



The need for sprinkler protection in a stay-in-place concept

Anticipating aging building population

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Performance based approach

Building characteristics:

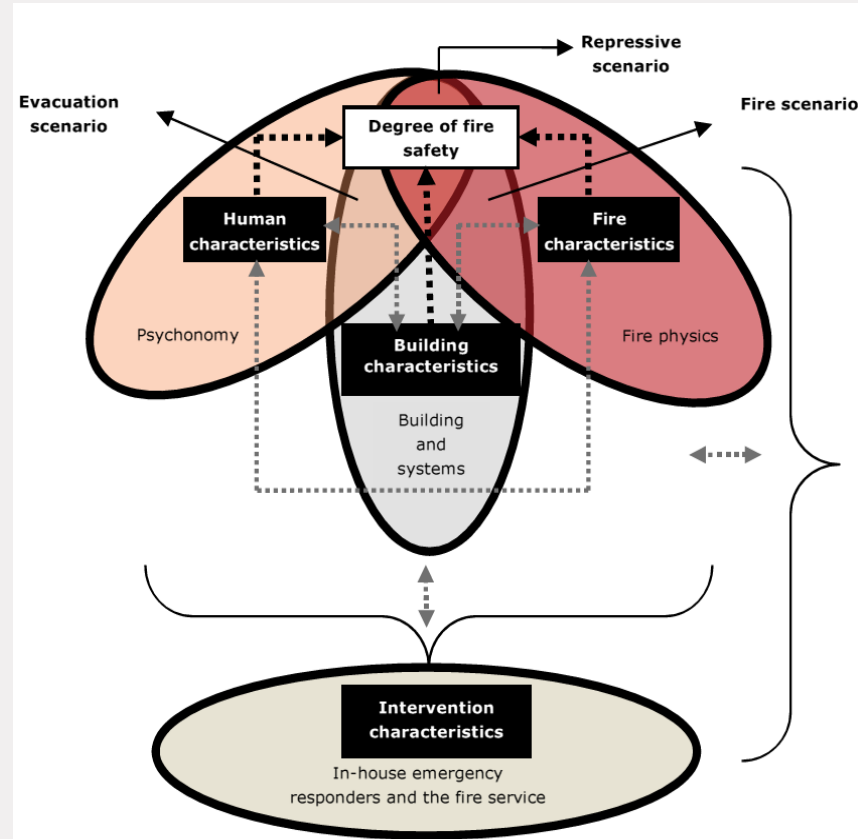
- Envelope: insulation, accumulation, air tightness, material properties
- Compartmentation for fire and smoke
- Load bearing structure
- Building Services

Fire characteristics:

- Type of fuel: related to building and user
- Ignition sources: related to building and user
- Source location: compartment, escape route, outside

Human characteristics:

- Self reliant or less self reliant



Performance based approach

Engineering in risk subsystems (in accordance with the building code):

- Safe escape route
- Safe attack route
- Safe compartments (limitation spread of fire) → *LOD*
- Safe subcompartments (limitation of smoke propagation) → *LOD*
- Safe building (structural safety) → *LOD*
- Safe environment (neighbouring plots)

Acceptable risk: **$AST > RST \times \gamma$**

Performance based approach

The concept of the Building Code:
Evacuation in case of fire!



Aging building population

Self reliant
building occupants

≠

Self evacuating
building occupants

Stay-in-place concept
instead of
Evacuation concept



Stay-in-place concept

Is a fire safe building possible
without escape routes?

Only when the LOD's are extremely reliable:

- Building (load bearing structure)
- Compartmentation (fire)
- Subcompartmentation (smoke)



Reliability LOD's

$$AST > RST \times \gamma$$

Safety factor depends on uncertainties in boundary conditions

Probabilistic:

$$p(AST < RST) < p_{\text{acceptable}}$$

Sensitivity analysis necessary

- Load bearing structure
- Fire compartmentation
- Smoke compartmentation

Sensitivity analysis

Each stochastic boundary condition (x_i):

Average value: \bar{x}_i

Variation: dx_i

Standard Deviation: s_i

Impact on AST-RST (t):

Variation: dt

Specific Variation: dt/dxi

Specific Variancy: $(s_i dt/dxi)^2$

Probability AST-RST for all boundary conditions:

Total Variancy: $var = \sum_i (s_i dt/dxi)^2$

Standard Deviation: $s = \sqrt{var}$

Compartmentation (residential buildings)

Thermal load on separation constructions:

- Fire characteristics (natural fire)
 - Fire load density (AVG: 780 MJ/m², residential)
 - RHR density (AVG: 250 kW/m², residential)
 - Time constant fire development (AVG: 300 s, residential)
- Building characteristics (worst case)
 - Adiabatic separation constructions
 - Opening factor in external separation constructions = 1 (no external flame)

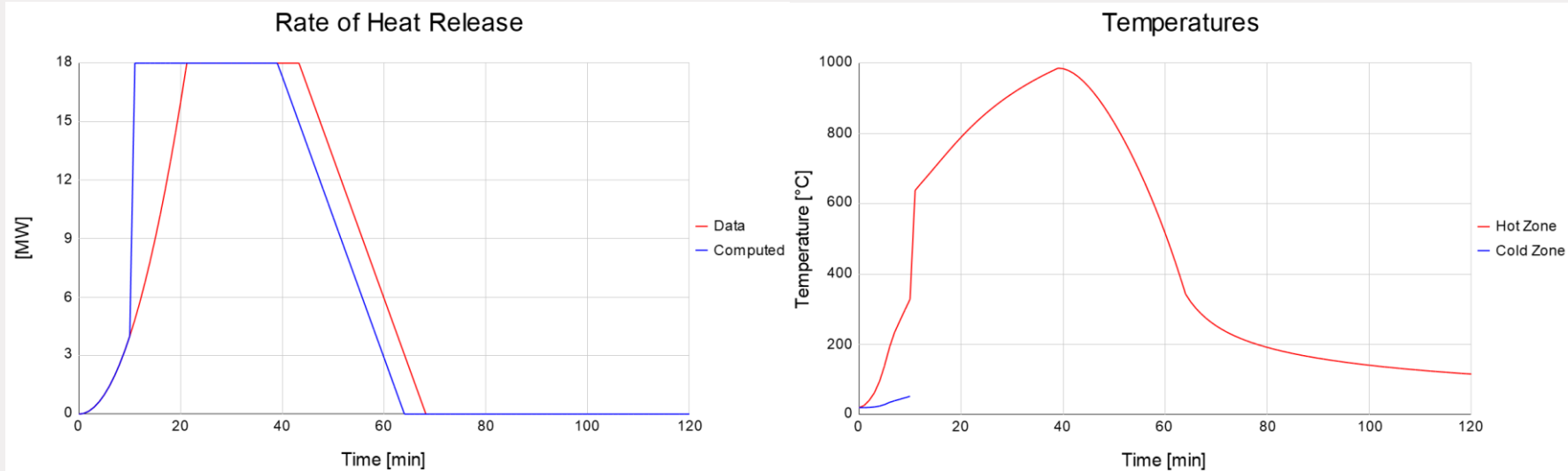
Evacuation concept: Escape routes safe during 30 minutes natural fire

Stay-in-place concept: Adjacent compartments safe during total natural fire

Compartmentation

Natural fire scenario:

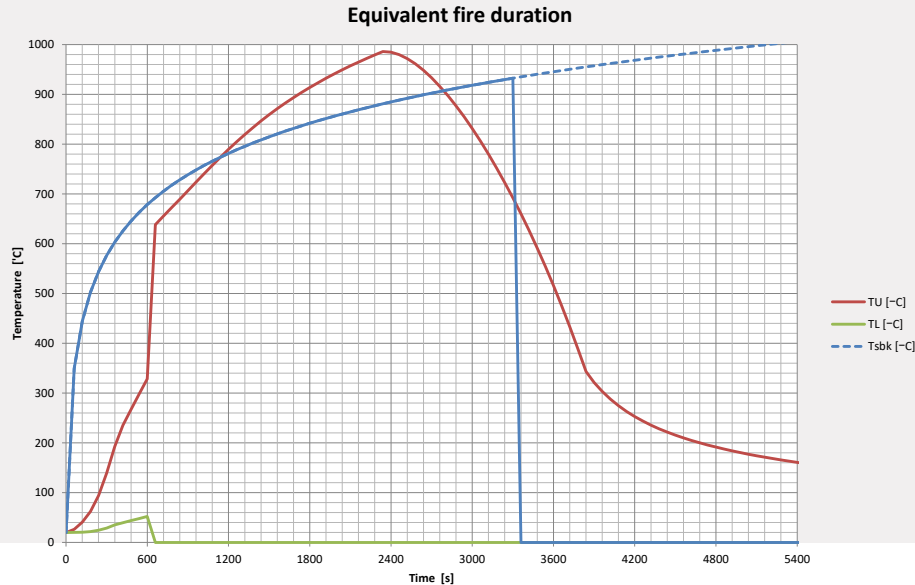
Apartment: floor = 72 m² H = 2.6 m (Ozone V.3.0.4)



Compartmentation

Natural fire → Standard fire

RST compartment = 54 min SFC (AVG)



RST escape route = 25 min SFC (AVG)



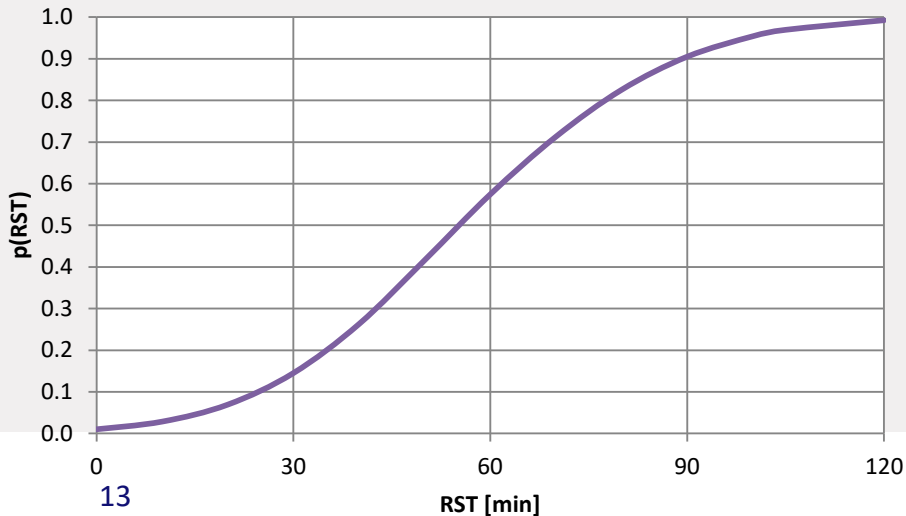
Compartmentation

Sensitivity analysis

RST compartment = 54 min SFC (AVG)

EI 90 → $p(\text{RST})=0.90$

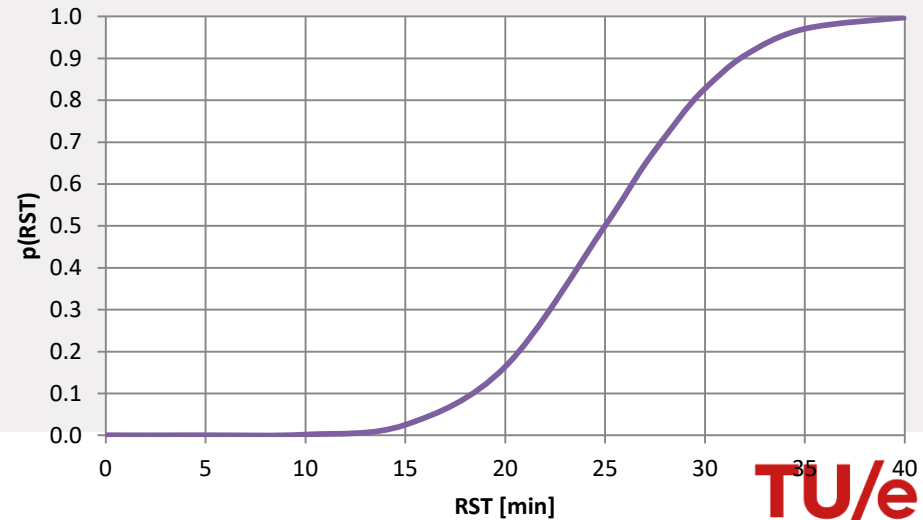
cumulative probability



RST escape route = 25 min SFC (AVG)

EI 30 → $p(\text{RST})=0.83$

cumulative probability

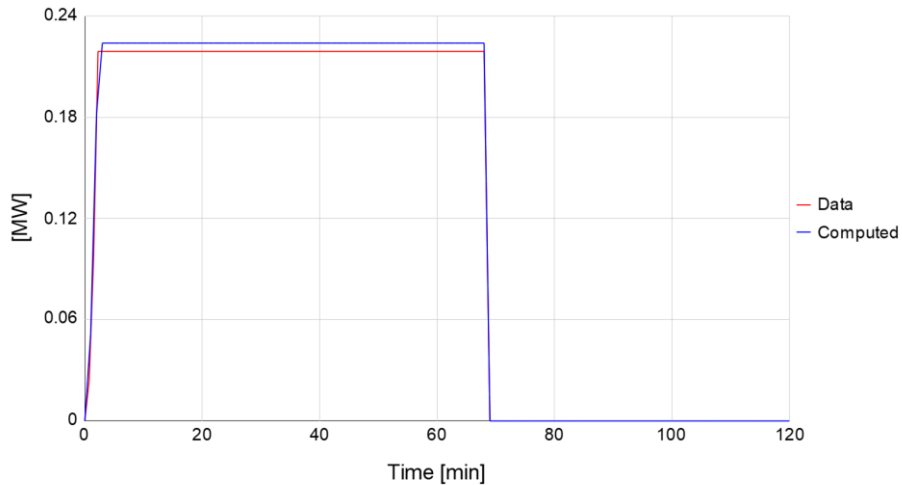


Compartmentation + sprinkler

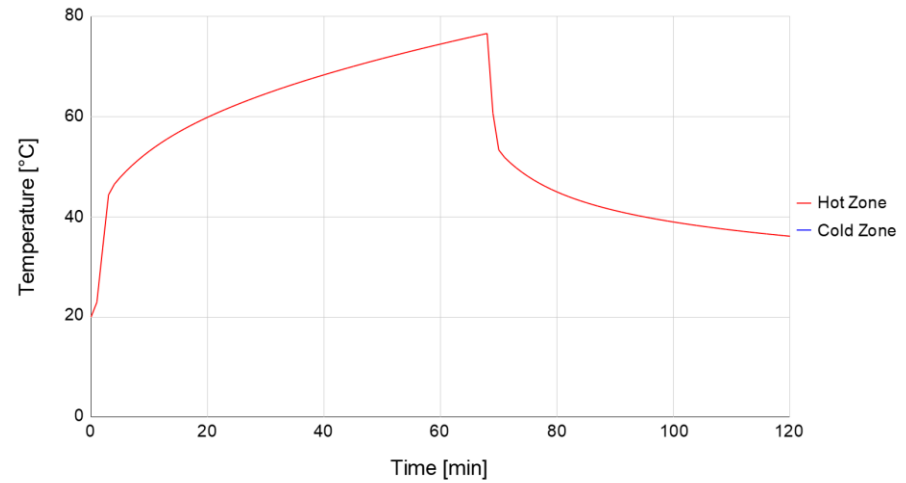
Natural fire scenario:

Apartment: floor = 72 m² H = 2.6 m + Sprinkler protection: 57 °C RTI = 35 → activation: 2 min.

Rate of Heat Release



Temperatures



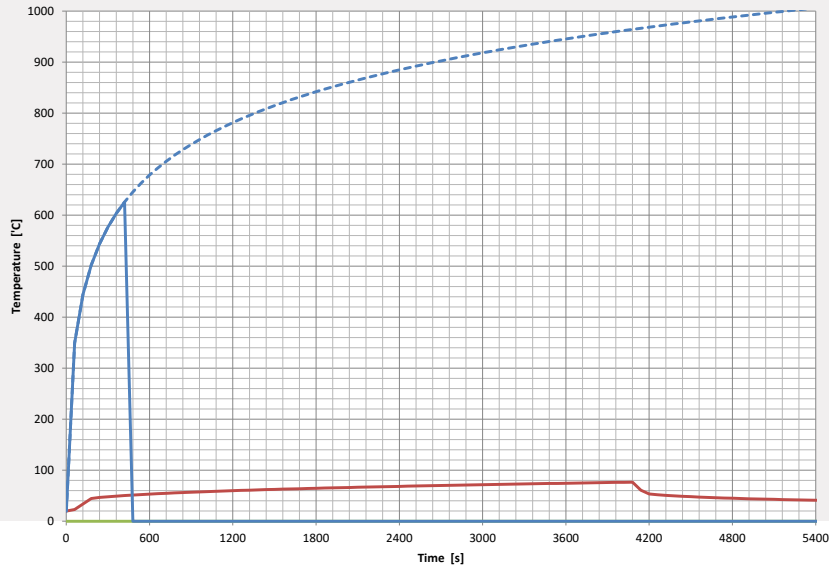
Compartmentation + sprinkler

Natural fire → Standard fire

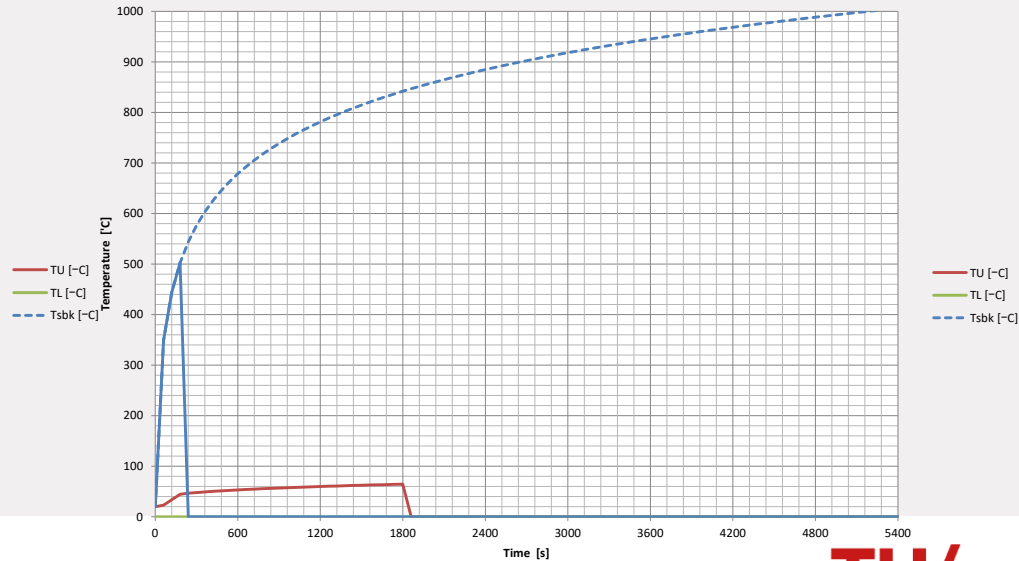
RST compartment = 7 min SFC (AVG)

RST escape route = 3 min SFC (AVG)

Equivalent fire duration



Equivalent fire duration



Compartmentation + sprinkler

Sensitivity analysis

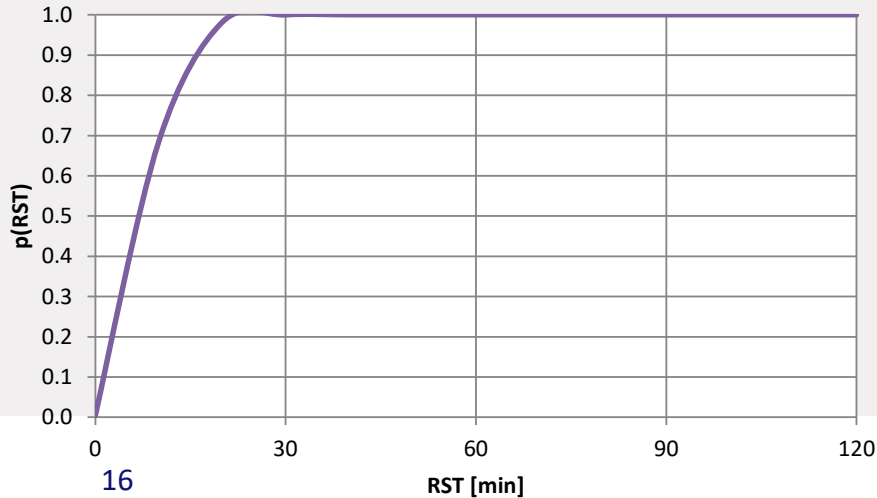
RST compartment = 7 min SFC (AVG)

EI 17 → $p(\text{RST})=0.90$

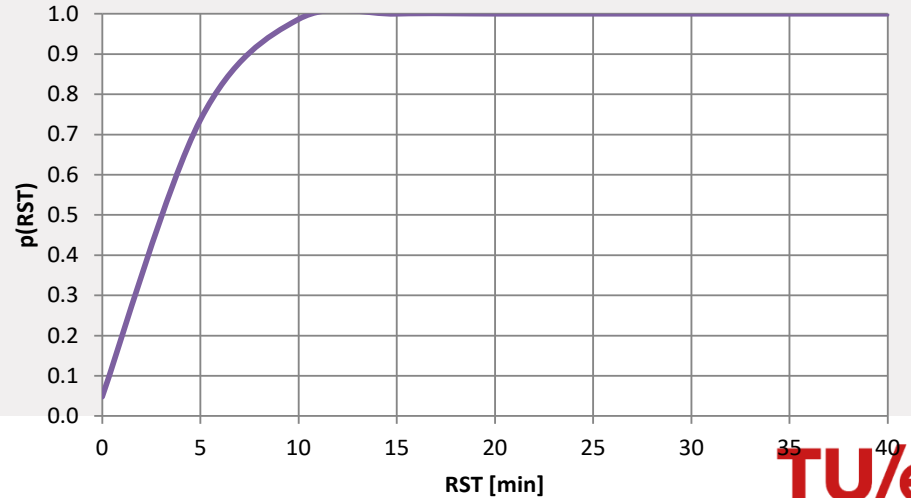
RST escape route = 3 min SFC (AVG)

EI 7 → $p(\text{RST})=0.83$

cumulative probability



cumulative probability



Subcompartmentation (residential buildings)

Smoke spread through separation constructions:

- Fire characteristics (natural fire, pre flashover situation only)
 - RHR scenario localized fire
 - Soot yield (Dm), HCN yield, CO yield
- Building characteristics
 - Air tightness external separation constructions
 - Air tightness internal separation constructions and shafts

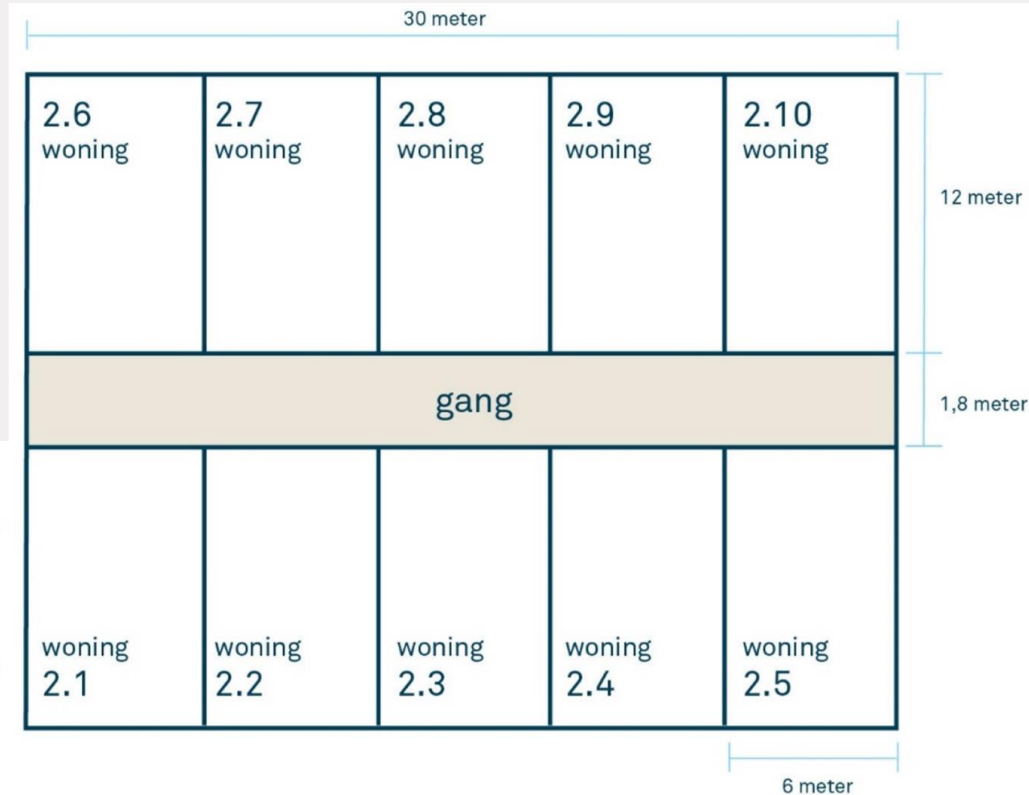
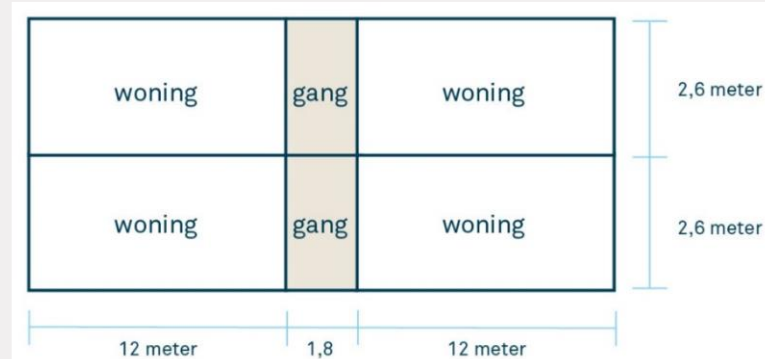
Evacuation concept: Escape routes safe during 30 minutes natural fire

Stay-in-place concept: Adjacent compartments safe during total natural fire

Subcompartmentation

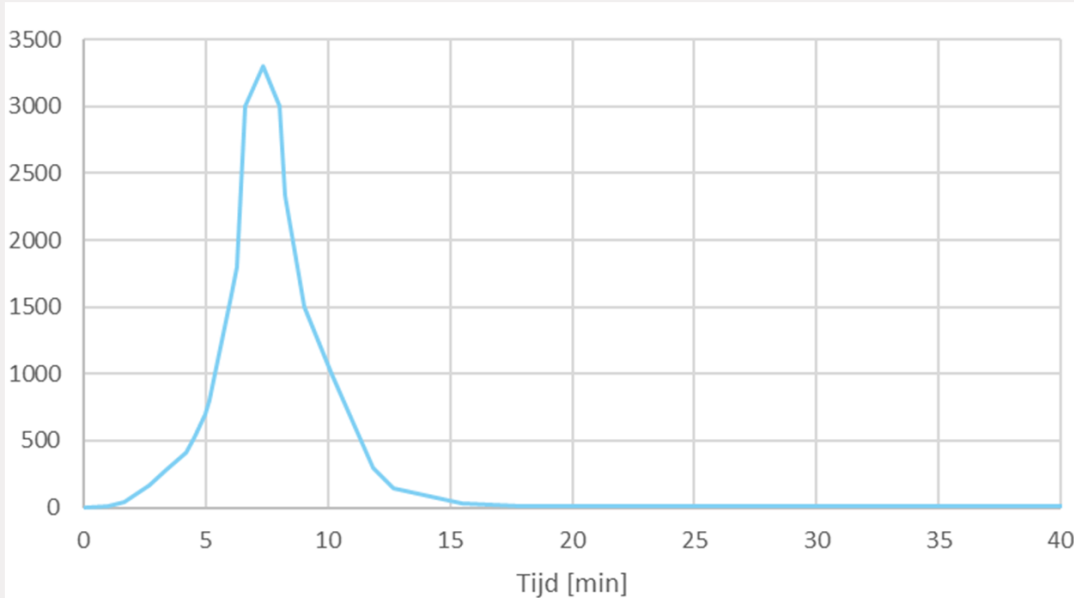
Multizone model

- Complex model with a lot of uncertainties
- Generic model almost impossible



Subcompartmentation

Localized fire scenario (RHR in kW)



Soot and CO yield
related to RHR scenario

Assessment criteria:
FED < 0.3 (ISO 13571)

- Visibility significant for escape route
- Toxicity significant for adjacent compartments

Subcompartmentation

Required safe time

Evacuation concept

RST Escape route:

- 1st apartment evacuates after 3 min. Other apartments start evacuating after 5 min.
- Total availability escape route: 30 min.

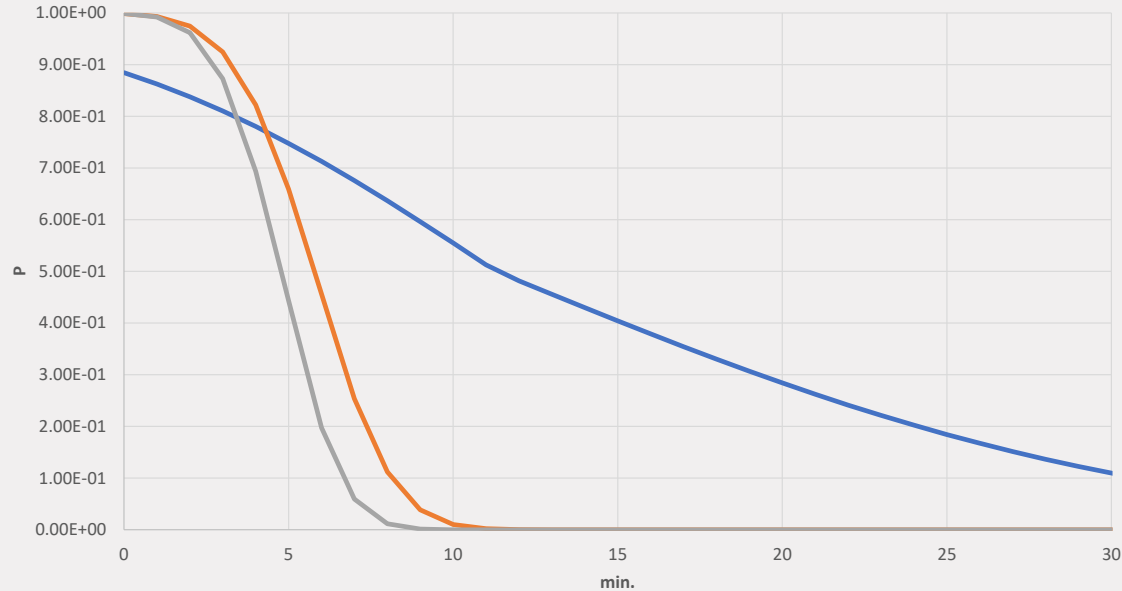
Stay-in-place concept

RST Apartments:

- Total natural fire duration

Subcompartmentation – Evacuation concept

Cumulative distribution AST (escape route)



— P(algemeen) — P(kwetsbaar) — P(zeer kwetsbaar)

FED=0.3

FED=0.1

FED=0.03

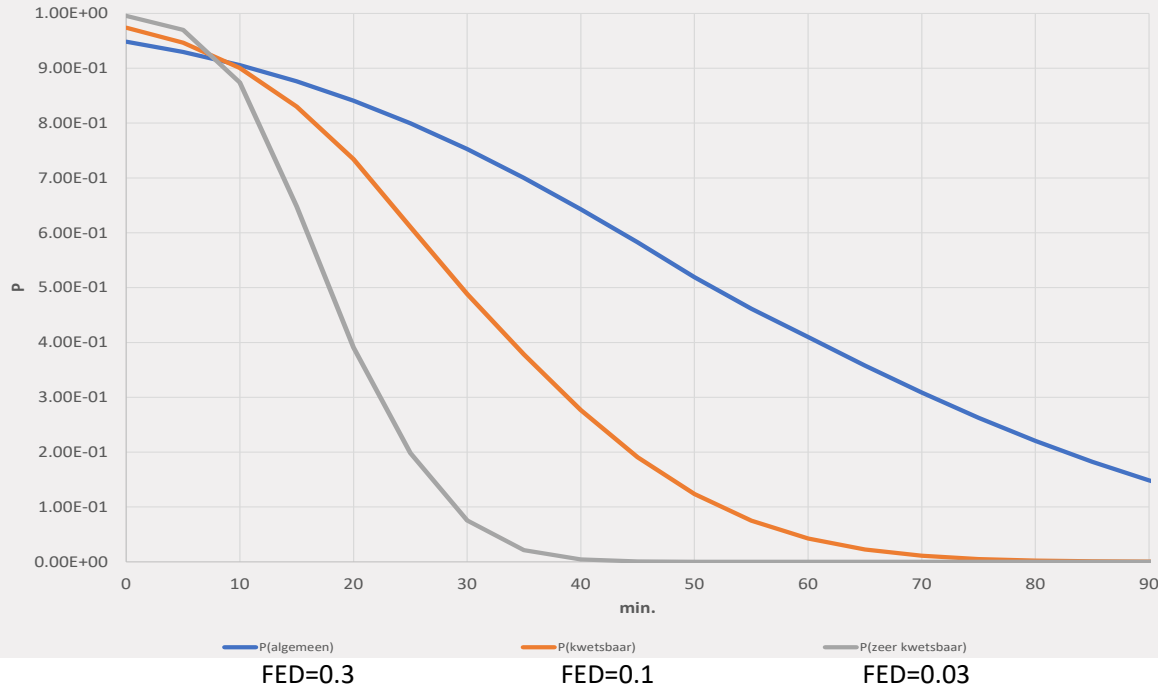
FEC_(smoke)=1.0

FEC_(smoke)=0.3

FEC_(smoke)=0.1

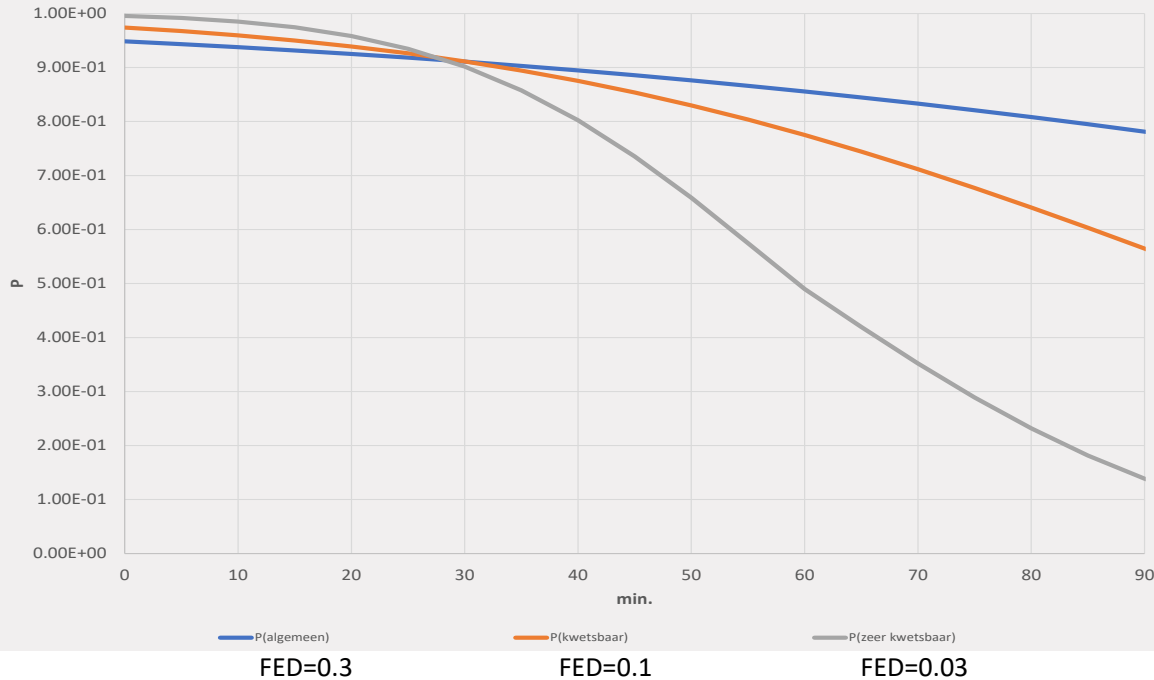
Subcompartmentation – Stay-in-place concept

Cumulative distribution AST (compartments)



Subcompartmentation – Stay-in-place + sprinkler

Cumulative distribution AST (compartments)



Conclusion (residential buildings)

Compartmentation and load bearing structure

- Higher reliability > higher fire resistance or sprinkler protection necessary (with reduction of fire resistance to approx. EI 20)

Personal safety

- Code compliant evacuation concept falls short in personal safety of the building occupants
- Alternative stay-in-place concept falls short in personal safety
- Sprinkler protection improves personal safety, especially in a stay-in-place concept

Thanks for your attention



Research team

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