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

## Anticipating aging building population

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# Performance based approach

## Building characteristics:

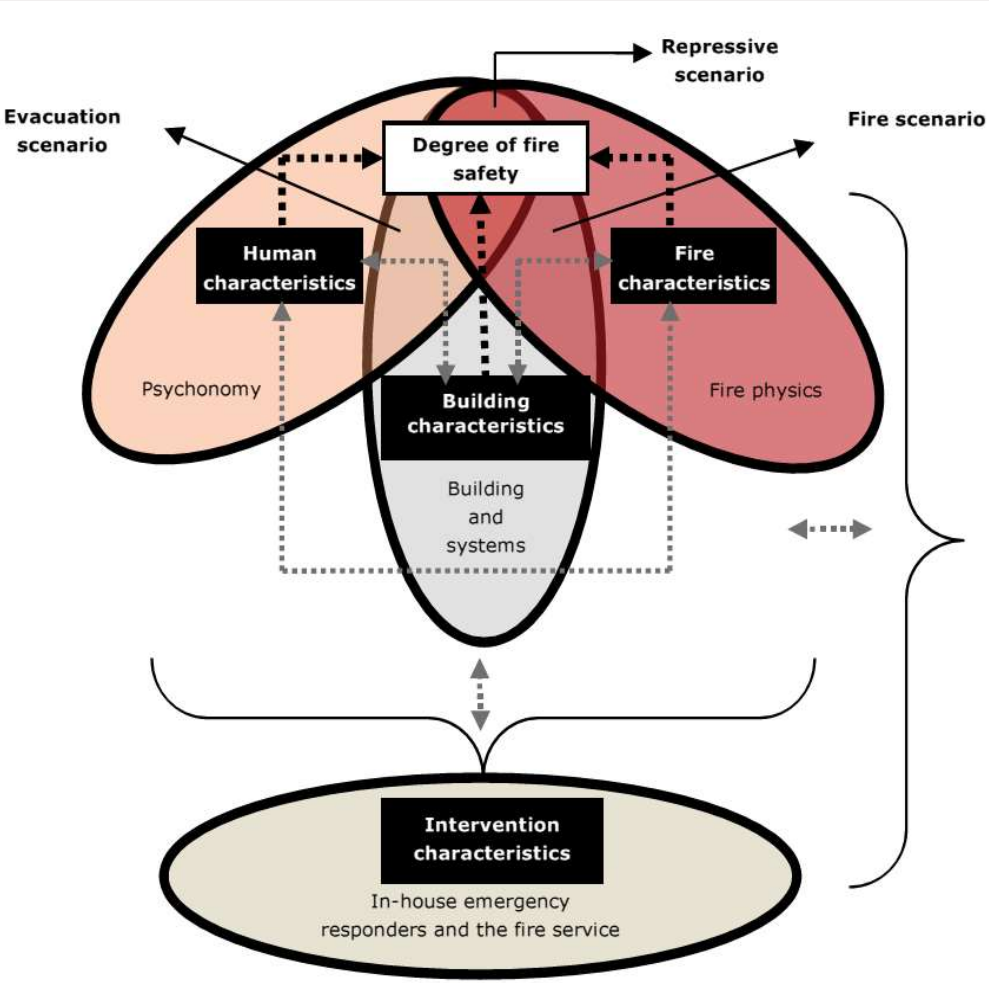
- Envelope: insulation, accumulation, air tightness, material properties
- Compartmentation for fire and smoke
- Load bearing structure
- Building Services

## Fire characteristics:

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

## Human chacacteristics:

- 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 subcompartmens (limitation of smoke propagation) → *LOD*
- Safe building (structural safety) → *LOD*
- Safe environment (neighbouring plots)

**Acceptable risk:** **AST > RST x γ**

# 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)
- Subcompartmentaton (smoke)

# Reliability LOD's

**AST > RST x γ**

Safety factor depends on uncertainties in boundary conditions

**Probabilistic:**

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

Sensitivity analysis necessary

- Load bearing structure
- Fire compartmentation
- Smoke compartmentation

# Sensitivity analysis

## Each stochastic boundary condition ($x_i$):

Average value: $\overline{x_i}$

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/m$^2$, residential)
  - RHR density (AVG: 250 kW/m$^2$, 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)

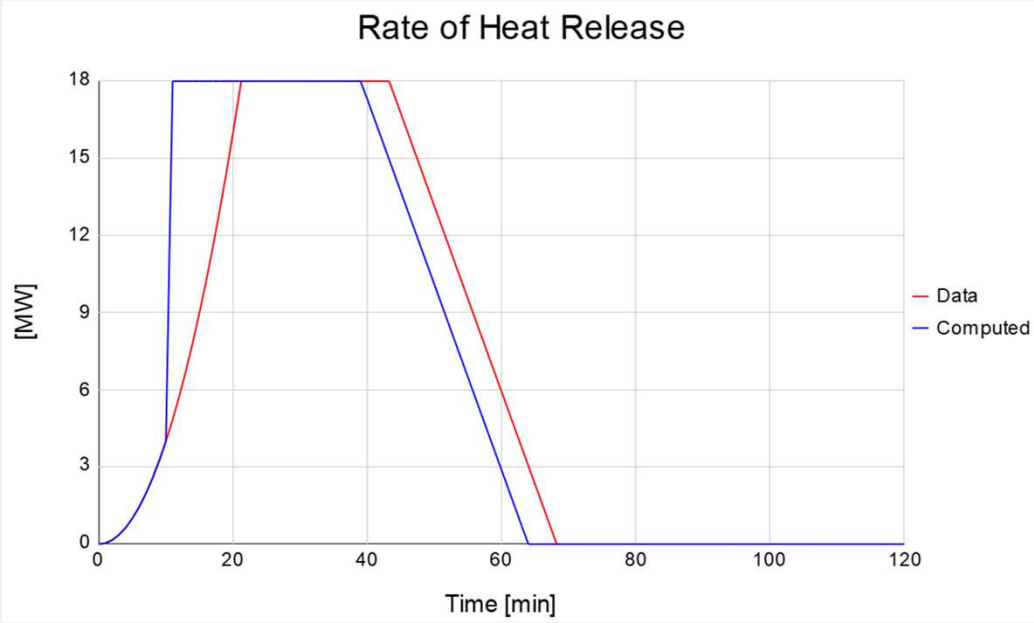
Evacuation concept: Escape routes safe during 30 minutes natural fire

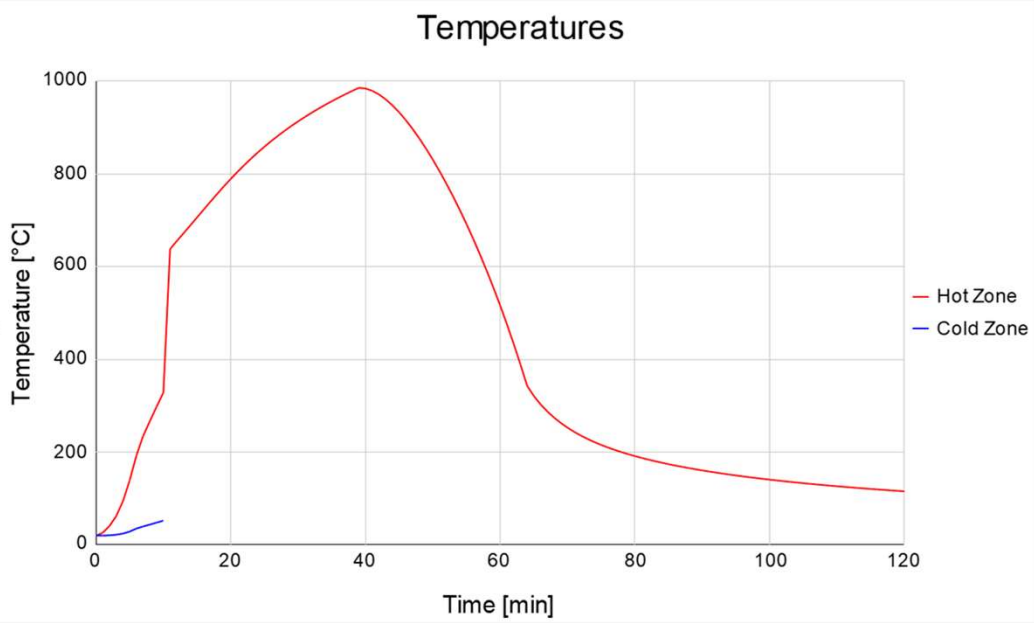
Stay-in-place concept: Adjacent compartmens safe during total natural fire

# Compartmentation

## Natural fire scenario:

Apartment: floor = 72 $m^2$ H = 2.6 m (Ozone V.3.0.4)



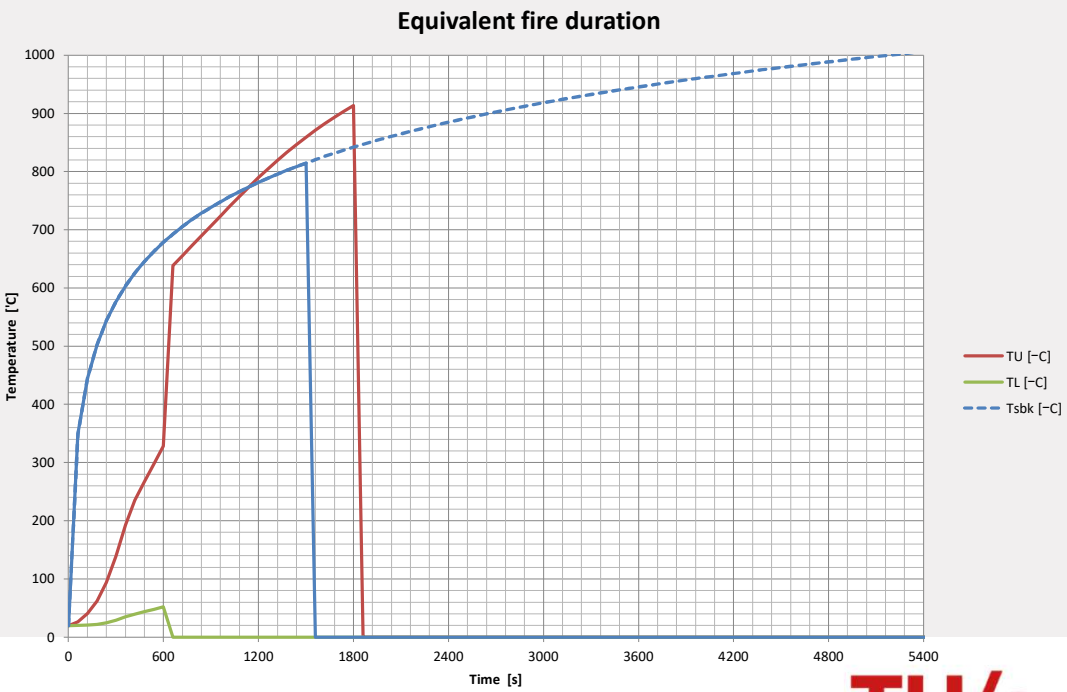



# Compartmentation

## Natural fire → Standard fire

RST compartment = 54 min SFC (AVG)


RST escape route = 25 min SFC (AVG)

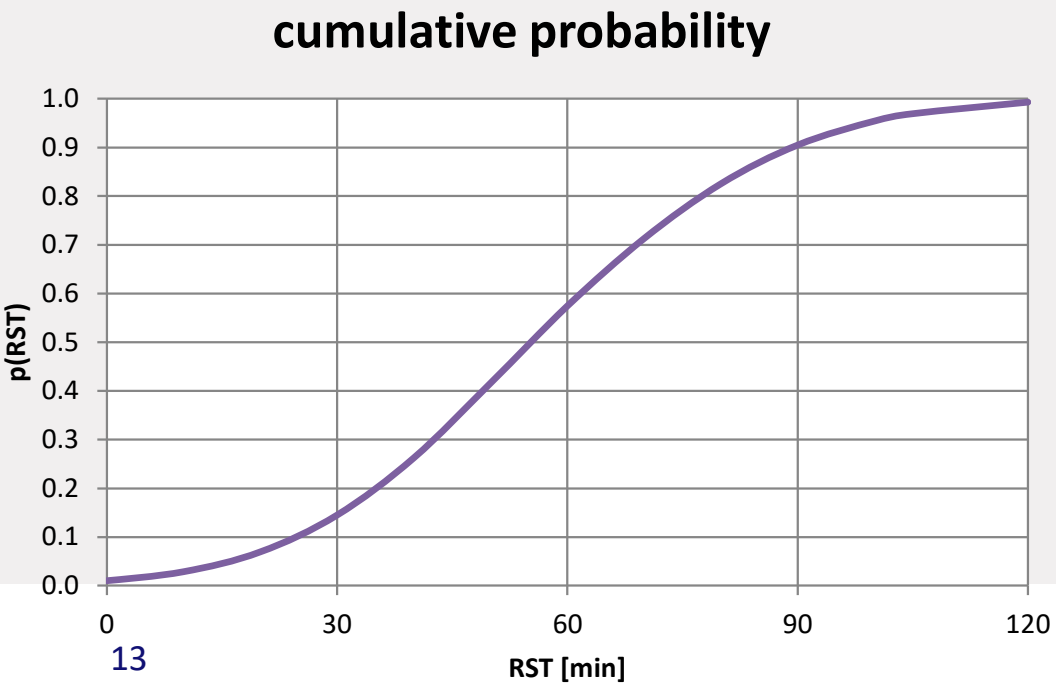


# Compartmentation

## Sensitivity analysis

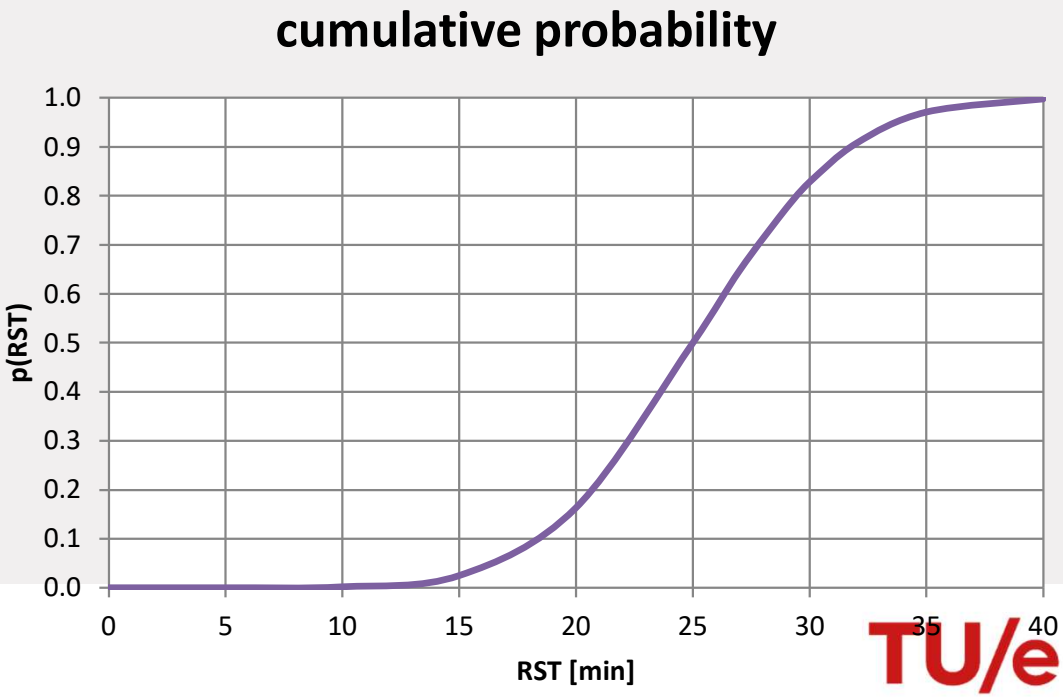
RST compartment = 54 min SFC (AVG)

EI 90 → p(RST)=0.90




RST escape route = 25 min SFC (AVG)

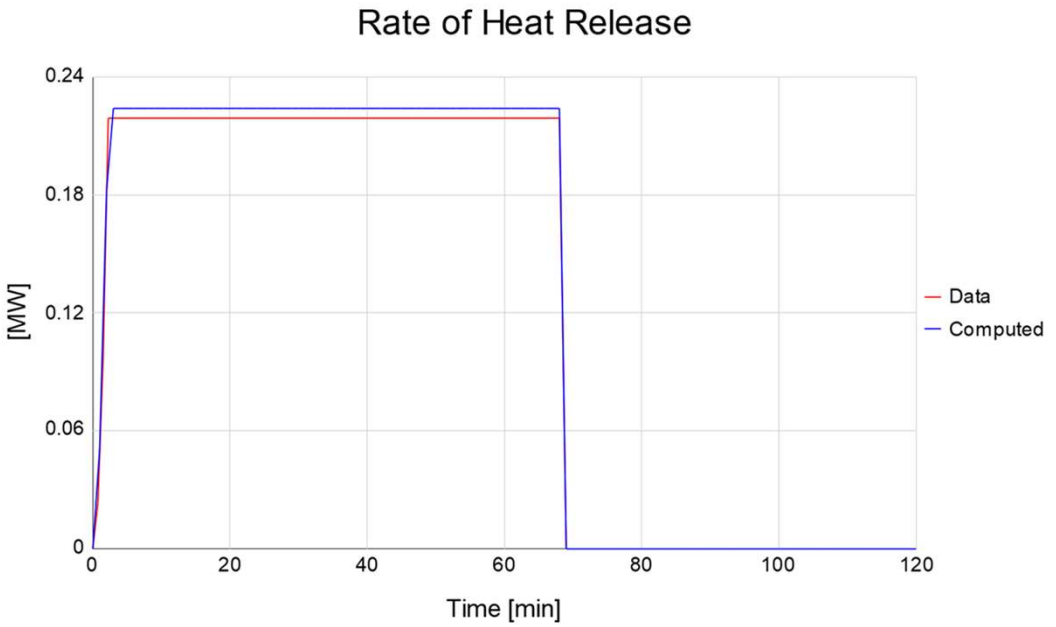
EI 30 → p(RST)=0.83

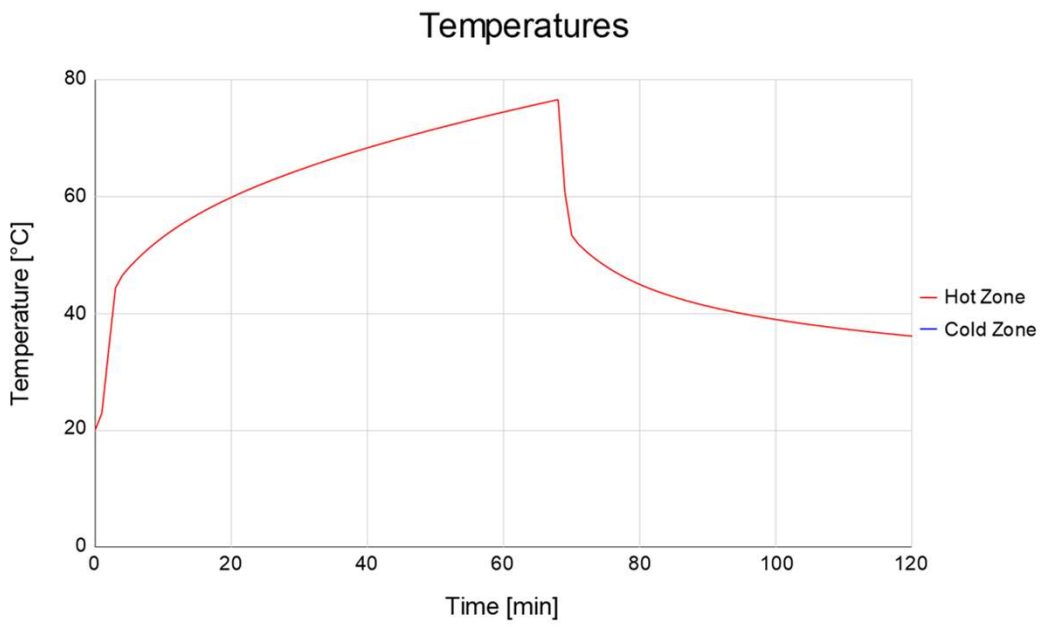


# Compartmentation + sprinkler

## Natural fire scenario:

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

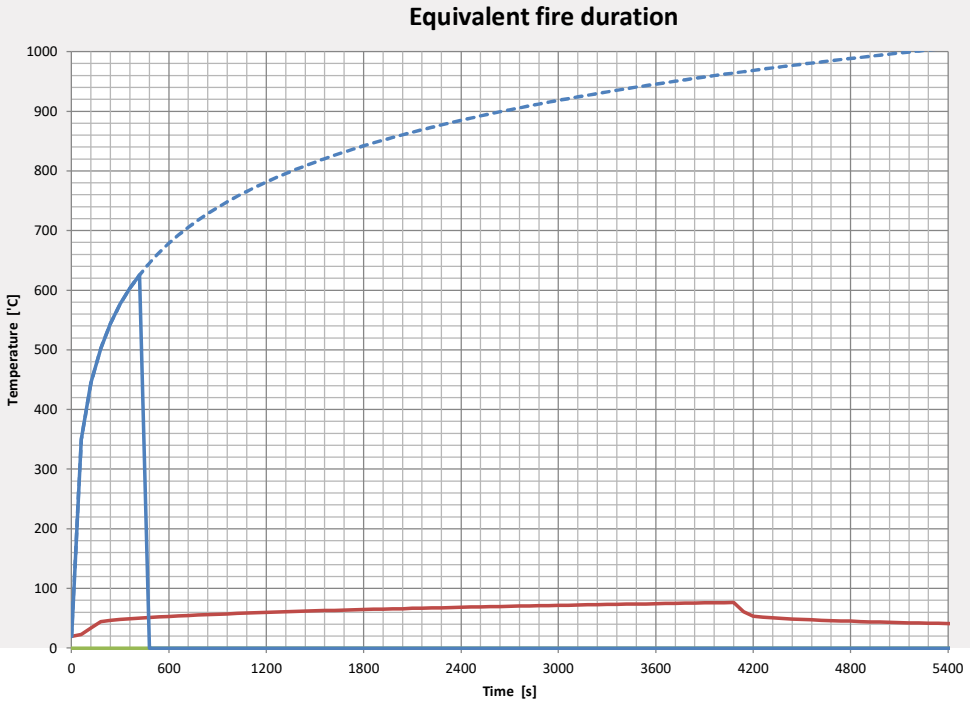


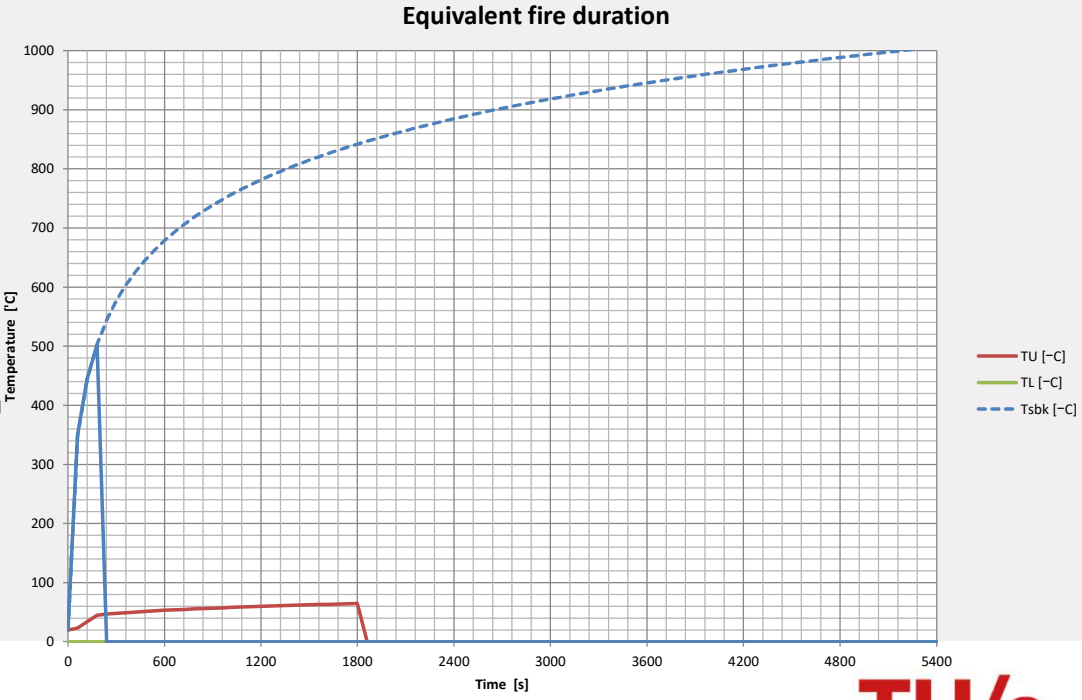
# Compartmentation + sprinkler

## Natural fire → Standard fire

RST compartment = 7 min SFC (AVG)




RST escape route = 3 min SFC (AVG)

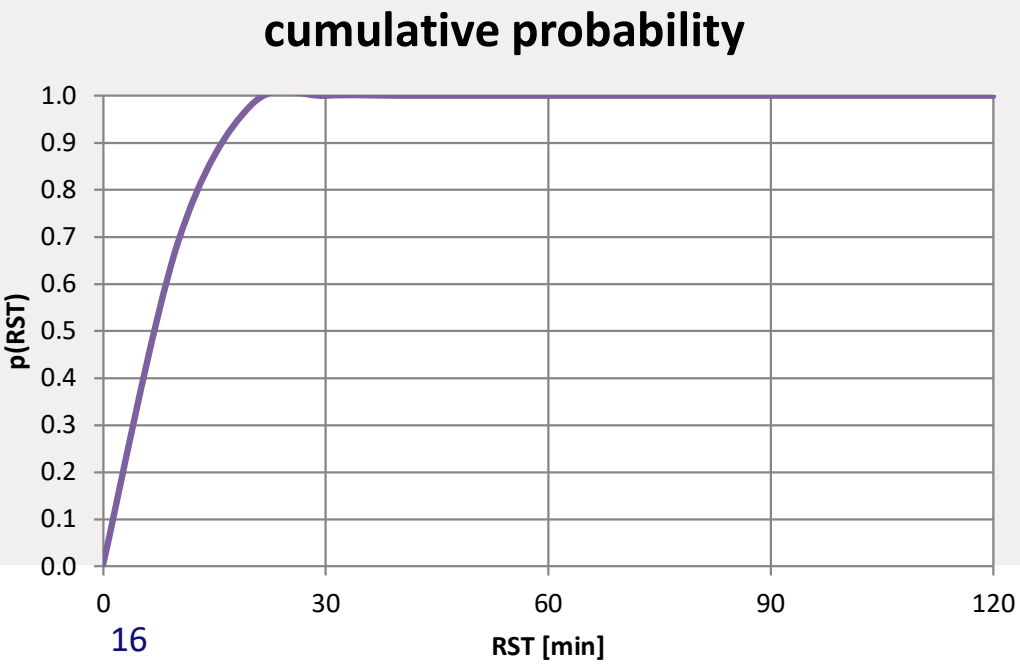


# Compartmentation + sprinkler

## Sensitivity analysis

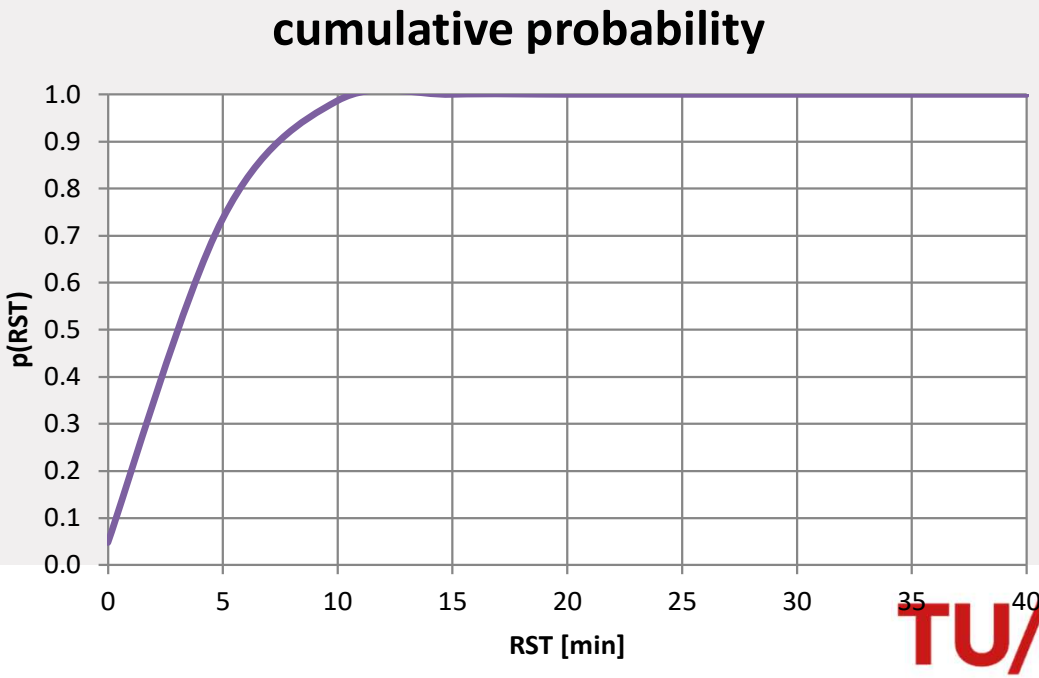
RST compartment = 7 min SFC (AVG)

EI 17 → p(RST)=0.90




RST escape route = 3 min SFC (AVG)

EI 7 → p(RST)=0.83



# 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

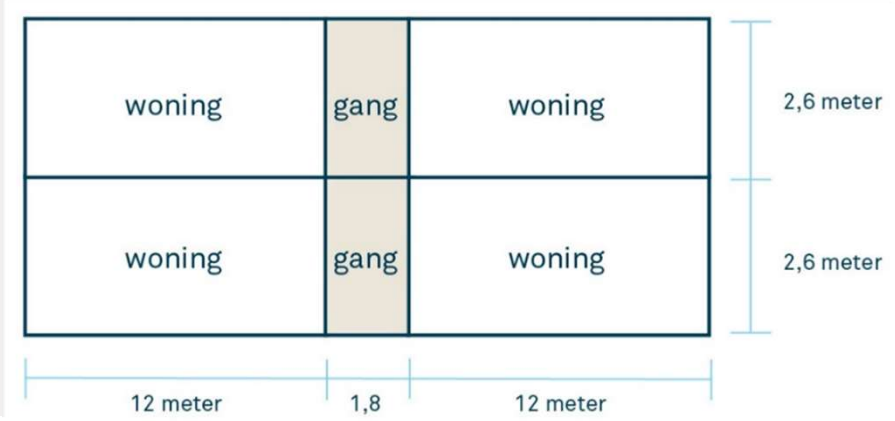
Evacuation concept: Escape routes safe during 30 minutes natural fire

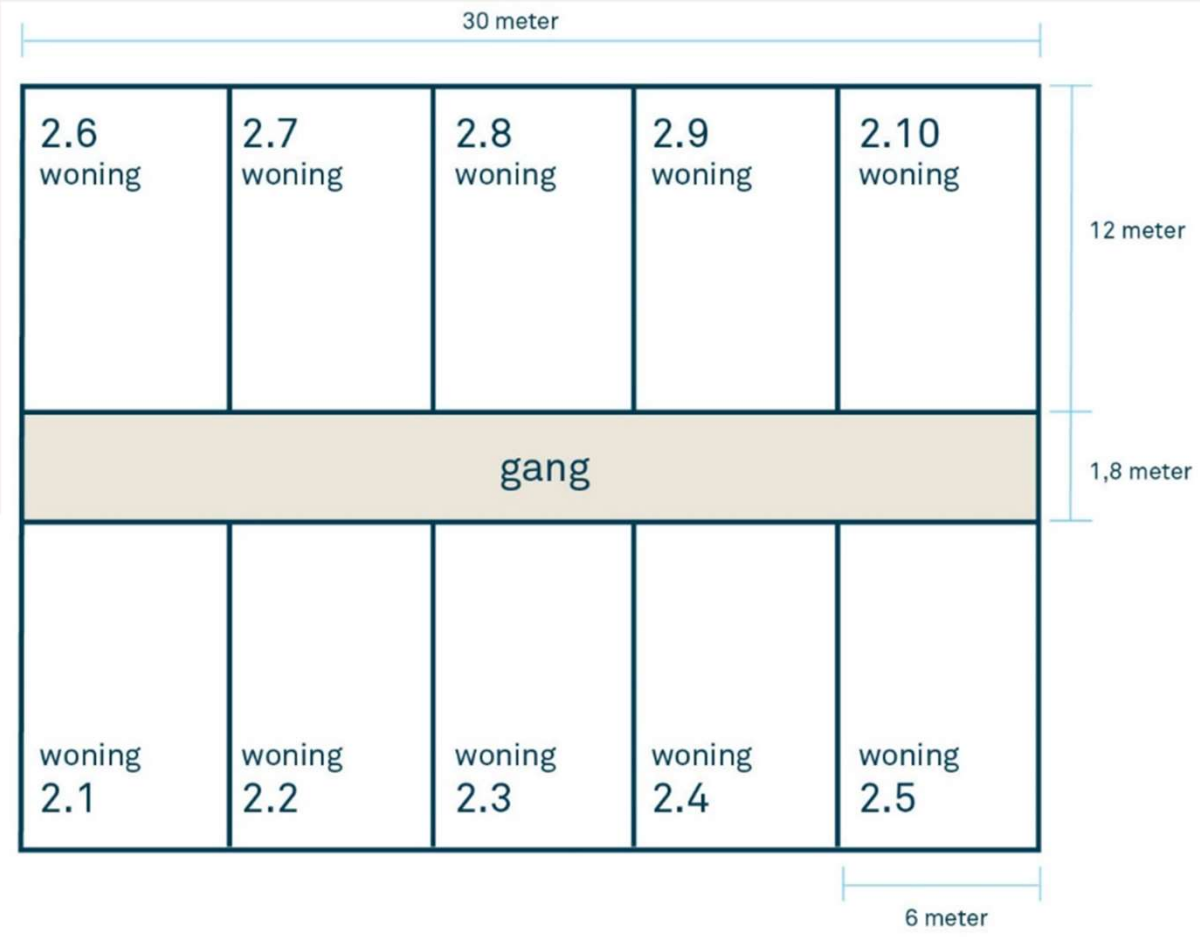
Stay-in-place concept: Adjacent compartmens safe during total natural fire

# Subcompartmentation

## Multizone model

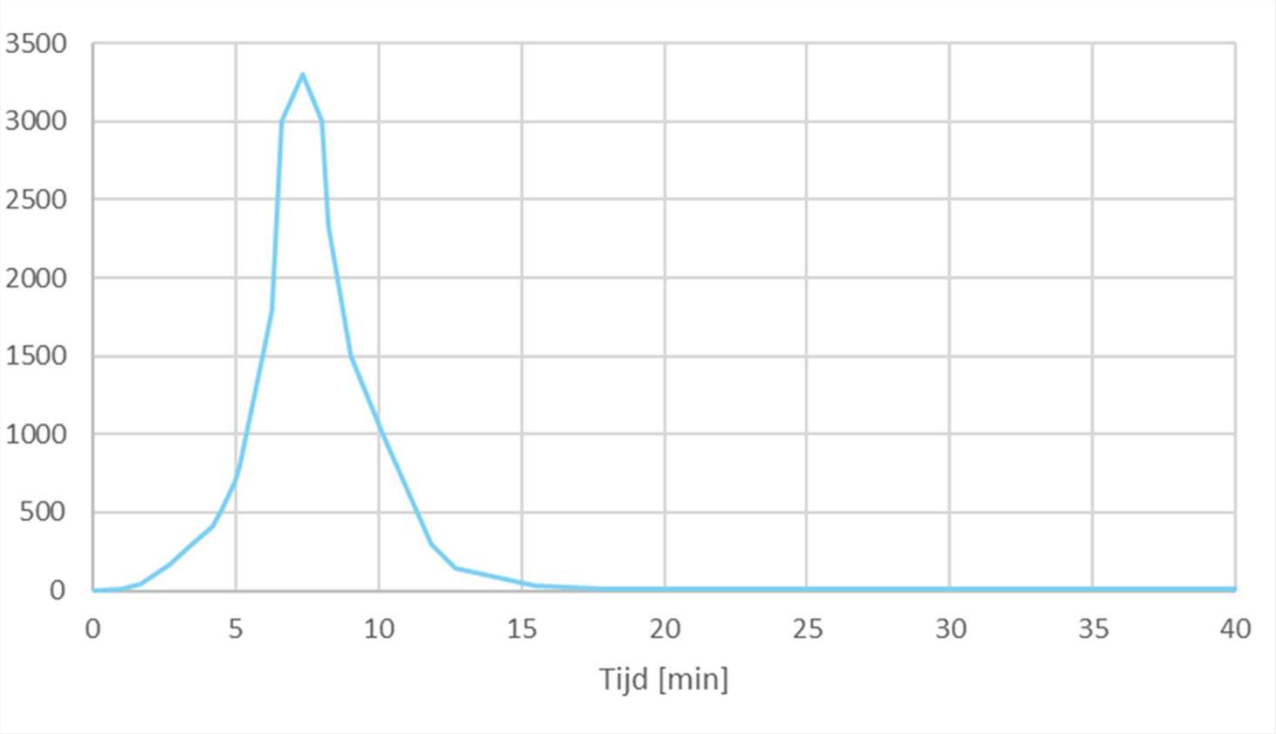
- Complex model with a lot of uncertainties
- Generic model almost impossible



# Subcompartmentation

## Localized fire scenario (RHR in kW)




Soot and CO yield
related to RHR scenario

**Assessment criteria:**
FED < 0.3 (ISO 13571)

- Visibility sinificant 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.

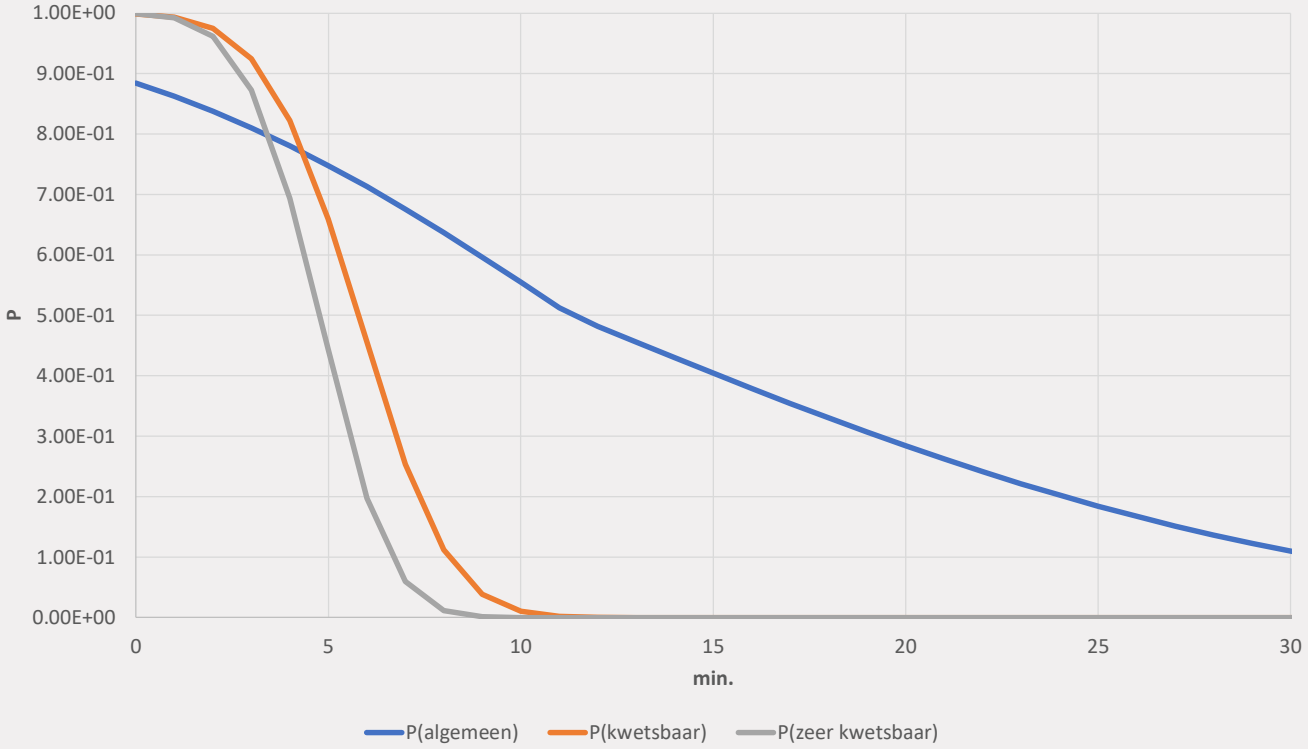
### Stay-in-place concept

RST Apartments:

- Total natural fire duration

# Subcompartmentation – Evacuation concept

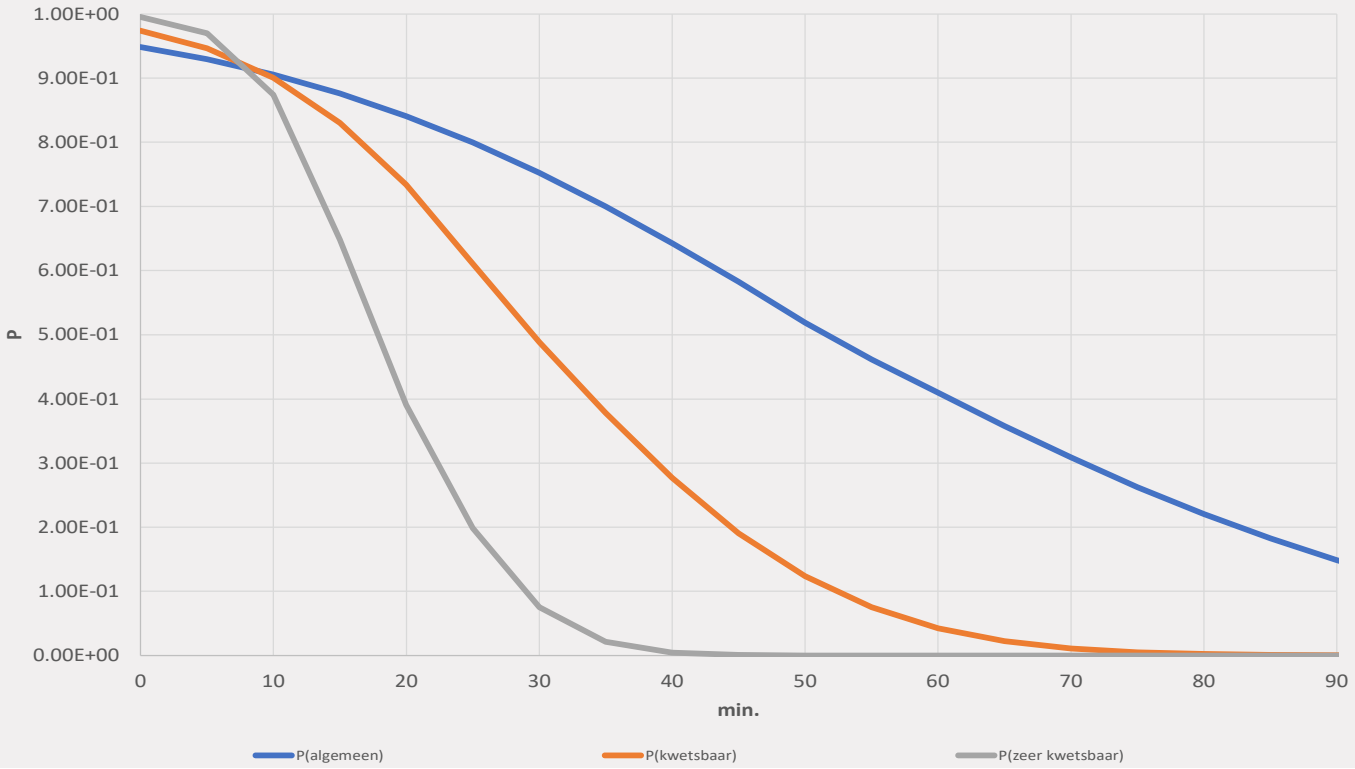
## Cumulative distribution AST (escape route)




| | | |
|---|---|---|
| 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

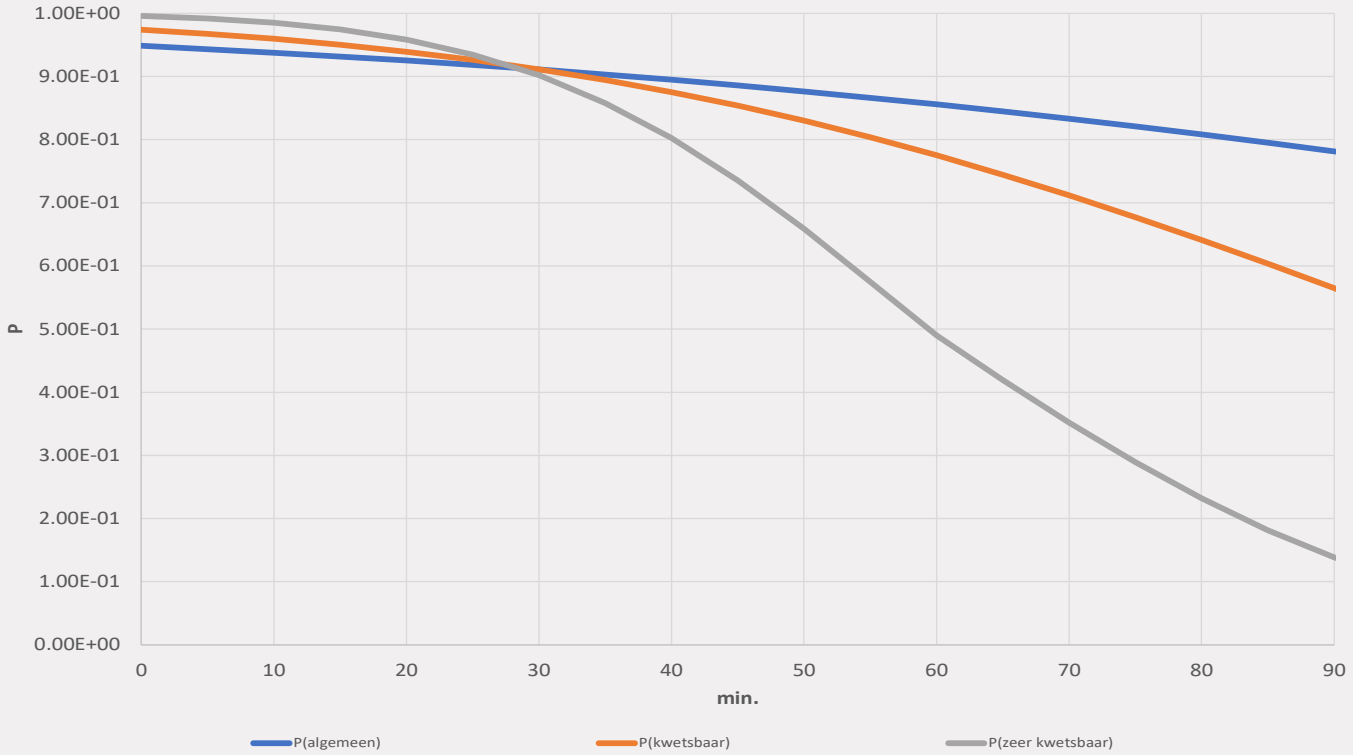
## Cumulative distribution AST (compartments)




FED=0.3 FED=0.1 FED=0.03

# Subcompartmentation – Stay-in-place + sprinkler

## Cumulative distribution AST (compartments)




FED=0.3 FED=0.1 FED=0.03

# 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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