Benefits of sprinkler protection for personal safety

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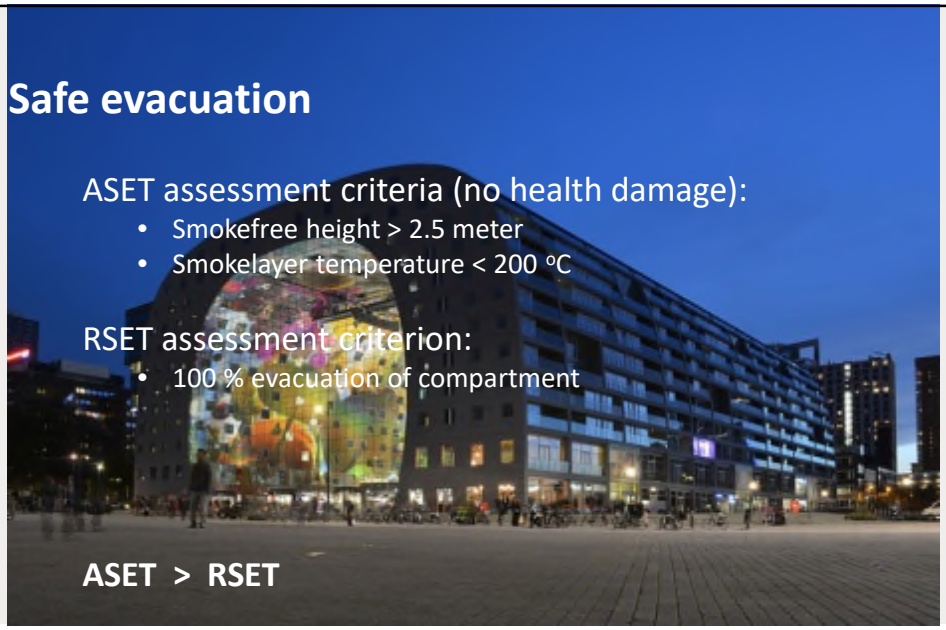

Safe evacuation

ASET assessment criteria (no health damage):

- Smokefree height > 2.5 meter
- Smokelayer temperature < 200 °C

RSET assessment criterion:

- 100 % evacuation of compartment

ASET > RSET

Market hall Rotterdam

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Safe evacuation

Does sprinkler make sense for egress safety?

NO → ASET is determined by control of smoke only?
YES → ASET is (also) determined by control of fire?

Market hall Rotterdam

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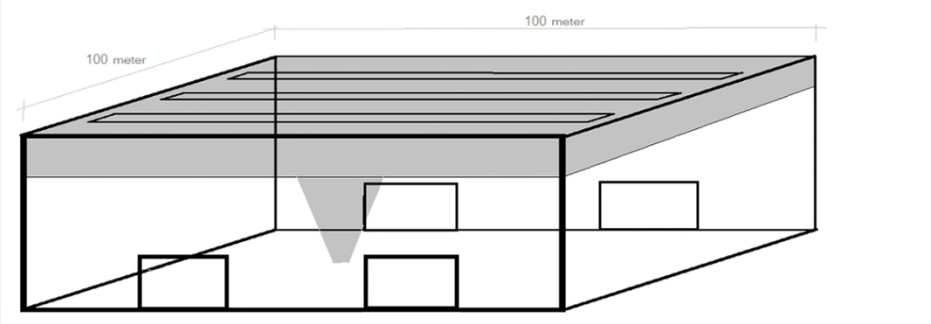
Market hall, model



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

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Market hall, boundary conditions

Mean conditions for ASET (smokelayer calculations):

Uniform distribution of fuel:

- Fire load 1200 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, no glass fall out during pre flashover fire (conservative assumption)

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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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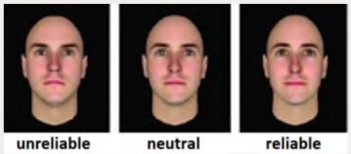
Market hall, results

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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Sensitivity analysis

For each stochastic boundary condition (x_i):

Mean value:	$\overline{x}_i$
Variation:	dx_i
Standard Deviation:	s_i

For ASET-RSET (t):

Variation:	dt
Specific Variation per stochast:	dt/dxi
Specific Variancy per stochast:	$(s_i\, dt/dxi)^2$
Total Variancy:	$var = \sum_i (s_i\, dt/dxi)^2$
Standard Deviation:	$s = \sqrt{var}$

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Sensitivity analysis ASET

ASET	T < 200 °C	H > 2.5 m
Mean fire conditions	13.9 min.	14.6 min.
Specific Variancy:		
Fire load density q (SD = 0.3 x AVG)	0.00 min²	0.00 min²
Rate of heat release RHRPUA (SD = 0.5 x AVG)	1.78 min²	1.00 min²
Time constant for fire spread (SD = 0.3 x AVG)	9.51 min²	8.03 min²
Start plume - fire height (SD = 0.5 x AVG)	0.50 min²	0.25 min²
Total Variancy:	**11.79 min²**	**9.28 min²**

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Sensitivity analysis RSET

RSET	100 % out
Mean egress conditions	7.7 min.
Specific Variancy:	
Nb. of building occupants (SD = 0.3 x AVG)	3.43 min^2
Nb. of exits (SD = 0.5 x AVG)	3.43 min^2
Pre movement time (SD = 0.3 x AVG)	1.00 min^2
Detection time (SD = 0.5 x AVG)	0.36 min^2
Total Variancy:	**8.22 min^2**

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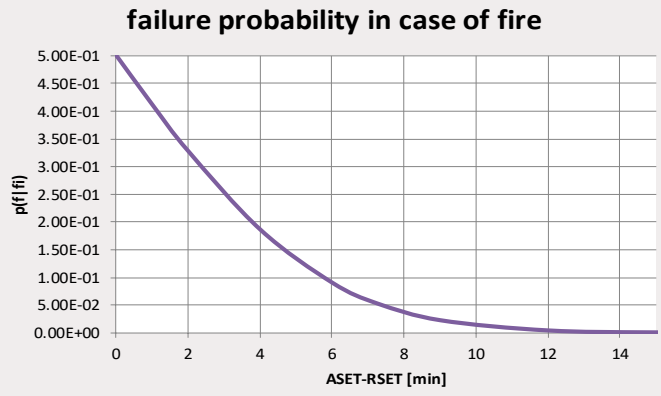
Probabilistic approach

Significant criterion: smokelayer temperature



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Probabilistic approach

Acceptable failure probability

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

CC 2, injuries (CBS - Dutch statistics: 14.5 x lethalities)
P(f|fi) = 5.25 E-02

Required:
ASET-RSET > 7.3 min

Available:
ASET-RSET = 6.2 min

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Improving safety

Active fire control: sprinkler system

Quick response (RTI = 50)

Grid 3 x 3 m at 7 m height

Activation Tact = 68 °C

Sprinkler activation

Model of Alpert

Constant RHR after activation

Stratified situation after activation
(masterthesis Nick Tenbült, TU/e, 2018)

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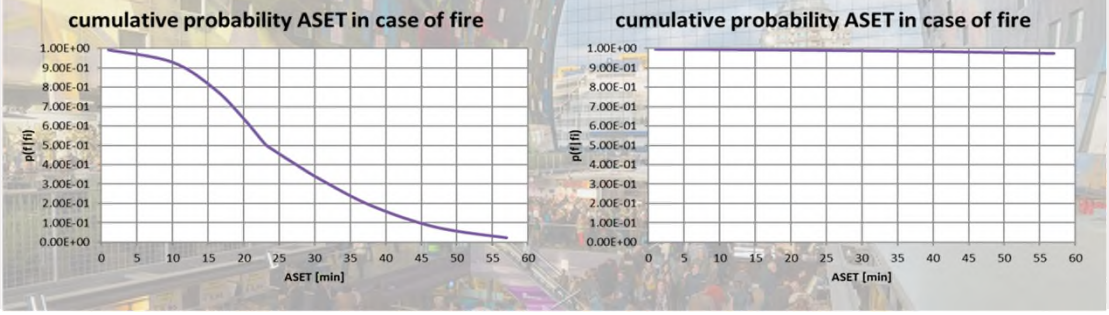
Results

ASET simulations in cfast (NIST)
Results:

- without sprinklerprotection (l) and with sprinklerprotection (r)



And in a mixed situation?

→ Low large compartment
→ Small room adjacent to corridor

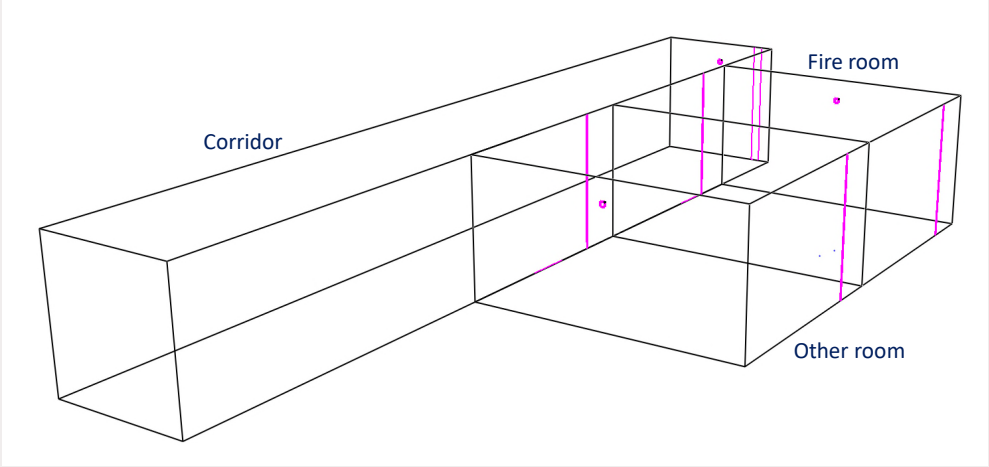
ASET Assessment criteria (no health damage):

- Visibility > 5 meter
- Gastemperature < 70 °C

ASET Assessment toxicity (no lethal damage):

- CO-dose < 35,000 ppm.min
- O_2 > 60,000 ppm

Small room / corridor



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Small room / corridor

Safe escape concept

Mixed situation, assessment in corridor

ASET > RSET

Stay-in-place (defend in place) concept

Mixed situation, assessment in other room

ASET > NATURAL FIRE DURATION

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Small room / corridor

Active fire control: sprinkler system

Quick response (RTI = 35)

Grid 3 x 4 m at 7 m height

Activation Tact = 68 °C

Spray density = 2.25 mm/min

Sprinkler activation

JET Algorithm (NIST, Davis)

RHR reduction after activation (Evans)

Mixed situation after activation

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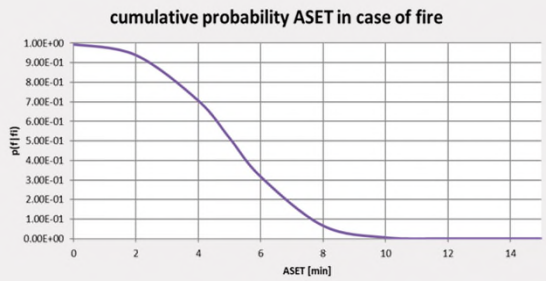
Results

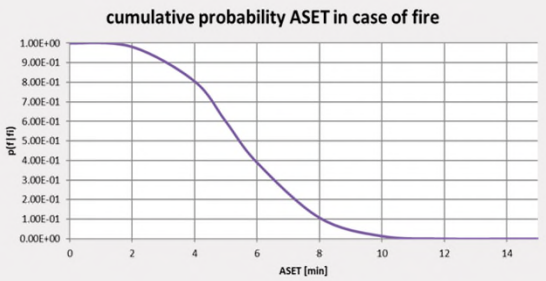
Assessment: health safety in corridor

- Visibility > 5 m
- Temperature < 70 °C

no sprinkler



sprinkler



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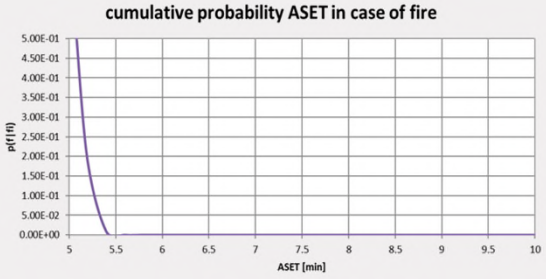
Results

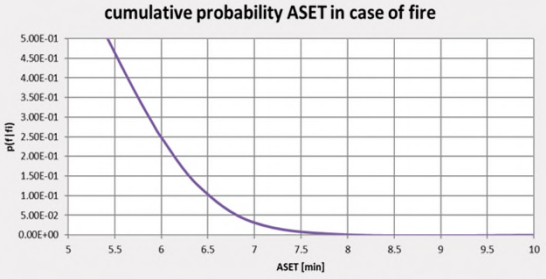
Assessment: health safety in corridor, after opening door fire room

- Visibility > 5 m
- Temperature < 70 °C

no sprinkler



sprinkler



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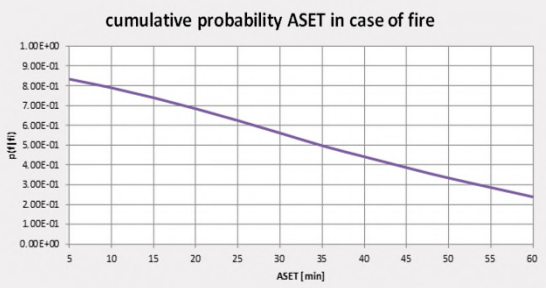
Results

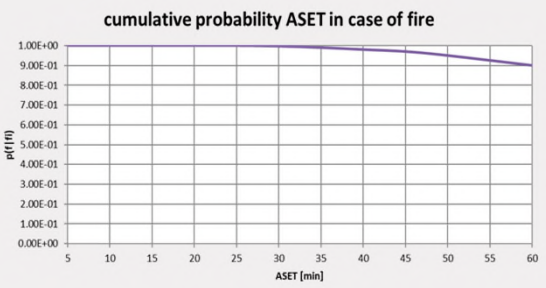
Assessment: life safety in corridor, after opening door fire room

- CO-dose < 35,000 ppm.min
- O_2 > 60,000 ppm

no sprinkler



sprinkler



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Results

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- CO-dose < 35,000 ppm.min
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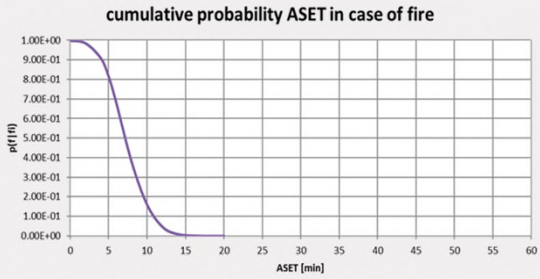
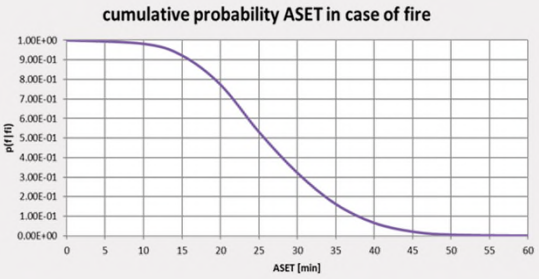
no sprinkler



sprinkler



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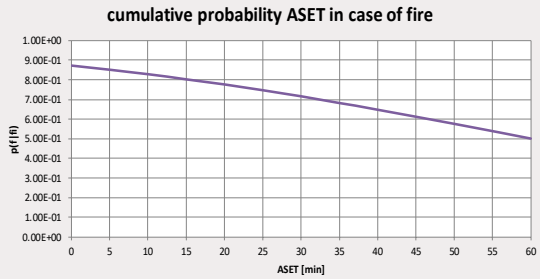
Results

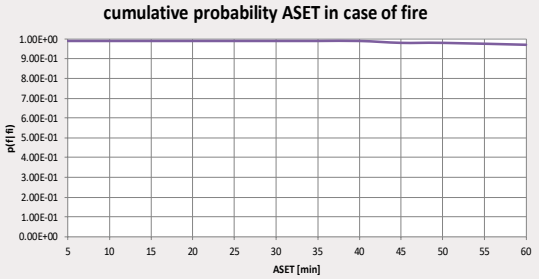
Assessment: health safety in other room

- Visibility > 5 m
- Temperature < 70 °C

no sprinkler



sprinkler



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Conclusions

Sprinkler protection increases egress safety in high compartments

In low compartmens this effect is smaller

Sprinkler protection increases tenability in escape route, fire room and adjacent rooms

Sprinkler protection is needed for a stay-in-place concept

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