Objective based approach

Failure probabilities

Introduction: fire safety objectives
Example 1: personal safety
Example 2: fire compartment

Introduction

RUUD VAN HERPEN
Eindhoven University of technology:
Fellow Fire Safety Engineering – 0,2 fte

Saxion University of applied sciences:
Professor Fire safety in buildings – 0,1 fte

Nieman consulting engineers

ANNEMARIE WEERSINK
Saxion University of applied sciences:
Researcher Smart Buildings
Lecturer Building Physics and sustainability

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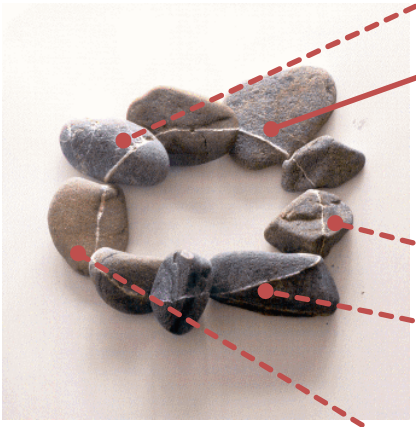
Fire safety chain



- Pro-action
- Prevention
  - (passive: building)
  - (active: installation)
  - (active: organization)
- Preparation
- Suppression
  - (automatic: installation)
  - (manual: organization)
- Aftercare

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Fire safety chain

Link TU/e with Dutch Fire Service Academy

Prevention and suppression

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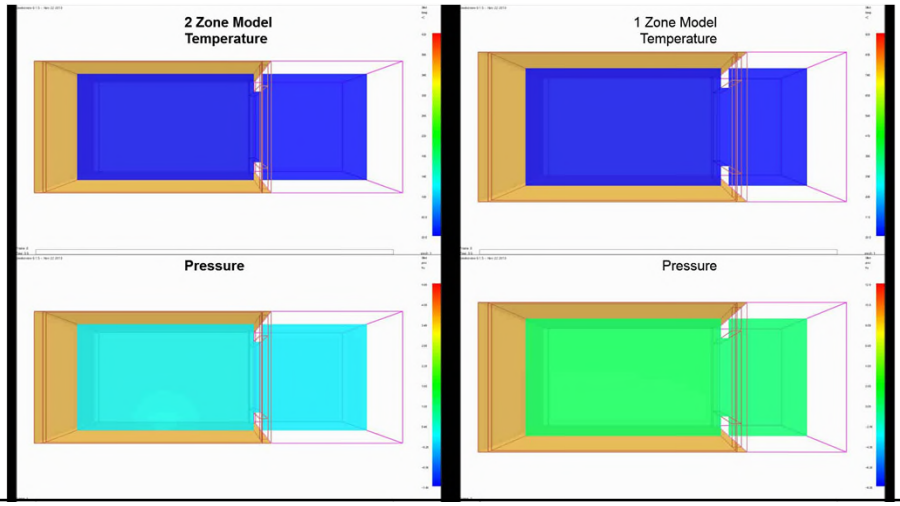
Fire safety chain

Link TU/e with Dutch Fire Service Academy



Definition of fire safety

(Fire)safety in the Dutch building code:

- **Personal safety of building users and fire fighters**
- **Protection of neighbouring plots and adjacent buildings**

- NO Protection of environment and public space
- NO damage control
- NO sustainability/robustness

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Building code: objectives

Critical event → fire start

Pre flashover (localized fire):

- Safe egress in compartment
- Safe attack in compartment (offensive fire attack)

Building code: objectives

Critical event → flashover

Post flashover (compartment fire):

- Safety of adjacent buildings and plots
- Safety of building (load bearing structure)
- Safety of fire and smoke spread (compartmentation)
- Safety of escape and attack routes

Are fire safe buildings possible:
- Without compartmentation?
- Without escaperoutes?

Objectives: assessment

Two examples:

1. Safe escape routes
   Probabilistic analysis for a large compartment: ASET > RSET
   (Available vs. Required safe egress time)

2. Safe fire compartments
   Probabilistic analysis for a retail function: AST > RST
   (Available vs. Required safe time in min. SFC)

Assessment: Acceptable failure probability?

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Example 1: personal safety

Markthal Rotterdam
(example)

Combination of fire load and people in a large compartment;

Pre-flashover situation is important for safety of building users:

ASET > RSET:

- ASET depends on smokelayer conditions
- RSET depends on evacuation process

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Example 1: personal safety

ASET:

- Assessment criterions:
  - Smokefree height > 2,5 meter
  - Smokelayer temperature < 200 ^{o}C

RSET:

- Assessment criterion:
  - 100 % of building occupants outside compartment

ASET > RSET

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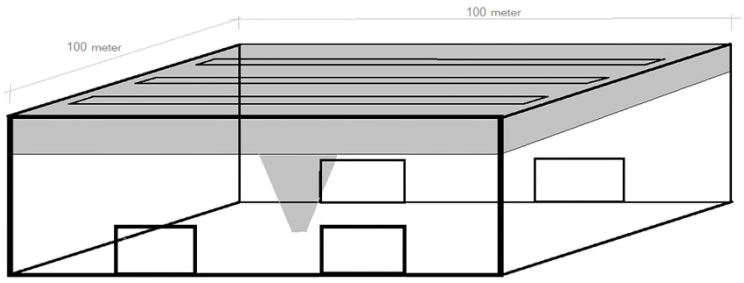
Market hall, large compartment



Market hall, simplified model
10,000 m^2 floor area
7 m height
P(fi) = 2 . 10^{-6} per m^2

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Market hall, boundary conditions

Mean conditions for ASET (smokelayer calculations):

- Uniform distribution of fuel (NEN-EN 1991-1-2/NB):
  - Fire load 900 MJ/m^2
  - RHR = 500 kW/m^2
  - Time constant tc = 150 s (fast)
  - Plume = Heskestad
  - Stoichiometric constant r = 1,27 (cellulose fuel)
- External separation constructions: adiabatic (except floor)

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Market hall, boundary conditions

Mean conditions for RSET (evacuation calculations):

- Uniform distribution of people
  - Number of people N = 3000 (mean)
- 3 exits available (mean)
- Walking speed = 1 m/s
- Detection time = 2 min.
- Pre movement time = 2 min.

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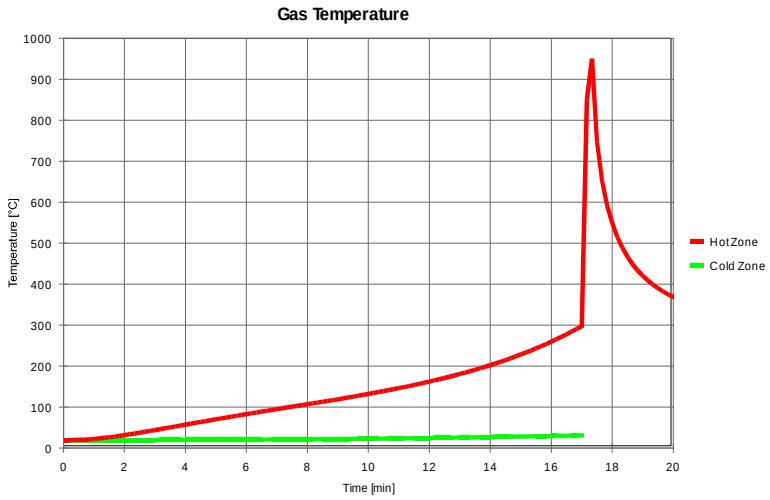
Market hall, ASET



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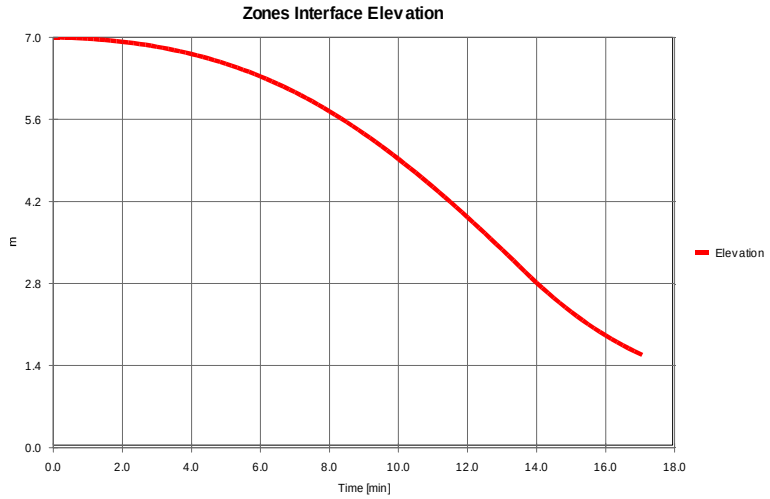
Market hall, ASET



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Market hall, ASET and RSET

- ASET (H>2,5 m): 14.6 min
- ASET (T<200 °C): 13.9 min
- RSET (building occupants): 7.7 min

- **ASET-RSET = 6.2 min**

Safe evacuation?

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Failure probability analysis

Take into account uncertainty of boundary conditions (stochastic parameters)

Calculate failure probability under fire conditons:

– $P(f|fi) = P(ASET - RSET) < 0$

Total failure probability:

– $P(f) = P(fi) \cdot P(f|fi)$

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Failure probability analysis

Acceptable failure probability (eurocode EN 1990 c.a.):

- CC 2, lethality P(f) = 7.23 E-05
  P(f|fi) = 3.62 E-03

CBS Statline: fire injuries/fatalities = 14.5

- CC 2, injuries P(f|fi) = 5.25 E-02

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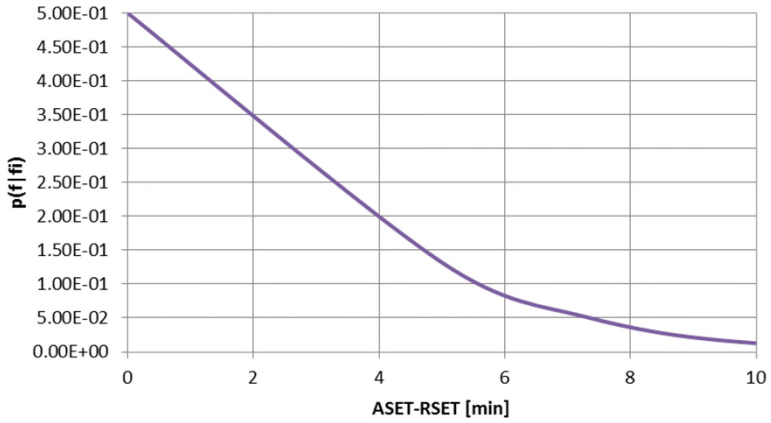
Failure probability analysis



Required: ASET-RSET > 7,3 min

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Improving personal safety

- Active fire control: sprinkler system
  - Source reduction → improving ASET
- Active smoke control: smoke outlet system
  - Increasing smokelayer buffering → improving ASET

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Example 2: safe compartments

Supermarket 1.000 m2

AST > RST:

- AST depends on fire resistance of separation construction
- RST depends on thermal load by a natural fire

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Example 2: safe compartments

AST:

- Assessment criterion:
  - Thermal load standard fire curve
  - Fire resistance 60 min. EIW (classification: EN 13501-2)

RST:

- Assessment criterion:
  - Thermal load natural fire curve
  - Probability analysis → reliability?

AST > RST

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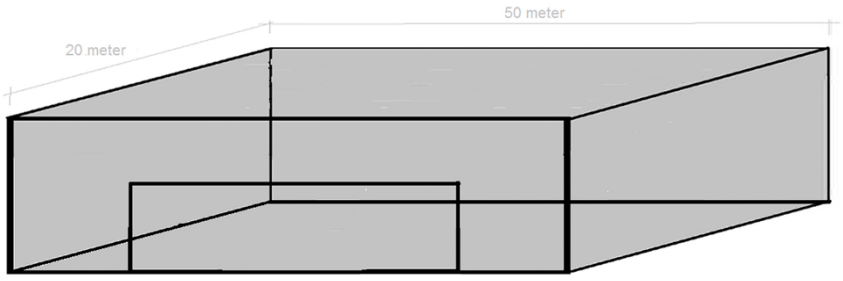
Supermarket, 1000 m2



Supermarket, simplified model
1,000 m^2 floor area
5 m height
P(fi) = 2 . 10^{-6} per m^2

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Supermarket, boundary conditions

Mean conditions for RST (natural fire calculations):

- Uniform distribution of fuel (NEN-EN 1991-1-2/NB):
  - Fire load 900 MJ/m^2
  - RHR = 500 kW/m^2 (medium)
  - Time constant tc = 150 s (fast)
  - Plume = Heskestad
  - Stoichiometric constant r = 1,27 (cellulose fuel)
- External separation constructions:
  - Adiabatic
  - Entrance facade open

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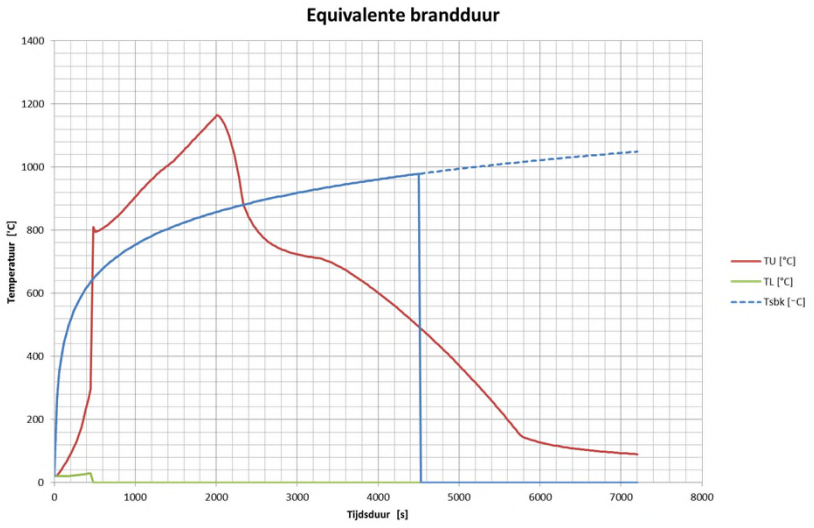
Supermarket, RST



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Supermarket, RST and AST

- AST : 60 min SFC
- RST : 70.5 min SFC

- **AST-RST = -10.5 min**

Safe compartmentation?

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Failure probability analysis

Take into account uncertainty of boundary conditions (stochastic parameters):

- Fire Load (MJ/m^2)
- RHR (kW/m^2)
- Time constant (s)
- Height of fire source (m)
- Openings (m^2)

Most important parameter?

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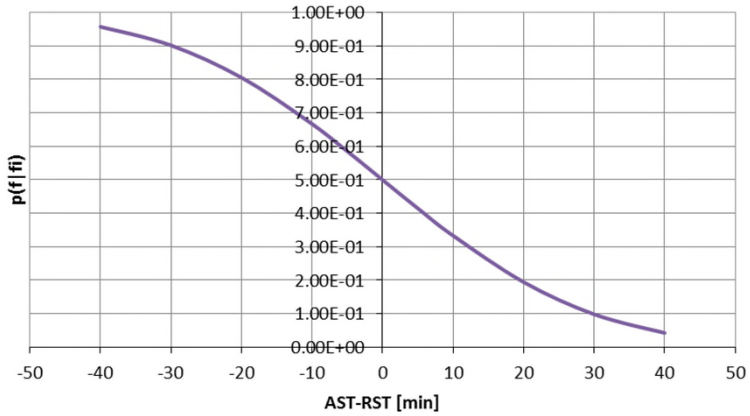
Failure probability analysis



AST: 60 min SFC, RST: 70.5 min SFC → **failure probability: 67.5 %**

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Improving safety compartments

- Increase fire resistance of compartmentwall
- Active fire control (sprinkler system)
- Active smoke control (smoke outlet system)
- Or Manual suppression/cooling by fire service

Without fire service:

BURN DOWN SCENARIO

in case of insufficient fire resistance compartmentwall

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What did we forget?

Adjoining separation constructions
(facade, roof, floor)

Openings
(doors, ducts, windows)

We need your expert judgement!

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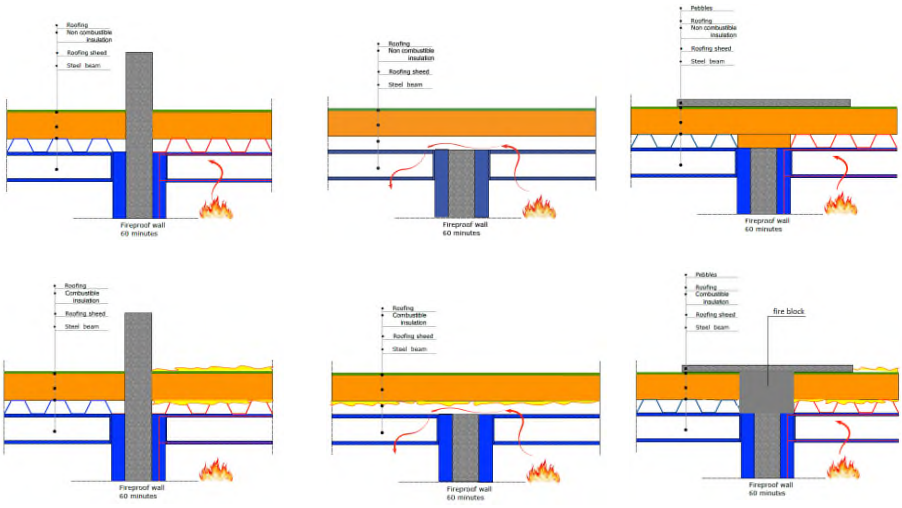
Wall-roof details



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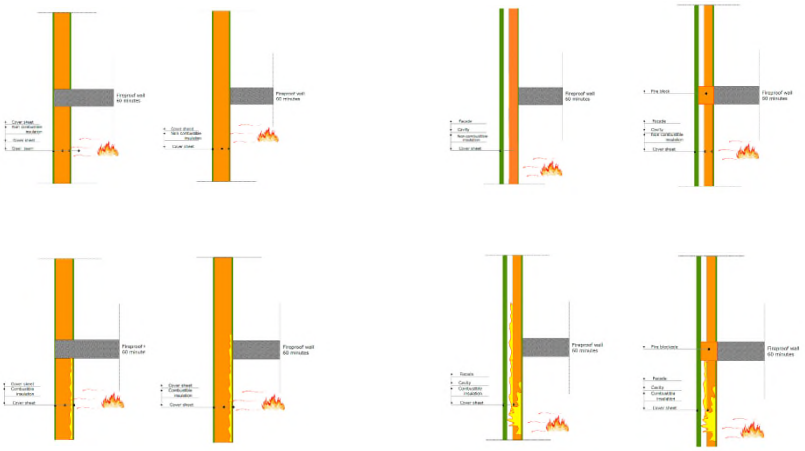
Wall-facade details



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Your expert opinion please….

https://play.kahoot.it/#/?quizId=12a18e30-08ce-4743-956f-f01d2b4cea35

Kahoot!

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