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SPECIAL MOBILITY STRAND

FIRE SAFETY ENGINEERING: Principles and application

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Introduction

Fire safety engineering (FSE)

- Relatively young engineering discipline
- Requires high level of interdisciplinary knowledge
- Advanced system of designing and assessing of fire safety
- Application of calculation methods, professional knowledge and engineering judgement

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What is Fire Safety Engineering

ISO 23932 Fire Safety Engineering

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.

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FSE and fire risk

Fire safety engineering= Fire risk analysis

2 forms

↙ ↘

Implicit

risk is „hidden“

↓

deterministic

„worst reasonable case“ approach

Explicit

risk is expressed

↓

probabilistic

„risk assessment“ approach

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Goals and objectives of FSE

To provide an adequate level of fire safety in cases, where the use of prescriptive approaches is not appropriate due to the specifics or complexity.

FSE involves not only methods and tools selection but also the selection of *fire safety objectives*.

Hence there is a risk of inappropriate objective definition = implementation of inadequate or insufficient fire protection measures.

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FSE application around the world

FSE is on the rise – modern architecture and design require innovative approach to fire safety.

An increasing number of countries adopt and use fire safety engineering:

- Internationally ISO 23932
- United Kingdom BS 7974
- USA – e.g. NFPA 101

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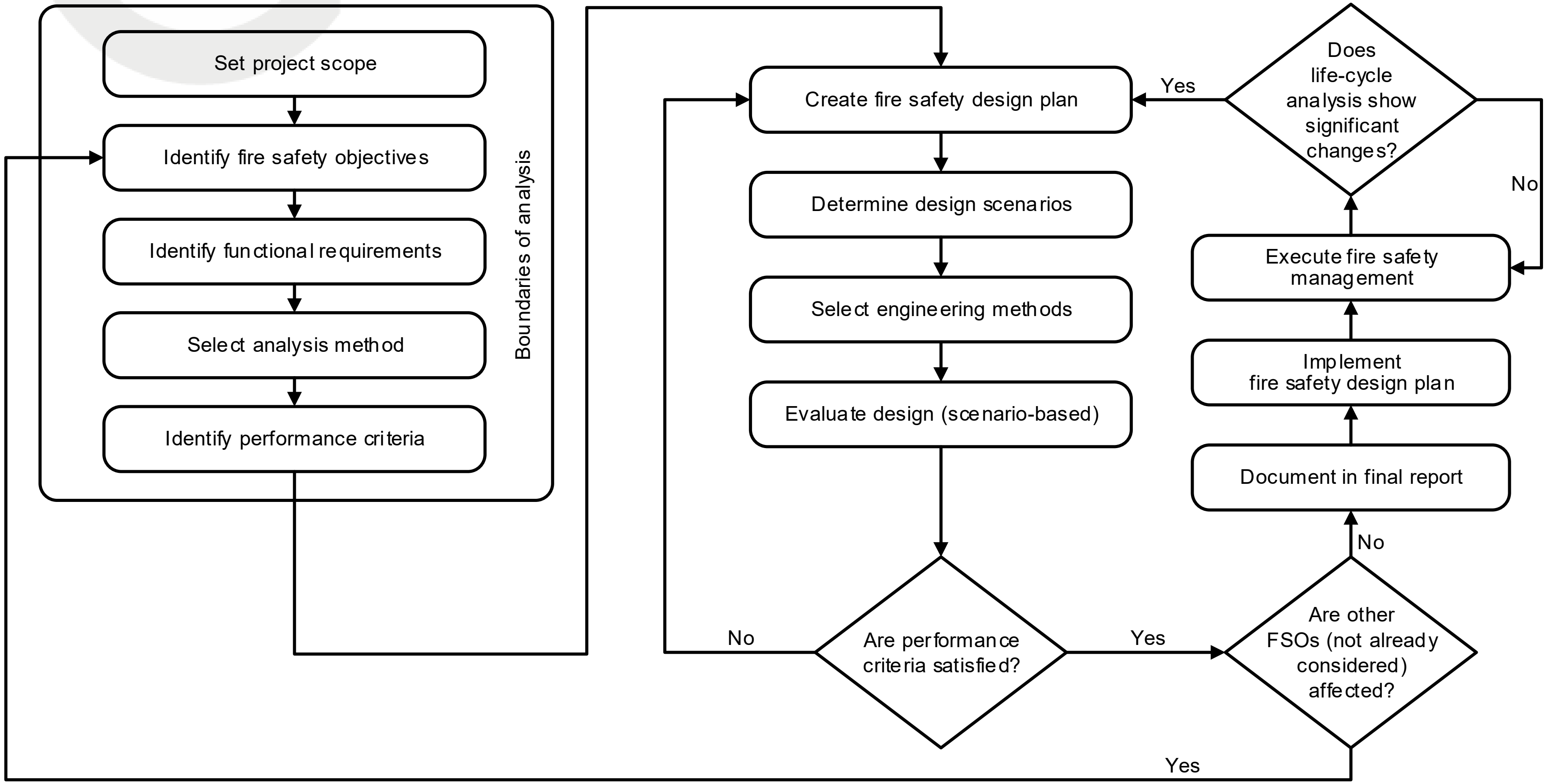
ISO 23932 FSE application



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Extent of analysis: Goal of project

At first, it is necessary to answer a number of questions:

1. What is the objective of the (construction) project?
(new building, alteration, extension, change of technology...)

2. Is / why is engineering approach required?
(prescriptive approach not sufficient, applicable, etc...)

3. What is the scope and extent of engineering approach?
(deviation justification, level of safety proof, entire / part of building,...)

4. Who are interested / involved parties?
(investor, user, public, AHJ, insurer,...)

5. Is there enough information available for engineering approach?
(building characteristic, use, occupants, internal and external factors...)

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85-15

Adequate ratio of standard (prescriptive) and engineering approaches in fire safety design.

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Specific cases requiring engineering approach

Engineering (performance-based) approach is possible / required in cases such as:

- Buildings with atrium
- Historical buildings
- Complex and combined-use buildings

<u>The goal is **not** to "recalculate" the design to satisfy all wishes of architects or investors!</u>

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Hierarchy of goal definition

1. Fire safety objectives
2. Functional requirements
3. Performance (acceptance) criteria

Areas of FSE goals:

- Life safety
- Property protection
- Business and operations continuity
- Environment protection
- Heritage protection

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Life safety example

Fire safety objective

The fire safety design shall be such that fire related injuries to occupants (away from the immediate areas of fire origin) are minimized.

Functional requirement

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.

Performance criteria

Analysis method is the deterministic analysis. PC corresponding to conservative estimates are chosen, i.e. levels of exposure to elevated temperatures (< 353 K), radiation (< 2,5 kW/m^2), toxic species (CO < 2 000 ppm, CO2 < 5 %, O2 > 15 %), irritant species FEC < 0,3 and reduced visibility (< 10 m).

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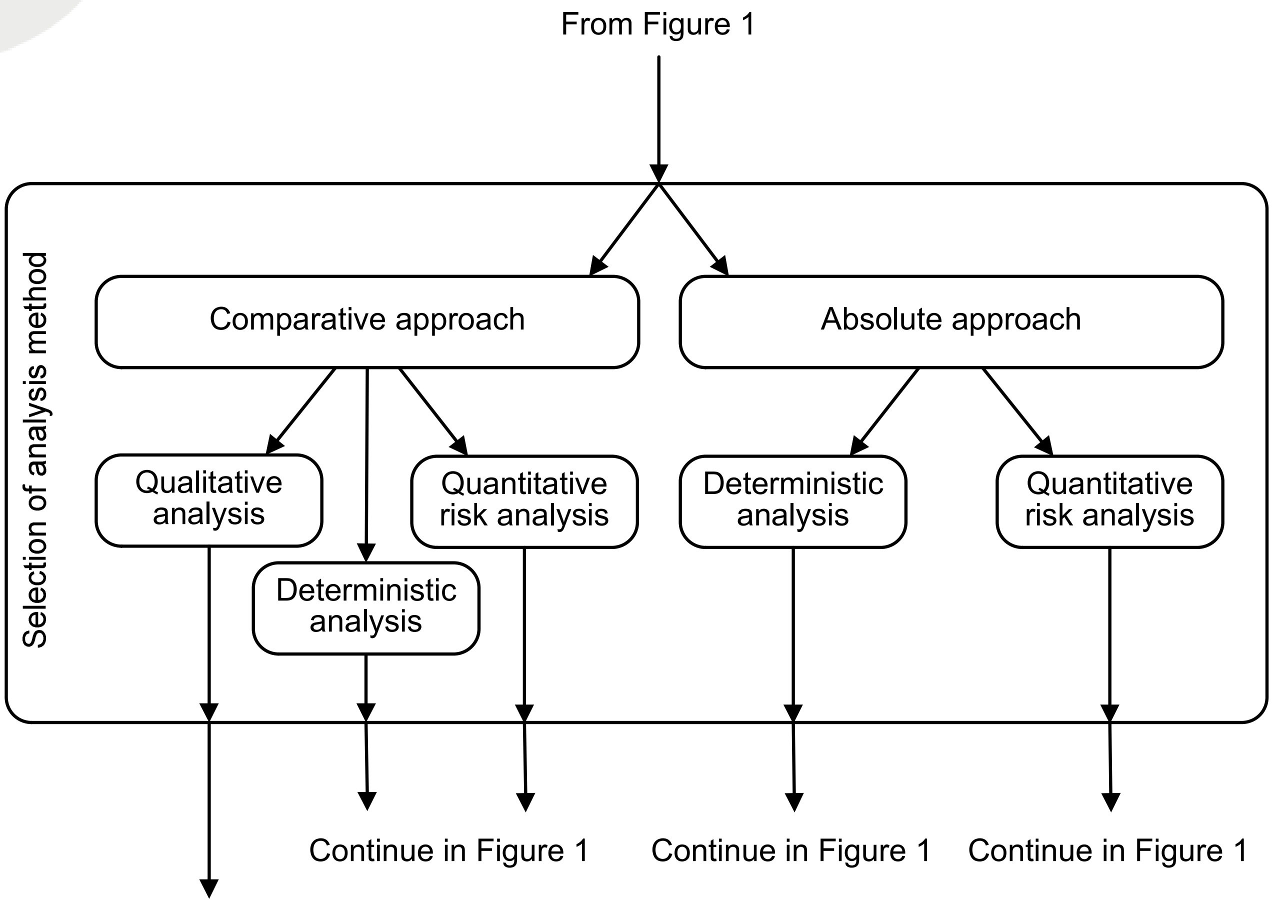
Analysis approach selection



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Comparative vs. absolute approach

Comparative approach

Design is acceptable if it is at least as good as the a prescriptive solution

↓

Assumption:

Fire risk is tolerable when the prescriptive requirements are fulfilled.

Necessary to have two designs – reference design (prescriptive) and assessed (engineered)

Absolute approach

Design is acceptable if all approved performance criteria are met.

↓

Assumption:

Fire risk is tolerable when the defined performance criteria are met.

Necessary to have a clearly identified tolerable risk level and expressed through performance criteria.

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Qualitative analysis

- comparative analysis
- applicable for small deviations from prescriptive reqs
- always necessary to compare against compliant prescriptive design
- risk is implicit
- deviations (noncompliances) are compensated for by additional fire protection measures
- necessary to assess the impact of all deviations on all FSOs

Qualitative analysis

Deviation from / Check against →	Stability and load-bearing structures	Fire spread between buildings	Fire compartments (cells)	Fire compartments (sections)	Linings/ finishes	Technical installations	Means of egress	Facilitating fire service operations	Comments
Stability and load-bearing structures	Primary	Tertiary		Tertiary			Secundary	Secundary	
Fire spread between buildings	Tertiary	Primary		Tertiary			Tertiary	Tertiary	
Fire compartments (cells)			Primary	Tertiary			Secundary	Secundary	
Fire compartments (sections)			Tertiary	Primary				Tertiary	Societal risks
Linings/ finishes			Tertiary		Primary		Secundary	Tertiary	
Technical installations			Tertiary	Tertiary		Primary	Tertiary	Tertiary	
Means of egress							Primary	Tertiary	
Facilitating fire service operations	Tertiary	Tertiary	Tertiary	Tertiary			Tertiary	Primary	

Primary focus of verification
Secundary focus of verification
Tertiary focus of verification

prINSTA/TS 951:2018

Deterministic analysis

- comparative or absolute analysis
- risk is expressed implicitly
- use of worst credible case scenarios
- need to identify all relevant scenarios from the perspective of defined fire safety objectives
- there is no universal worst credible case scenario
- wide spectrum of analytical tools – from calculations of detector activation times to CFD models

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Probabilistic analysis

- comparative or absolute analysis
- risk is expressed explicitly

Semiquantitative

- broader definition of design scenarios
- part of risk can be expressed quantitatively part qualitatively

Quantitative

- use of a wide spectrum of design scenarios
- probabilistic input distributions, reliability and availability

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Semiquantitative probabilistic analysis

1 component of risk quantified

		Frequency			
		beyond extremely unlikely	extremely unlikely	unlikely	anticipated
Consequence	high				
	moderate				
	low				
	negligible				

ISO 16733-1:2015

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Fire safety design plan

Starting point for definition and assessment of fire scenarios.

Due to occupancy and use specifics the plan should contain information and design elements in the following categories:

- fire initiation and effluents production
- fire and effluents spread
- constructions and compartmentation
- detection, activation and suppression
- occupants characteristics and evacuation
- fire-fighting action (if relevant)

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Design scenario definition

There are two categories of design scenarios:

- design fire scenarios
- design behavioural scenarios

For design scenario specification, the 1st step is fire hazard identification where the following specifics are considered:

Internal - building occupancy type, processes and activities, construction and materials, equipment and furnishings, systems and technologies (fire protection and other)

External – neighbouring buildings, environmental hazards…

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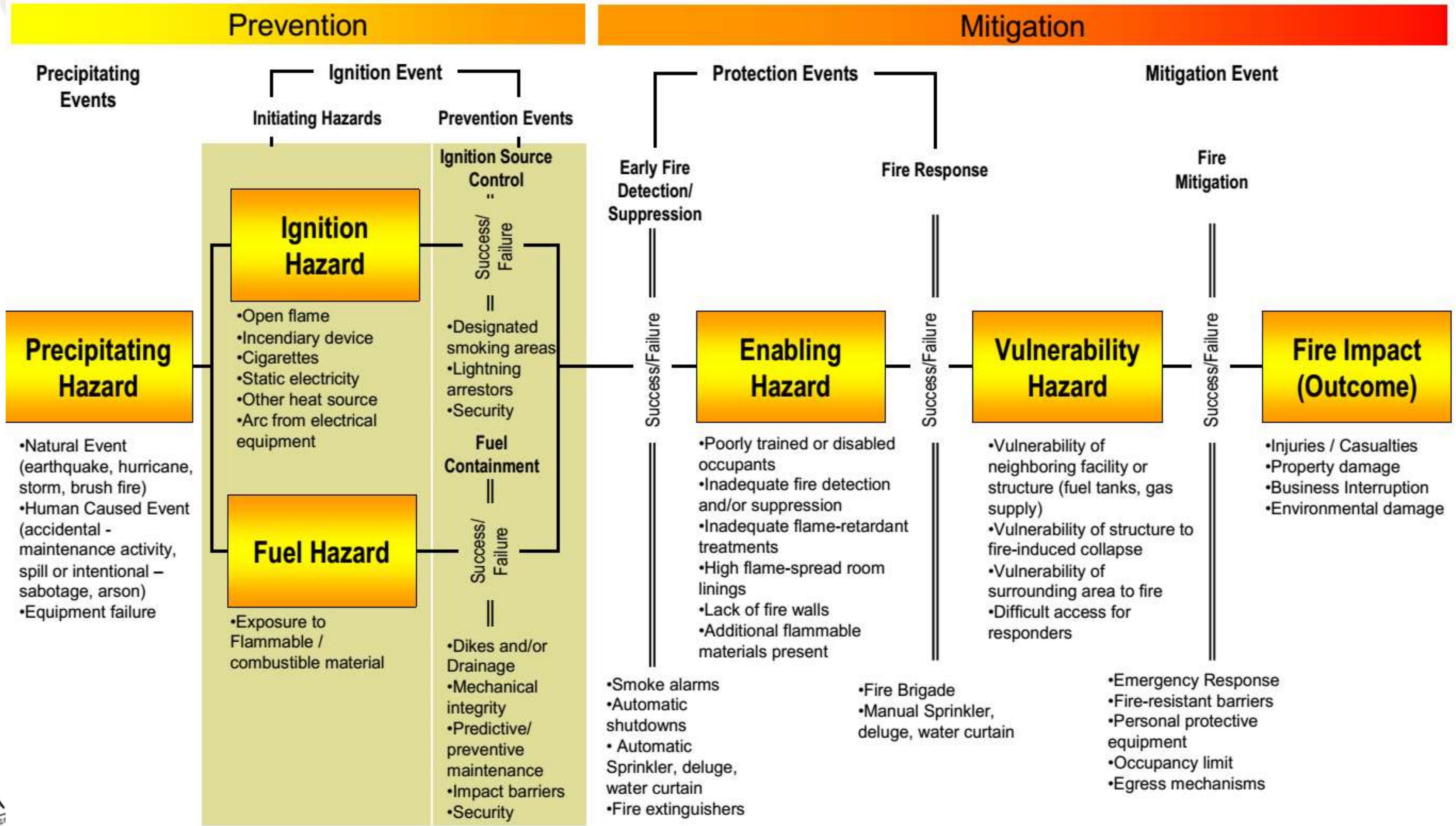
Fire hazard identification



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Fire scenario definition

Fire scenario specification is a 2-step process:

1. **Fire scenario selection** - ISO 16733-1:2015

Qualitative process. Identification and characterisation of aspects affecting fire development.

2. Specification of design fires - ISO 16733-2 (WiP)

Quantitative process. Fire development quantification – time vs. HRR

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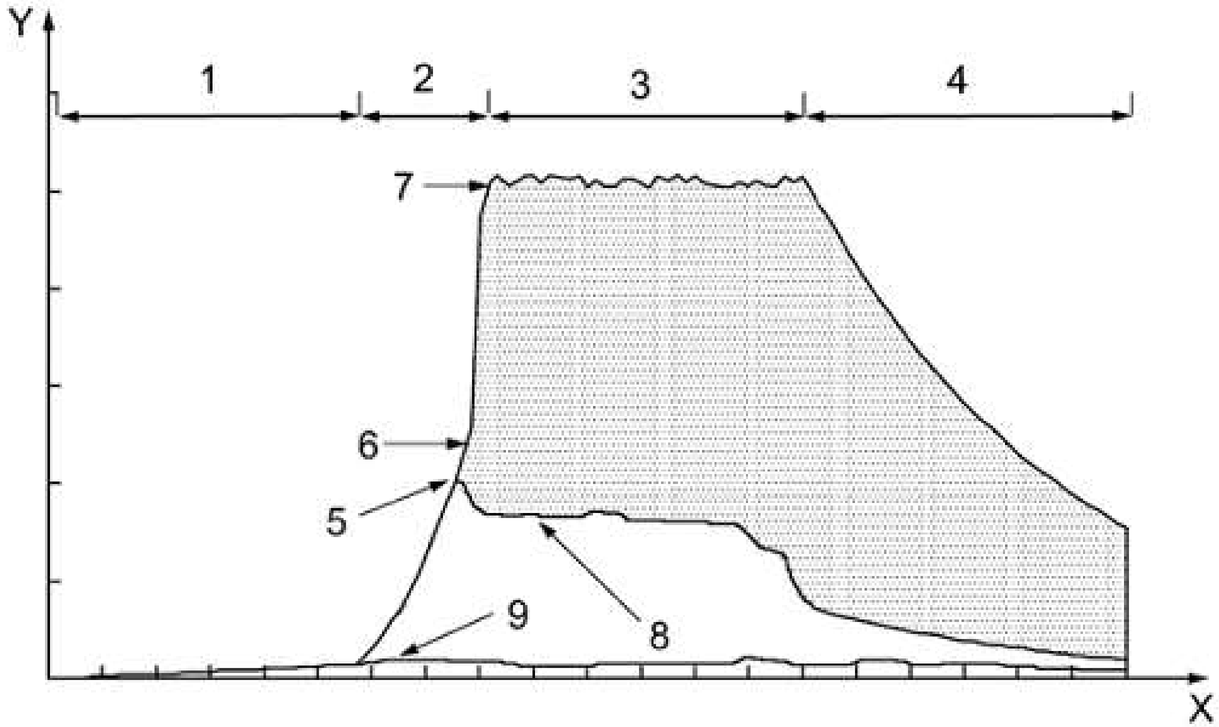
Fire scenario definition



Key

1 incipient
2 growth
3 fully developed
4 decay
5 sprinkler activation
6 flashover
7 ventilation-controlled
8 sprinkler-controlled
9 smouldering
X time
Y heat output

ISO 16733-1:2015

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Behavioural scenarios

ISO TR 16738:2009 recommends to consider the following:

persons: number and distribution, awakes, familiarity, mobility

building and systems: detection and alarm system, fire safety management and training, spatial configuration

fire scenarios: fire and effluent characteristics

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Occupants characteristics example

Category	Occupant alertness	Occupant familiarity	Occupant density	Enclosures/ complexity	Examples of occupancy types
A	Awake	Familiar	Low	One or many	Office or workshop areas
B1	Awake	Unfamiliar	High	One or few	Shop, restaurant, circulation space, bar
B2	Awake	Unfamiliar	High	One with focal point	Cinema or theatre auditorium
C	Asleep				Dwelling bedroom
Ci	Individual occupancy	Familiar	Low	Few	Without 24 h on-site management
Cii	Managed occupancy	—	—	—	Bedroom in serviced flats, halls of residence, residence, etc.
Ciii	Asleep	Unfamiliar	Low	Many	Hotel, hostel bedroom
D	Medical care	Unfamiliar	Low	Many	Residential (institutional)
E	Transportation	Unfamiliar	High	Many	Railway station/airport halls

ISO TR 16738:2009

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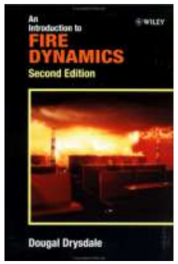
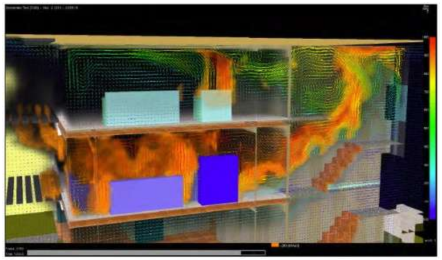
Analytical tools for FSE

- simple “hand” calculation
- computer models
- probabilistic studies and calculations
- experimental methods

The appropriateness, ease of use, necessary simplifications and approximations, compatibility with defined FSOs





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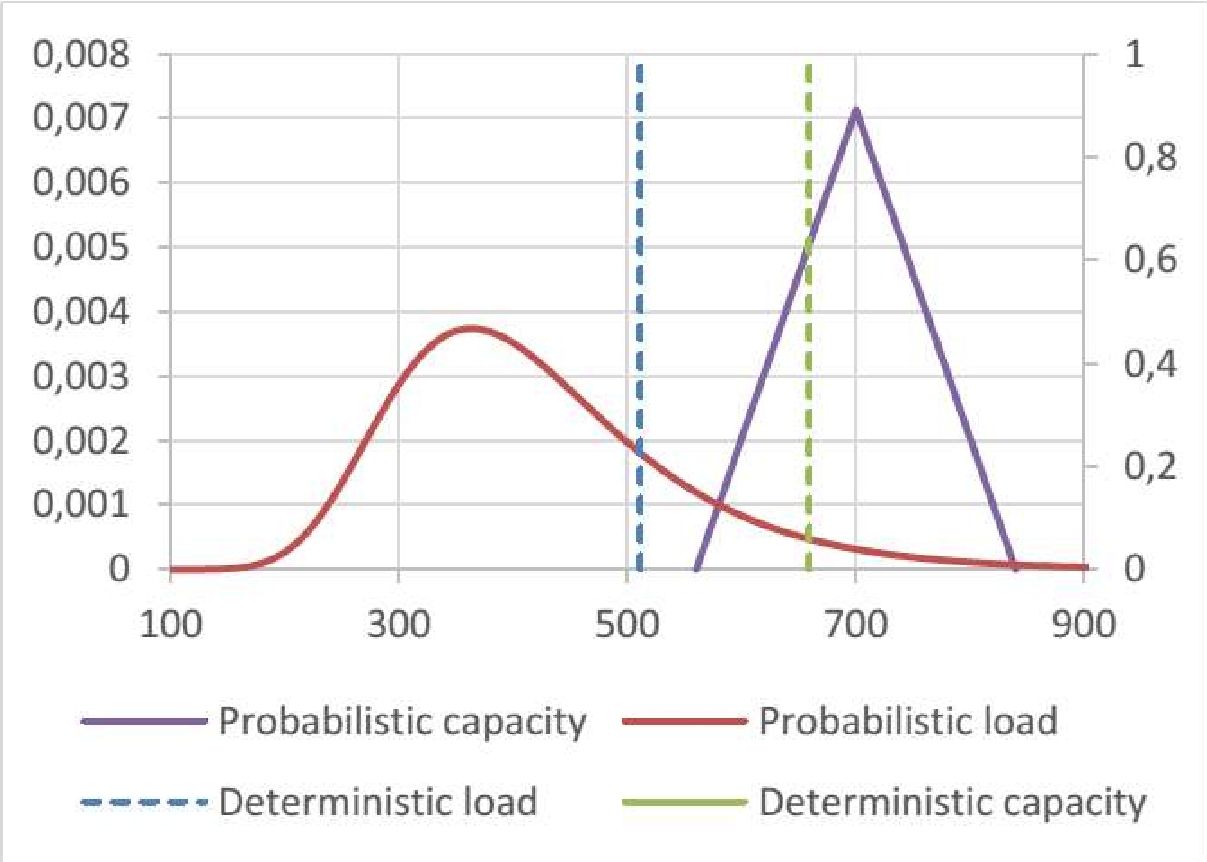
Design and scenario evaluation



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Documentation for FSE

- detailed approach required
- necessary to provide information in right extent and format
- in addition to design description and justification it is necessary to state conditions of use and modifications
- following design approval a fire safety manual and operations and maintenance manual should be prepared

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Implementation and fire safety management

- after construction and installation it is necessary to check functionality of systems individually and in combination
- proper and thorough testing before handover
- sound inspection and maintenance programme
- keep fire safety documentation “live” and up to date
- all modifications must be properly consulted and assessed
- periodically check on sum effect of “negligible” changes

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Thank you
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