitative terms. Design occupant behaviour is defined in quantitative terms such as time to recognition and response, as well as travel speed, over the course of an evacuation. These elements, used in combination, can be used to predict a design-basis total evacuation time for that occupant scenario. Total evacuation time is the required safe egress time (RSET) for a design. The evaluation of a particular fire safety design will involve comparing RSET for an occupant behavioural scenario to the available safe egress time (ASET) estimated for its associated design fire scenario. It is understood, of course, that an actual evacuation is not separated into such discrete intervals, but this representation allows an engineering analysis of evacuation.

The user should remember that staying in place is an evacuation option for occupants. This behaviour differs from refuge in place, where the occupant is forced to deal with the threat of fire and its effects.

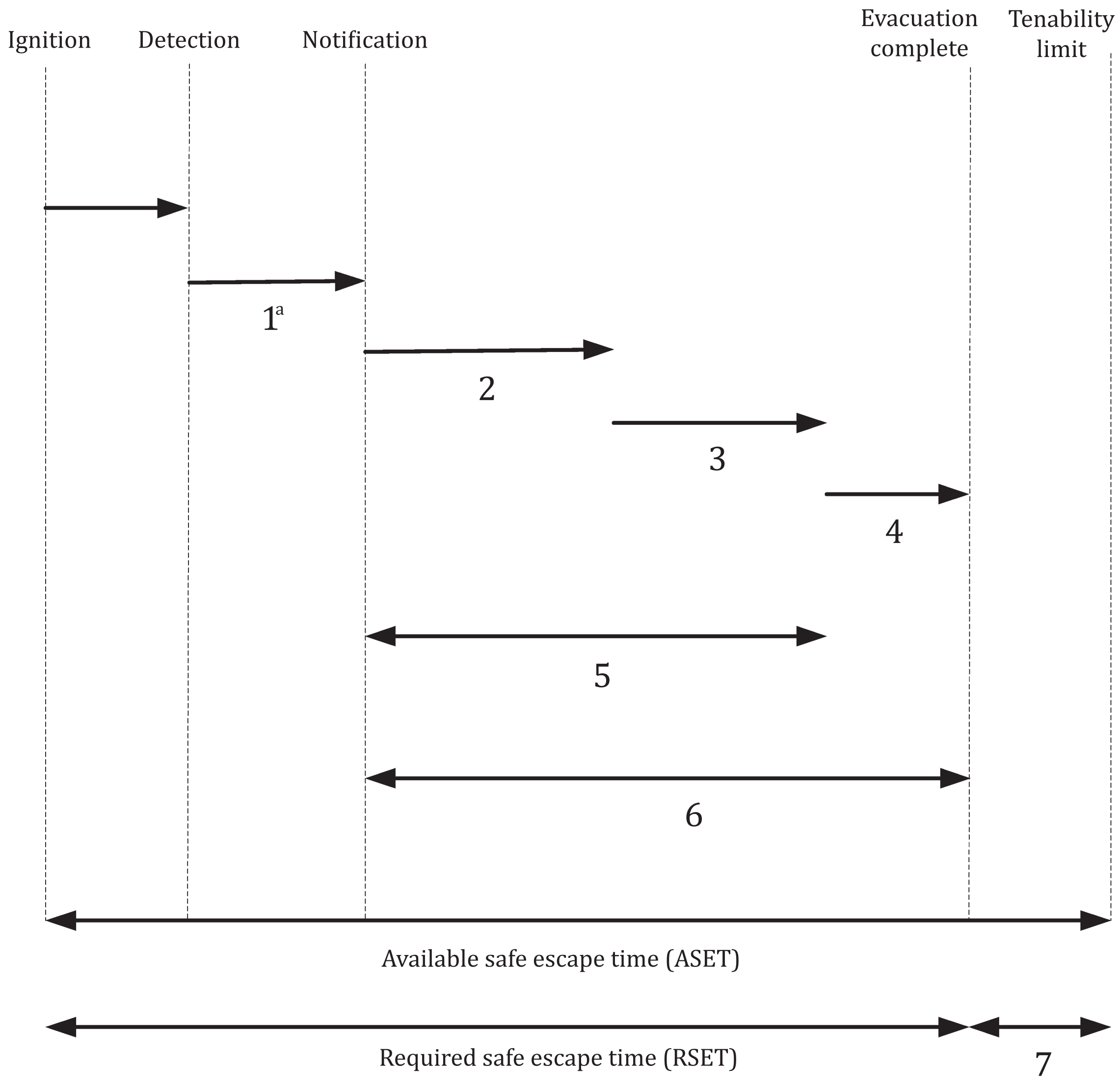
A full specification of a design occupant behaviour (see Figure 1) may include the following phases:

- pre-travel activity phase — recognition time — covering the time before occupants become aware of a fire cue;
- pre-travel activity phase — response time — covering the time after occupants become aware of the fire cue, but before they begin moving toward a safe location;
- travel phase — characterized by a travel speed;
- termination — when all occupants have reached a safe location or have become trapped (requiring rescue) or incapacitated.

The first three phases are affected by the nature of the fire effluent, e.g. is it something that engenders concern, does it lead to (less rational or altered) decisions, does it change efficacy along the intended path or alter it, etc.

Design occupant behaviour has to be understood as the description of the full duration of an evacuation. This description includes the following:

- parameters provided by the design fire scenario (size of the room, location of the fire, presence and performance of notification devices, performance of fire suppression or smoke management systems, geometry of the spaces, potency of the effluent, etc.);
- parameters provided by the design occupant behavioural scenario (number and location of occupants, sensory and mobility characteristics of the occupants, means of notification of occupants if not by other occupants, presence and performance of staff, etc.);
- parameters required to make the assessment of the evacuation (delay times before beginning to travel toward a safe location; travel speed);
- events which result in a change in any of the above parameters.



Key

1 alarm time
2 recognition time
3 response time
4 travel time
5 pre-movement time
6 evacuation time
7 margin of safety
[a] Alarm time refers to the time at which notification is transmitted to the occupants, which may be by an alarm or any other mechanical or human means.

Figure 1 — Example of elements of design occupant behaviour

7.2 Basic characteristics

7.2.1 General

Design occupant behaviour is usually characterised in terms of the following variables with respect to time (as needed by the life safety objective and consequently, by the analysis):

- time of recognition of fire cue(s) by target population(s);
- time for target population(s) to initiate active response to fire cue(s);
- route choice;
- travel speed for target population(s).

The factors influencing the time to recognition and response include the following:

a) presence of occupant disabilities (possibly disabling the receipt of cues);

b) presence of an alarm or other means of notification;

c) location of occupants, relative to the fire, its effluent, and/or alarm;

d) presence and activities of other occupants;

e) dependency (needs assistance) or affiliation (family, associates);

f) available information from the notification system, or other occupants (situation awareness);

g) alertness of the occupants (awake/asleep, incapacitated, intoxicated, medicated);

h) training of the occupants or members of staff.

The factors determining travel speed include the following:

- age of occupants;
- mobility of occupants;
- available egress paths;
- egress path characteristics (width, length, obstructions, openings, horizontal, stairs, etc.);
- crowdedness/density;
- movement of groups of people (taking into consideration the characteristics of individuals in the group and the affiliations within the group);
- presence and degree of intensity of smoke, water, lack of lighting, etc.

The initial travel speed is subsequently modified by events that occur during the design occupant behavioural scenario. These events can modify the travel speed either positively or negatively. Typical events and their effects are as follows:

— increased crowdedness, counterflows	slowing of movement;
— directions from staff or emergency responders	influence exit choice, accelerate movement;
— increasing density of smoke in escape routes	slowing of movement;
— degradation of the environment (water, smoke, etc.)	slowing of movement.

Determination of the initial travel speed shall consider these aspects. Evacuation models are available that can predict evacuation time under defined conditions. Some include behavioural aspects that affect pre-travel activity delays as well. Data from experiments and actual events are also available[12] to assist in the determination of delay times and travel speeds.

7.2.2 Pre-travel activity time

7.2.2.1 General

Occupants should never be assumed to begin to travel to exits or other safe locations immediately upon receiving a cue that a fire event is occurring. Some period of time occurs while occupants recognize the cue and then another period of time before they start to move to a safe location. The two phases can be calculated or selected separately, or pre-travel activity time can be calculated or selected as an aggregate time. The two phases of pre-travel activity time, recognition time and response time, are described below.

7.2.2.2 Recognition time

After a fire is detected, by either mechanical or human means, some sort of notification is transmitted to the occupants. From that moment until the occupants recognize that they are being warned of a fire condition is “recognition time”, the first component of pre-travel activity time. The beginning of this time interval, the transmission of a warning to occupants, is dependent on the design fire scenario, which will define the speed of growth of the fire, the spread of smoke, and the presence of detection and signalling devices. Others might alert occupants before a warning signal is activated or if the occupants did not perceive or recognize the warning themselves. The duration of the recognition phase will depend on the location of the occupants relative to the warning and their sensory and cognitive ability to perceive and interpret the signal.

7.2.2.3 Response time

Once the occupants recognize a signal or cue as a warning of fire, a period of time will elapse before they begin to move to a safe location. That time interval can be close to zero, for occupants who move immediately, or can extend a significant period of time. During that time, occupants may engage in several actions such as fighting the fire, warning others, gathering valuables, etc. The response time duration, the second component of pre-travel activity time, can be affected by factors set out in the design occupant behavioural scenario, such as wakefulness, commitment to a task, social interactions between occupants, staff intervention, etc.

7.2.3 Exit choice

Exit choice is a key factor in the calculation of evacuation times, as the choice of exit will determine the travel path, and the distance of that path and the occupant density along that path will influence the travel time. Since it has been observed that occupants will tend to attempt to evacuate by way of the path they used to enter a structure, it is important to ensure that any egress model used in an evaluation reflects that reality or includes the flexibility to allow the user to simulate appropriate exit choices based on supporting data. At some point during their evacuation attempt, occupants may decide to choose a different exit. There is currently little or no data available as to how and when that choice is made.

7.2.4 Travel time

Travel time includes both movement time, while occupants are progressing toward a safe location, and any delays, for example rest stops, changes in direction, queuing etc. Travel time is largely a function of travel distance and travel speed. Factors that impact travel speeds, such as mobility and other impairments, will be determined by the design occupant behavioural scenario. Design factors, such as stairs and ramps, and occupant density (crowdedness) will affect travel speed as well. Developing fire and smoke conditions, defined by the design fire scenario, can cause smoke effects that slow travel speeds, or can result in route blockages that can extend travel distances. Travel speed data for a range of occupants, on horizontal and inclined paths, are available in the literature.[12]

7.2.5 Intervention by fire services and other emergency responders

National regulations may prohibit reliance on the fire service to achieve a safe evacuation. It would be unusual for an engineered design to assume that intervention by responding fire services to rescue occupants is required, although it may be appropriate for relocating patients of a health-care facility or in a building with a secure refuge area where people with mobility and other impairments wait for firefighter assistance. Only in such cases should the intervention be considered to influence the design occupant behaviour, and the designer shall be able to ensure that a sufficient number of emergency responders will always be available and equipped for the assignment.

Emergency responders can have other impacts on the evacuation. Their presence in stairwells can impede travel flows and affect containment systems (doors, vents), unless the design provides separate access for firefighting operations.

7.2.6 Intervention by others

People other than emergency responders who are at the fire location, for example, members of staff, might intervene in a way that influences evacuation. They may be in place from the beginning of the event to take correct actions, and a design would more appropriately include these as part of the evacuation plan, rather than the fire department which would arrive several minutes later. The intervention of others can expedite the evacuation by providing information on the need to evacuate and influencing exit choices and so reduce milling time.

7.2.7 Completion of the evacuation

The evacuation is considered complete when all occupants of the built environment have reached a safe location (either outside or in a place of refuge), are trapped (and require rescue if they are to survive), or are deemed to be incapacitated based on fire conditions, occupant location, and the criteria of ISO 13571.

7.3 Parameters provided by the design occupant behavioural scenario

Any design fire scenario that assumes that occupants are present will have a set of design occupant behavioural scenarios associated with it. For each of these design occupant behavioural scenarios, several parameters will be set. These parameters include the following:

- the number of occupants;
- the spaces they occupy, in general terms, such as hotel guest rooms, lobbies, subway platforms, etc.;
- their level of awareness or sensory and cognitive capabilities, such as awake, asleep, intoxicated, focused on activities, etc.;
- the presence of any occupants with mobility and other impairments that would impact their travel speeds or need for assistance;
- level of training of occupants and/or staff, if any.

7.4 Parameters to be defined

7.4.1 Pre-travel activity time

There is data in the literature on total pre-travel activity time (also referred to in the literature as “pre-movement time”) reported in actual fires or observed in drills, where the period of time is not separated into the recognition and responses phases (for example, see Reference [12]). Methods have been described for quantifying behaviour to be used in escape time calculations (for example, see Reference [13]). An engineering model for the estimation of pre-travel activity time has been proposed (for example, see Reference [14]) and a quantitative method to calculate pre-travel activity time based on the geometry of the habitable spaces is also in use (for example, see Reference [15]). Any method used should be sound and based on science. Users should decide what data is appropriate for them to use, this is just an example. Care should be taken to use appropriate data, justified for the conditions and characteristics of the occupant population, in any scenario analysis.

7.4.1.1 Recognition time

Occupants can be alerted to an emergency situation by a large variety of cues: alarm systems, warnings from other occupants, interruption of building systems (e.g. power failures, etc.), smoke, flames, heat, glass breaking, etc. How long it takes occupants to recognize that a cue they have received is associated with a fire depends on their sensory abilities, their cognitive abilities, their knowledge of the environment, their past experience (e.g. familiarity, training, etc.). Recognition time can be found in the literature from actual fire evacuations or drills or it can be calculated as part of the overall pre-travel activity time. Care should be taken to use appropriate data, justified for the conditions, in any scenario analysis.

7.4.1.2 Response time

A model for occupant response was developed based on observations of actual fire incidents.[16] Once occupants have recognized that an emergency situation exists, they enter a preparation stage and then an action stage, with activities that include instruct (e.g. alert, direct, etc.), explore (e.g. seek information, investigate, etc.) and withdraw (e.g. wait for information, instructions, rescue, etc.), which may lead to firefighting, warning, waiting, or evacuating. The response time interval includes all activities other than evacuating.

During this time period, once occupants have decided to move to the outside or another safe location, they may undertake some preparation, such as dressing, securing valuables or equipment, shutting down processes, rescuing or assisting others, etc. Studies have found that training, as a part of good building management, can reduce the duration of this part of the evacuation process.[17]

Response time can be found in the literature from actual fire evacuations or drills, or it can be calculated as part of the overall pre-travel activity time. Care should be taken to use appropriate data, justified for the conditions, in any scenario analysis.

7.4.2 Exit choice

Choice of exit path is an important determinant of travel distance and therefore travel time. Some egress models use the shortest route algorithm, which will optimize evacuation time since it takes the occupants along the shortest path from their initial location. Research has shown, however, that building occupants, particularly those in places that are not familiar to them, will try to leave a building by the same path they came in. When occupants have received training on actions to take in an emergency, or if trained staff are available to assist them, they will be more likely to use emergency exits with which they might not otherwise have been familiar, thus reducing their travel paths and travel time.

Exit choice should be selected in a manner appropriate for the expected users of an occupancy. If they are not familiar with the structure, they should not be expected to follow an optimal path.

7.4.3 Travel speed

Movement time includes both the time spent in travelling to the outside or a safe location, plus any rest periods or other delays during that process. Travel time is a function of travel distance and travel speed. Walking speed has been found to be a function of crowd density, physical ability, group size (e.g., family groups travel at the speed of their slowest member), incline, lighting, etc. Crowd density is a function of the number of people in a space, and the size of those people. Some of these variables will be set by the design fire scenario and others by the design occupant behavioural scenario.

Travel speeds can be found in the literature from actual fire evacuations or drills. Some of the data sets are decades old and derived from pedestrian commuter traffic.[18] Details on walking speeds based on expected occupant densities can be found in the literature as well.[19] No specific values are presented here because, as shown in Reference [12], reported travel speeds range widely, depending on factors such as mobility, travel surface (stairs vs. horizontal surfaces, for example), crowdedness, lighting, type of occupancy, etc.

7.4.4 Parameters that need to be defined when simplistic calculation models are employed

Whereas most advanced computational models require detailed information about the occupants and their distribution and other characteristics as input to a calculation of the total evacuation time, there is a class of models that is simpler in nature and requires less sophisticated input data. For example, the hydraulic flow calculations discussed in 7.5.2.2 are based on simpler information such as the geometry of the space and the width of the exit path.

7.5 Estimates of evacuation time and occupant condition

7.5.1 General

For a given design occupant behavioural scenario, the parameters determined in 7.3 and 7.4 should be employed to predict the total evacuation time and potential impact of toxic products on the occupants using simple calculation methods, advanced calculation methods, or ad hoc test results. It is important to recognize that some calculation methods deal only with occupant movement or travel while others more broadly include delays and other activities that might occur during evacuation.

NOTE A review of models can be found in Reference [20] and a link to a directory of available evacuation models in Reference [21].

The methodology presented in ISO 13571, combined with input data for the yields of the effluent components (see ISO 16312-1 and ISO/TR 16312-2) and with a physical fire model that transports the effluent throughout the structure, can be used for the estimation of the time at which individuals can be expected to experience compromised tenability. Methods for the calculation of toxic effects can be found in the literature (for example, see Reference [22]). Currently, no method exists for including sub-incapacitating effects of fire effluent that might affect the quality of a person's egress actions.

7.5.2 Simple calculation methods for evacuation time

7.5.2.1 Single-parameter estimation models

Equations for the prediction of total evacuation time based on observed evacuations can be found in Reference [23]. These equations are based simply on the number of occupants per metre of effective stair width. These equations are based on older data that may no longer be valid and may not adequately account for pre-travel activity time. Also available in Reference [23] is a method of estimating evacuation time based on calculated flows. This method does not factor in pre-travel activity time. Methods exist for estimating pre-travel activity time.[15]

7.5.2.2 Movement models

Simple movement models are computer models that calculate total evacuation time for large numbers of occupants. These models, also referred to as hydraulic models or network flow models, tend to calculate optimal evacuation times, since occupants begin to move at the same time, travel at the same speed, and usually follow the shortest paths from their initial locations. They are useful in providing a benchmark evacuation time: if the available safe egress time for a design fire scenario is longer than the evacuation time predicted by such a model, then the actual evacuation time in a real fire will certainly be too long.

7.5.3 Advanced calculation methods for evacuation time

More complex computational models that incorporate some characteristics of human behaviour are also available. In these models, the occupants can be assigned individual characteristics. The models simulate their movement and their locations are tracked throughout the evacuation. Their individual characteristics can include their travel speed and delay times or can be attributes that are used to calculate their travel speeds and delay times. Because occupants are tracked individually, their exposure to toxic products as they move through spaces and the effect on their condition can be estimated. These models often produce sophisticated graphical output to show the evacuation as it progresses. Although this type of model can produce results that appear realistic, users should consider that there is currently limited behavioural data available, particularly related to decision making, and limited data on walking speeds for subpopulations (including occupants with disabilities) on which to base these models. There are limited data available on cultural differences related to these variables as well. Care should be taken to use appropriate data, justified for the conditions, in any scenario analysis. The main advantage of such models is that they provide a dynamic description of the system (e.g. showing the time to clear building spaces and exits) and can be a very powerful tool to identify problems in the building design and evacuation plan.

7.5.4 Tests

In many cases, calculation methods are not available for certain estimations, and it may not be clear whether the available literature is relevant. It is possible in some cases to conduct tests to demonstrate the effectiveness of innovative strategies, such as photoluminescent material in stairs, or staff response to emergencies, in lieu of more conventional systems for lighting or alarm systems.

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