PROBABILISTIC SIMULATION OF FIRE ENDURANCE OF STEEL CONSTRUCTION

PhD Students‘ Seminar on Fire Safety Science

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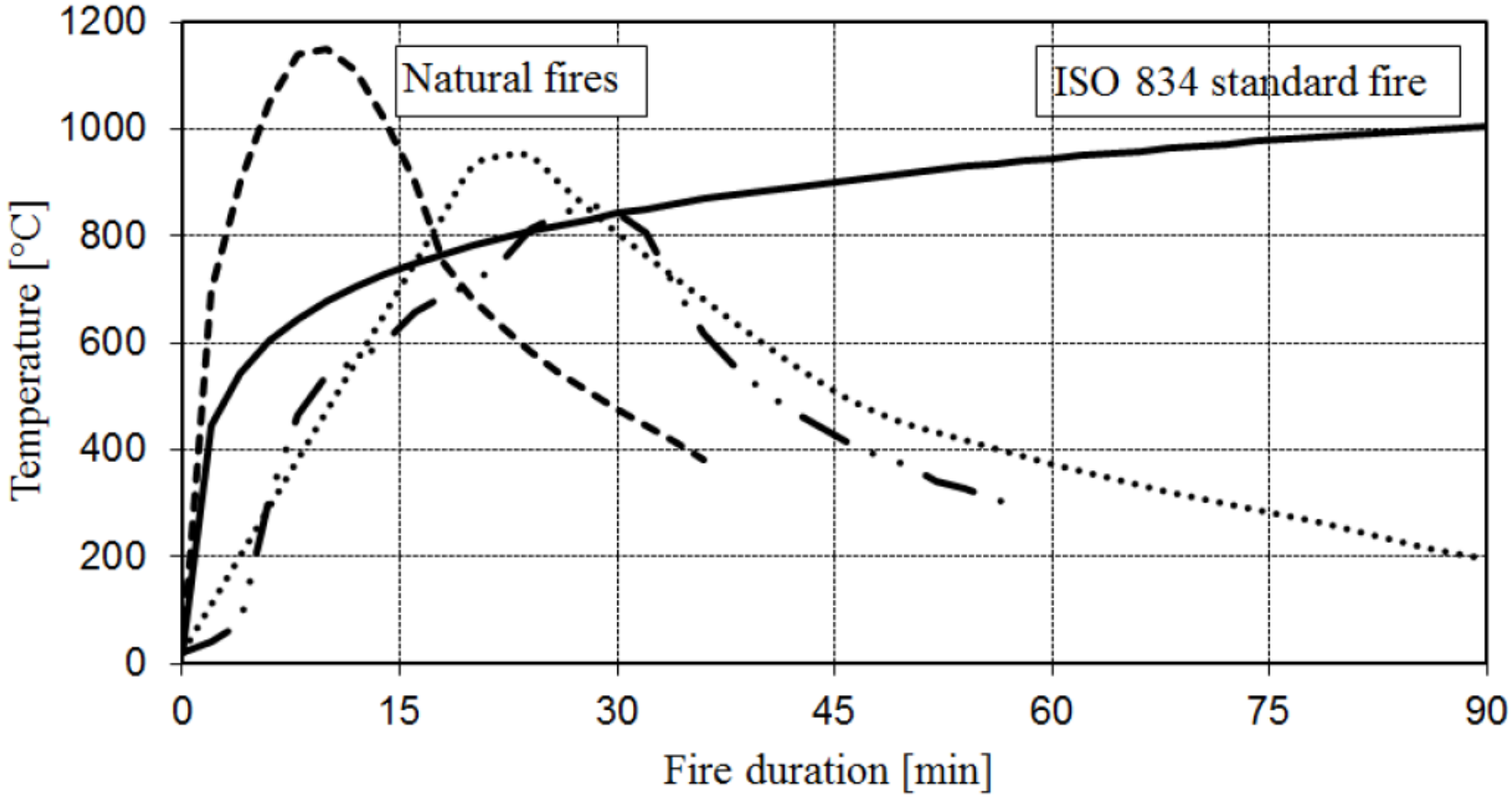
Prescriptive-Based Building Design

Regulation of the Polish Minister of Infrastructure of April, 2002,

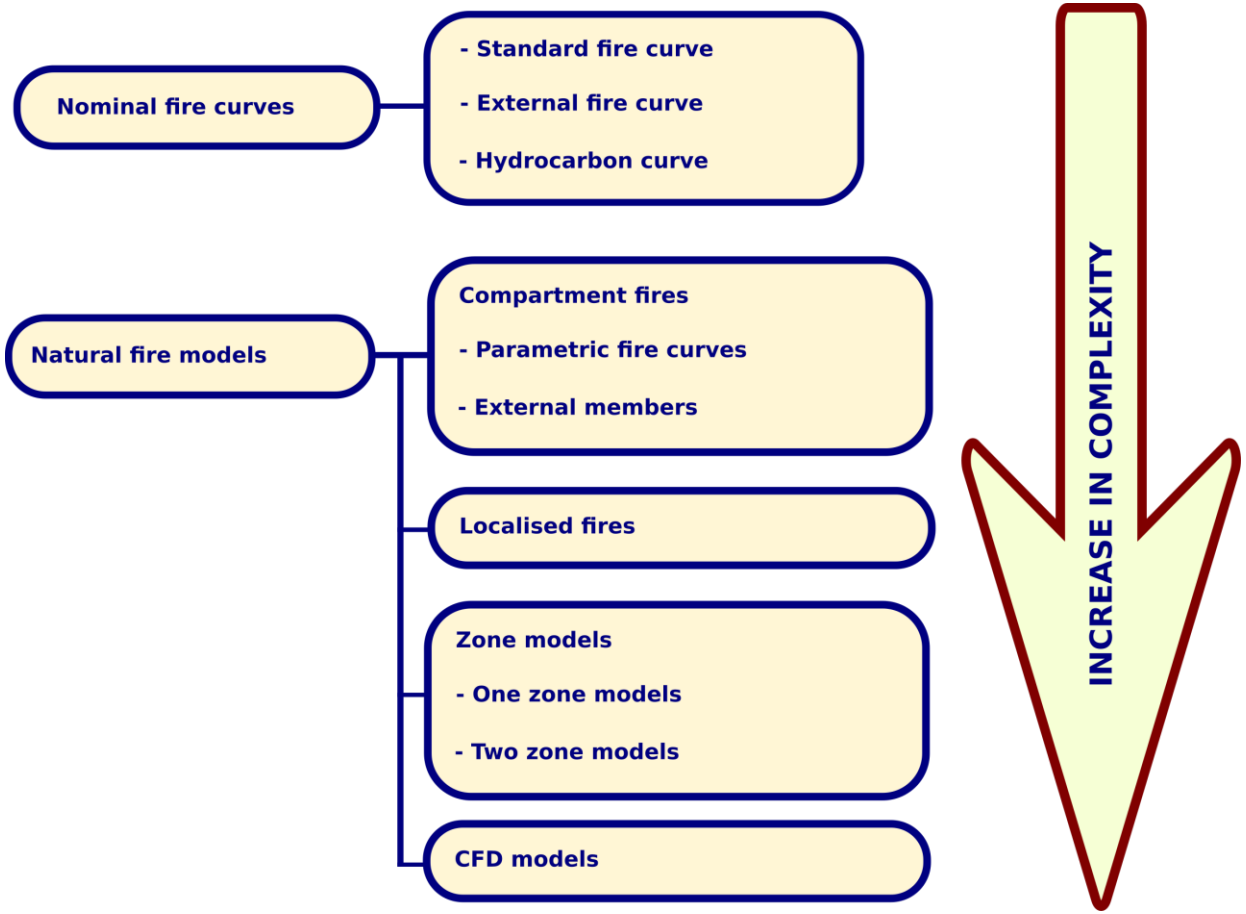
on the technical conditions which should be met by buildings and their location.

Natural fire model for the structural fire design



Source: Lyzwa, J., Zehfuss, J.: Thermal material properties of concrete in the cooling phase. ASFE conference 2017

Natural fire model for the structural fire design



Source: Eurocode 1: Actions onstructures - Part 1-2: General actions - Actions onstructures exposed to fire

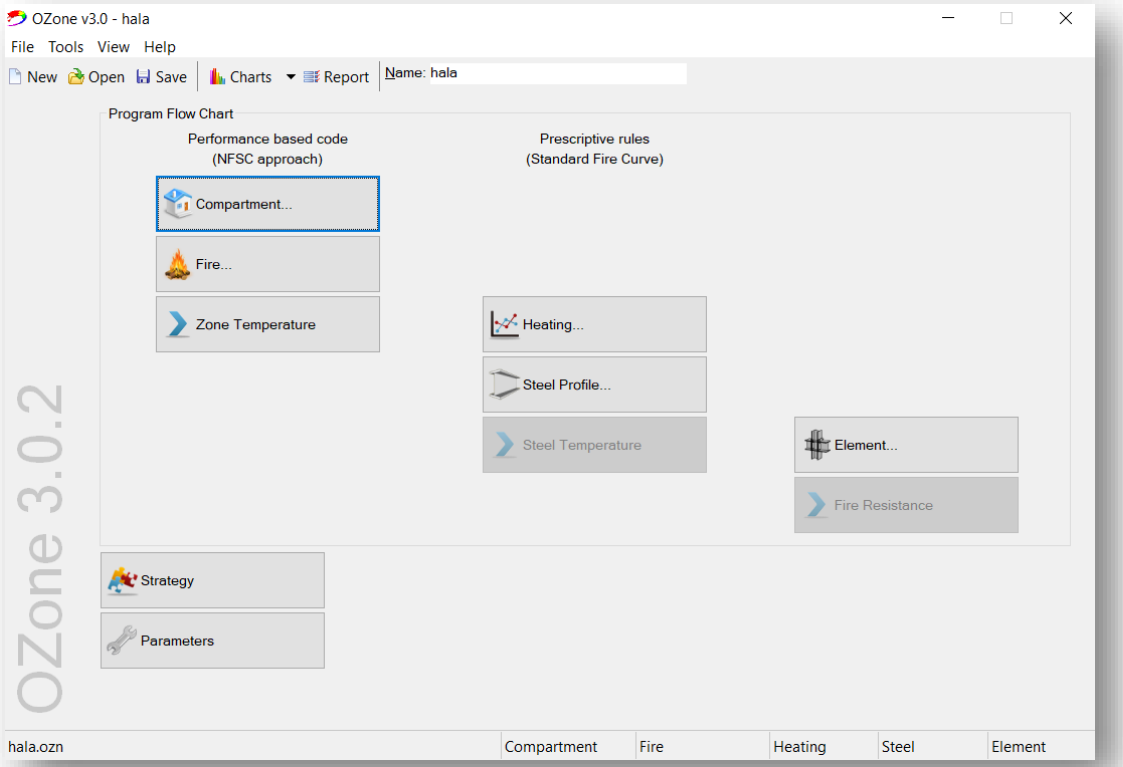
Verification of load-bearing capacity at specific temperatures

$$\theta_{a,cr} = 39.19ln[\frac{1}{0.9674 \cdot \mu^{3.833}} - 1] + 482$$

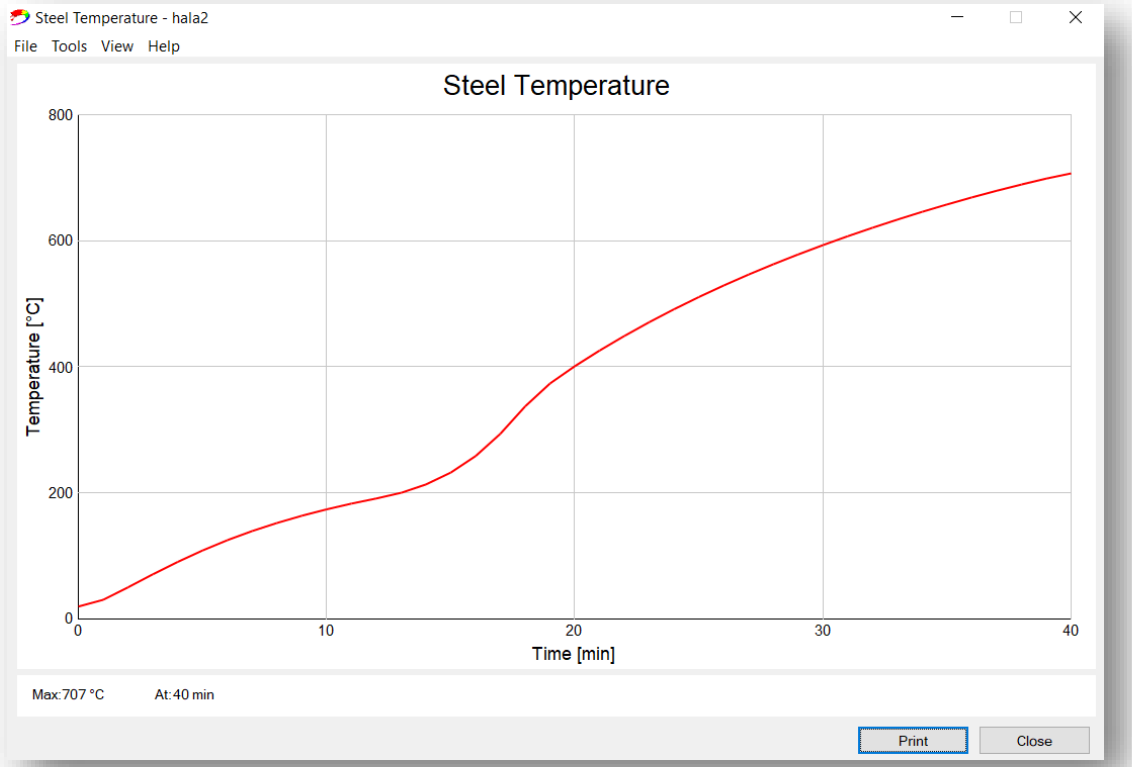
$$\theta_{a,cr} = 39.19ln[\frac{1}{0.9674 \cdot 0.7^{3.833}} - 1] + 482 = 526^{\circ}C$$

Source: Eurokod 3 - Design of steel structures – Part 1-2 - General rules – Structural fire design

The computer code Ozone V3



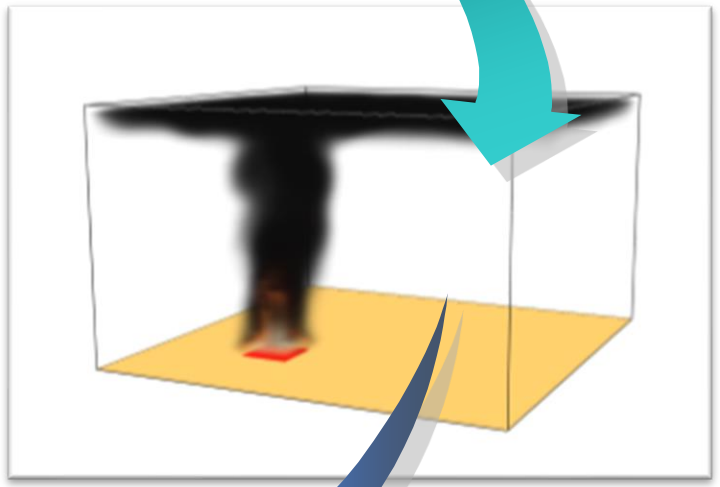
Source: Main window (Ozone)



Source: Chart window (Ozone).

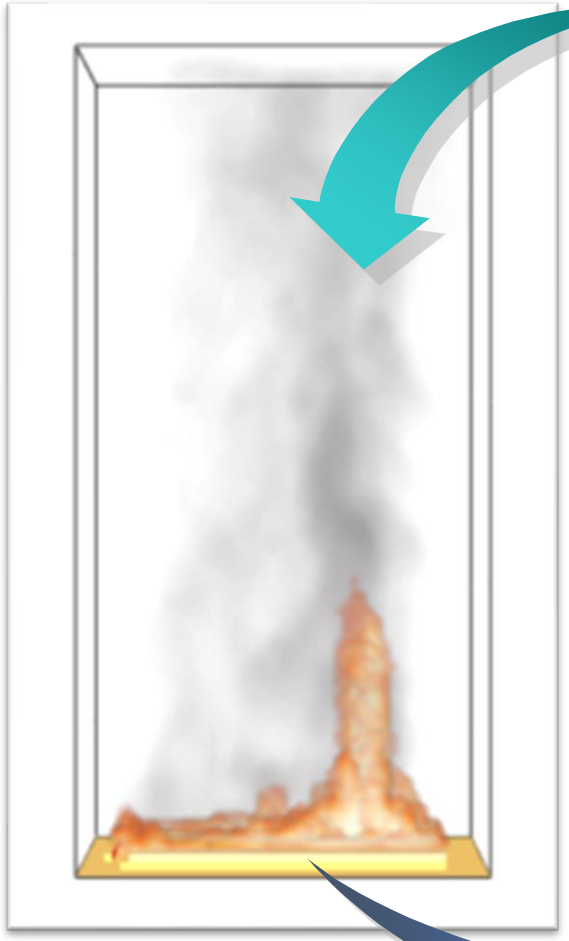
Deterministic approach

Simple Pyrolysis Model



HRR prescribed by the user

Complex Pyrolysis Model



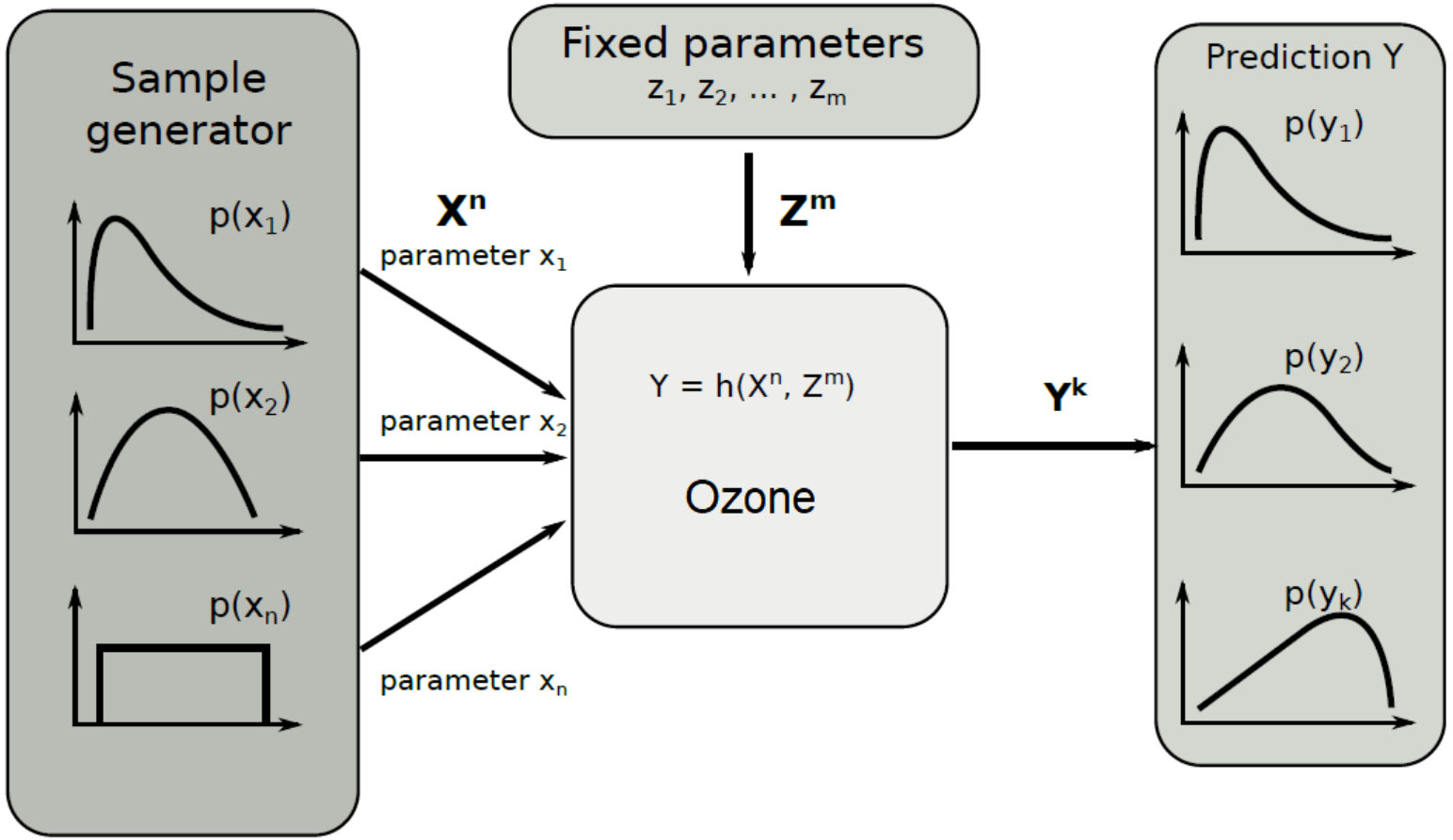
HRR predicted by the model

Source: own study

Risk assessment

$$\mathbb{R} = \mathbb{P} \times \mathbb{S}$$

The computer code McOZone

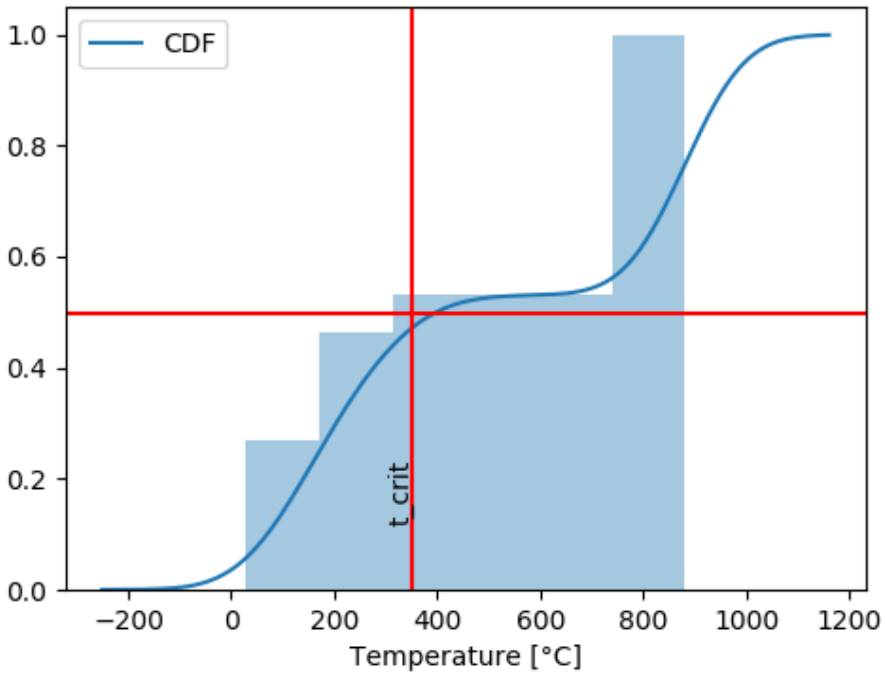


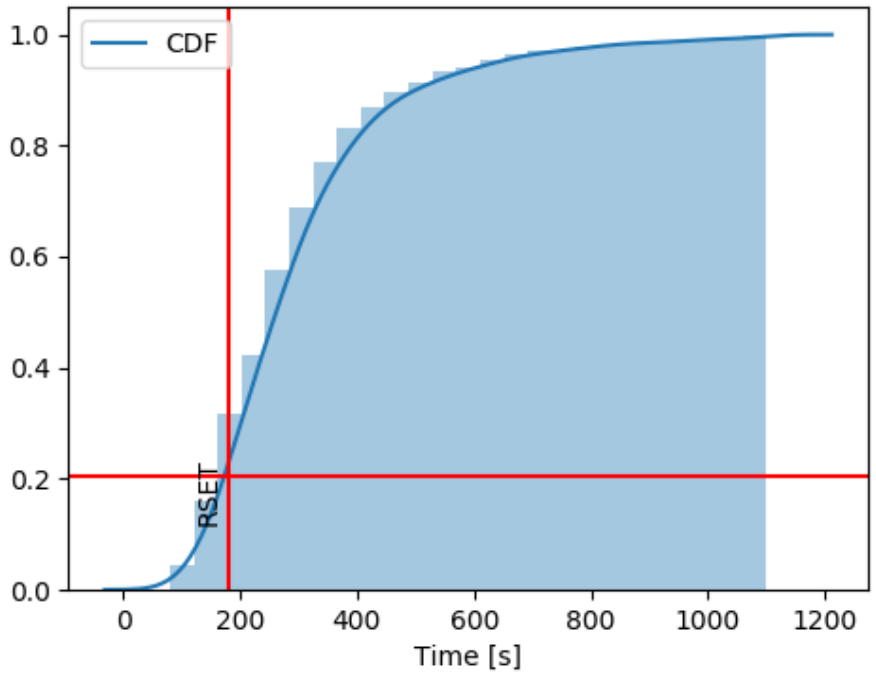
Source: own study

McOZone configuration files

- Room dimensions (.geom)
- Properties of building materials (.mat)
- Opening in walls and ceilings (.cel, .op)
- Parameters of mechanical ventilation (.ext)
- Input data for fires (.ful)
- Analysis strategy (.str)
- Other simulation settings (.par)

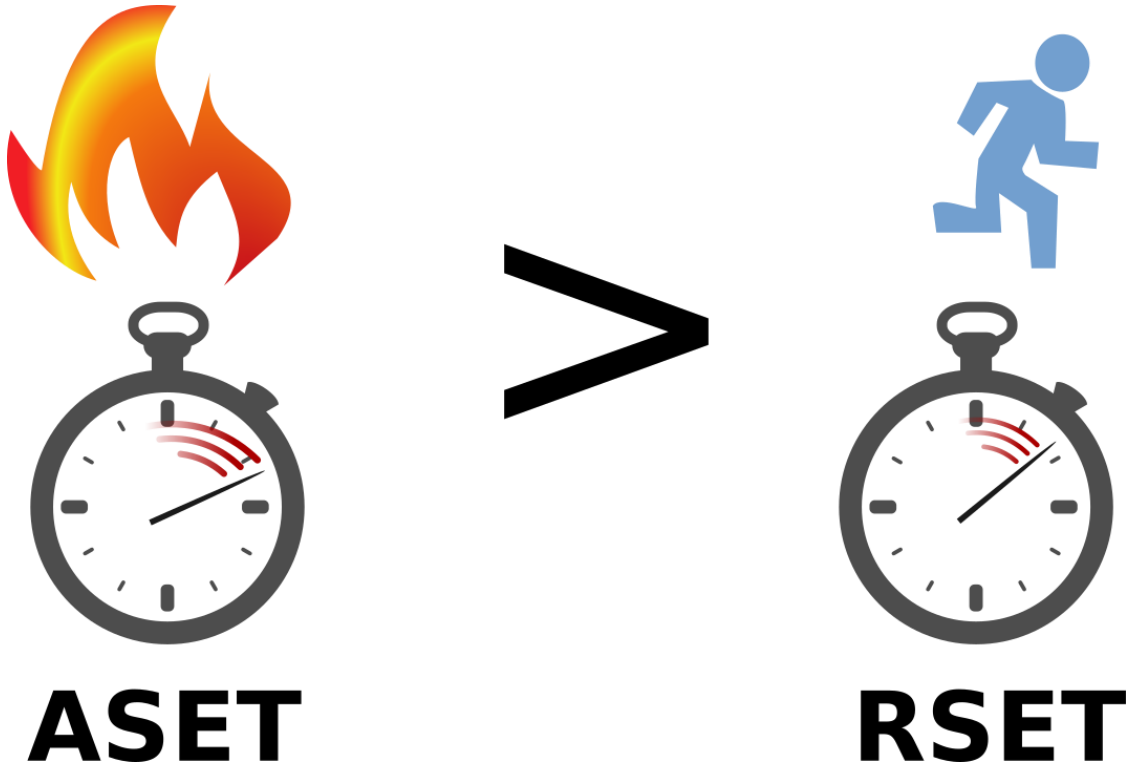
Results





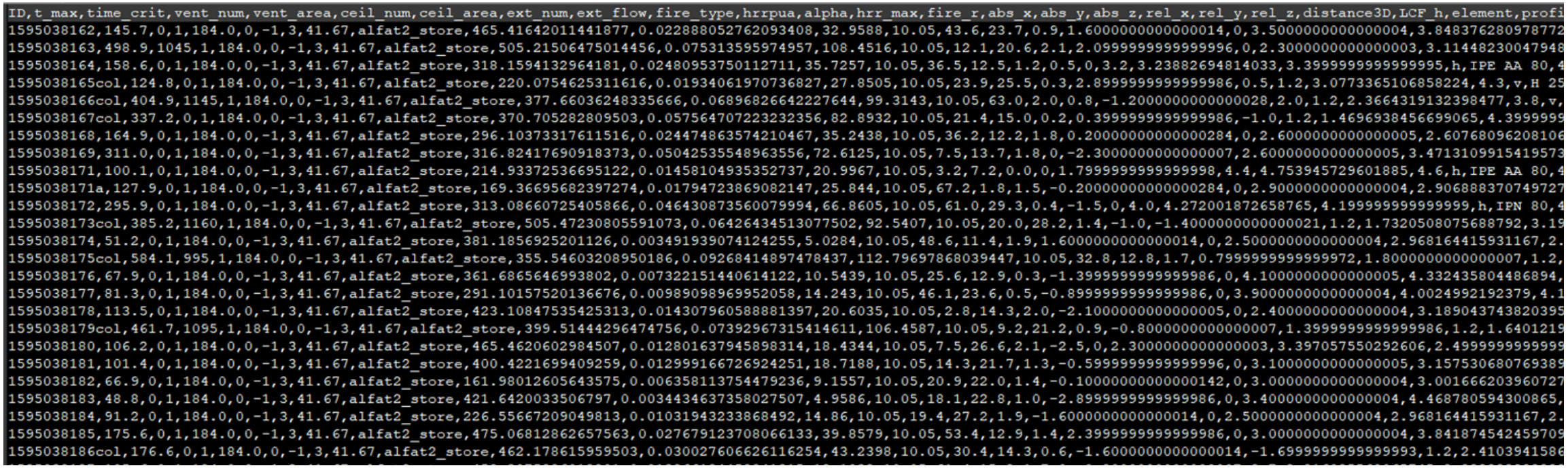
Source: own study

Performance-based building design



Source: own study

Results



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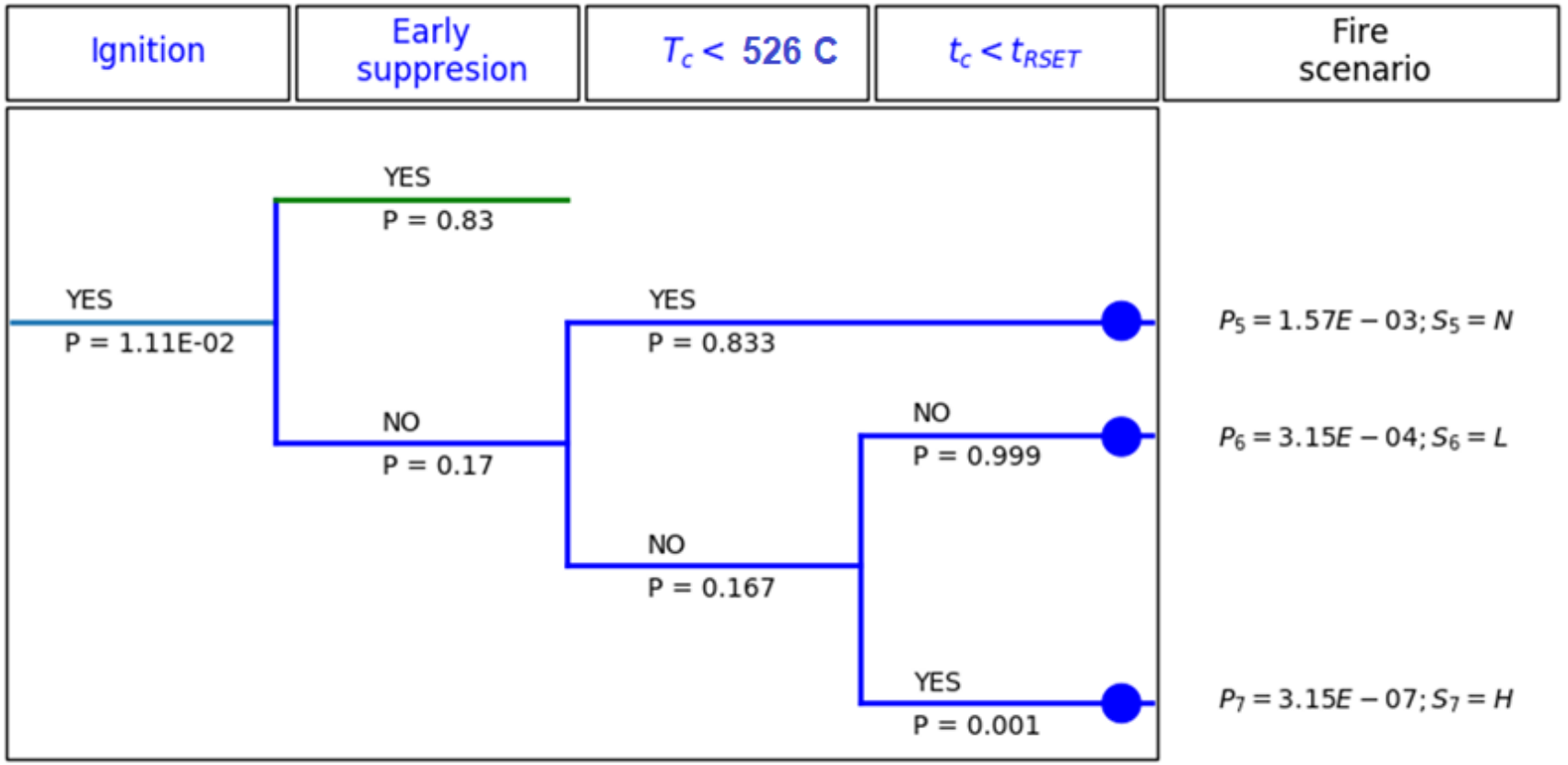
Source: own study

The event tree for the traumatic injury base risk calculation



Source: own study

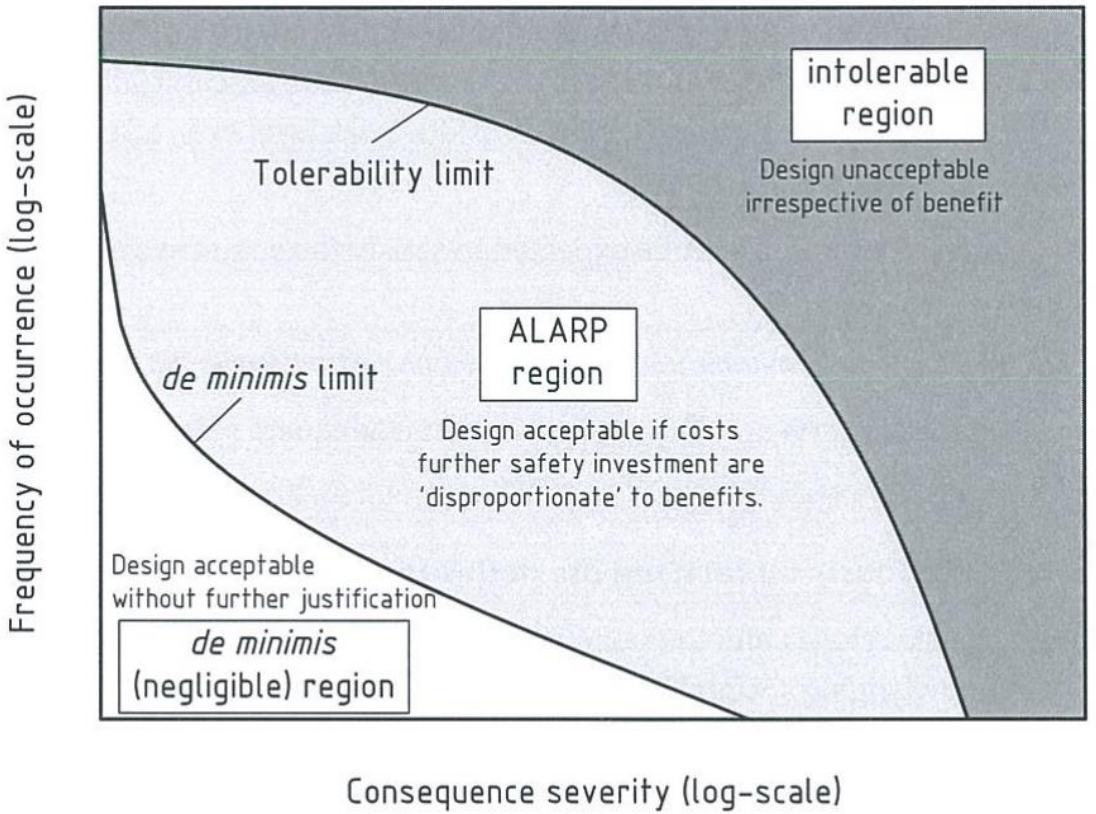
Categorisation of risks

Frequency ▶ / Consequence ▼	Beyond extremely unlikely $f \leq 10^{-6}yr^{-1}$	Extremely unlikely $10^{-4} \geq f > 10^{-5}yr^{-1}$	Unlikely $10^{-2} \geq f > 10^{-4}yr^{-1}$	Anticipated $f > 10^{-2}yr^{-1}$
High	10	7	4	1
Moderate		8	5	2
Low		9	6	3
Negligible	11	12		

Key

High Risk | Moderate Risk | Low Risk | Negligible risk

Source: SFPE Handbook of Fire Protection Engineering, 2016.



Source: PD 7974-7:2019

McOZone limitations

- Enables to use localised fires.
- Enables to use compartment fires (One-zone or Two-zone fire models).
- Analyzes the theoretically isolated cross-section.
- Does not analyze the mechanical response of the structure.

Reduction of the Burning Rate

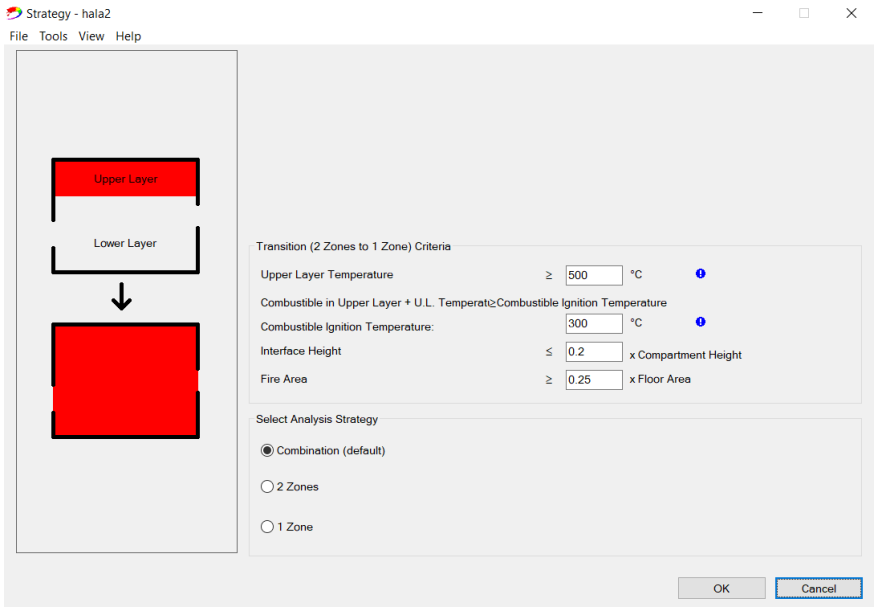
$$Q = Q_0 e^{-k(t-t_0)}$$

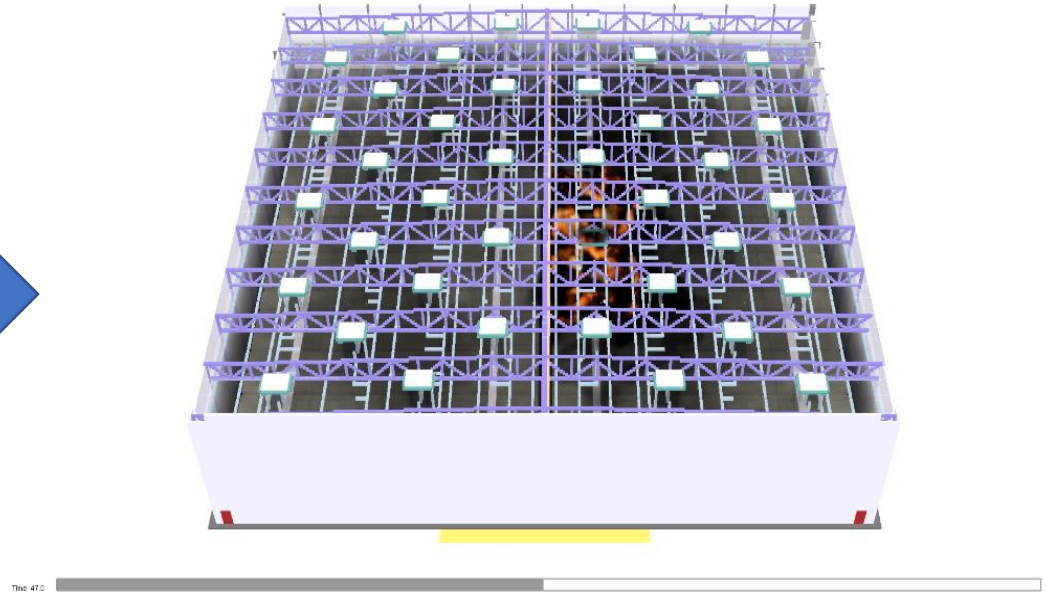
Q_0 – HRR at sprinkler actuation t_0 [kW]

k – fuel dependent constant

Source: H.Z. Yu, J.L. Lee, and H.C. Kung. Suppression of Rack-Storage Fires by Water. In Fire Safety Science – Proceedings of the Fourth International Symposium, pages 901–912. International Association For Fire Safety Science, 1994

Computational fluid dynamics, CFD

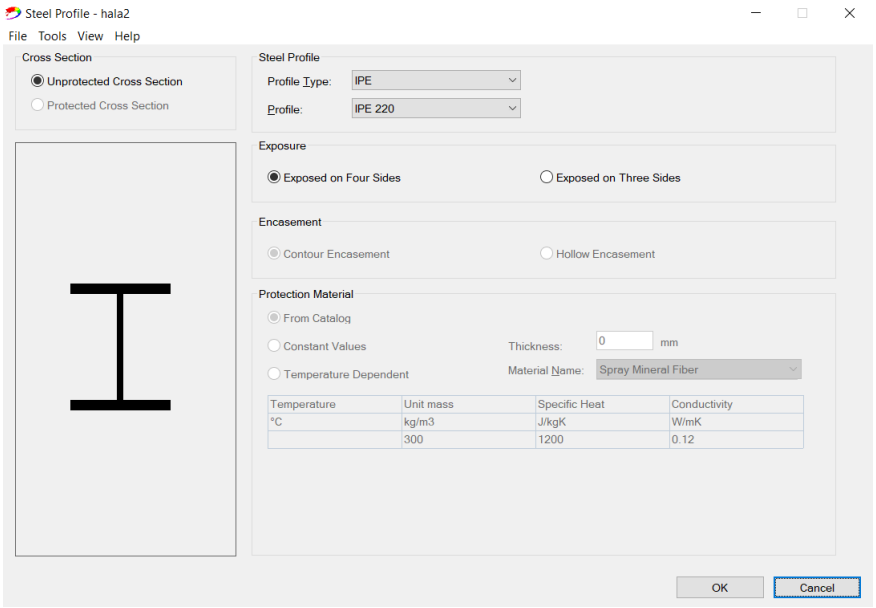


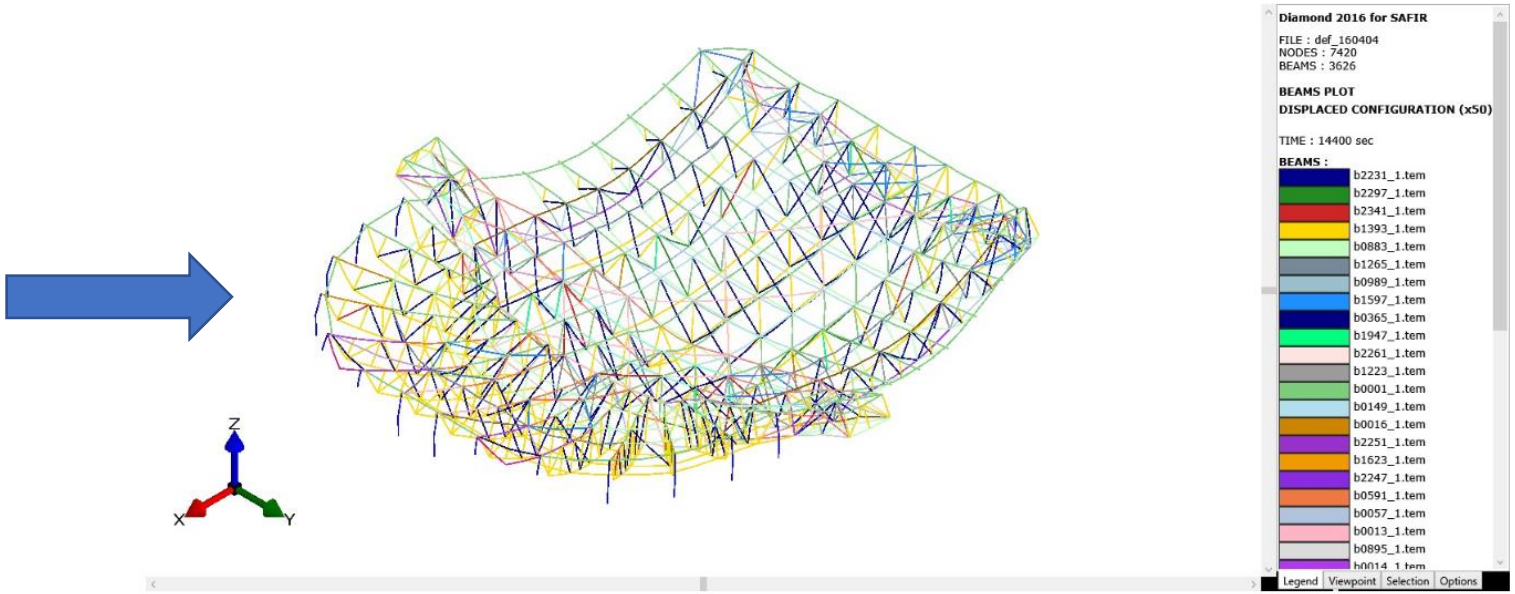


Source: strategy for compartment fires (Ozone)

Source: own study

Finite element method, FEM

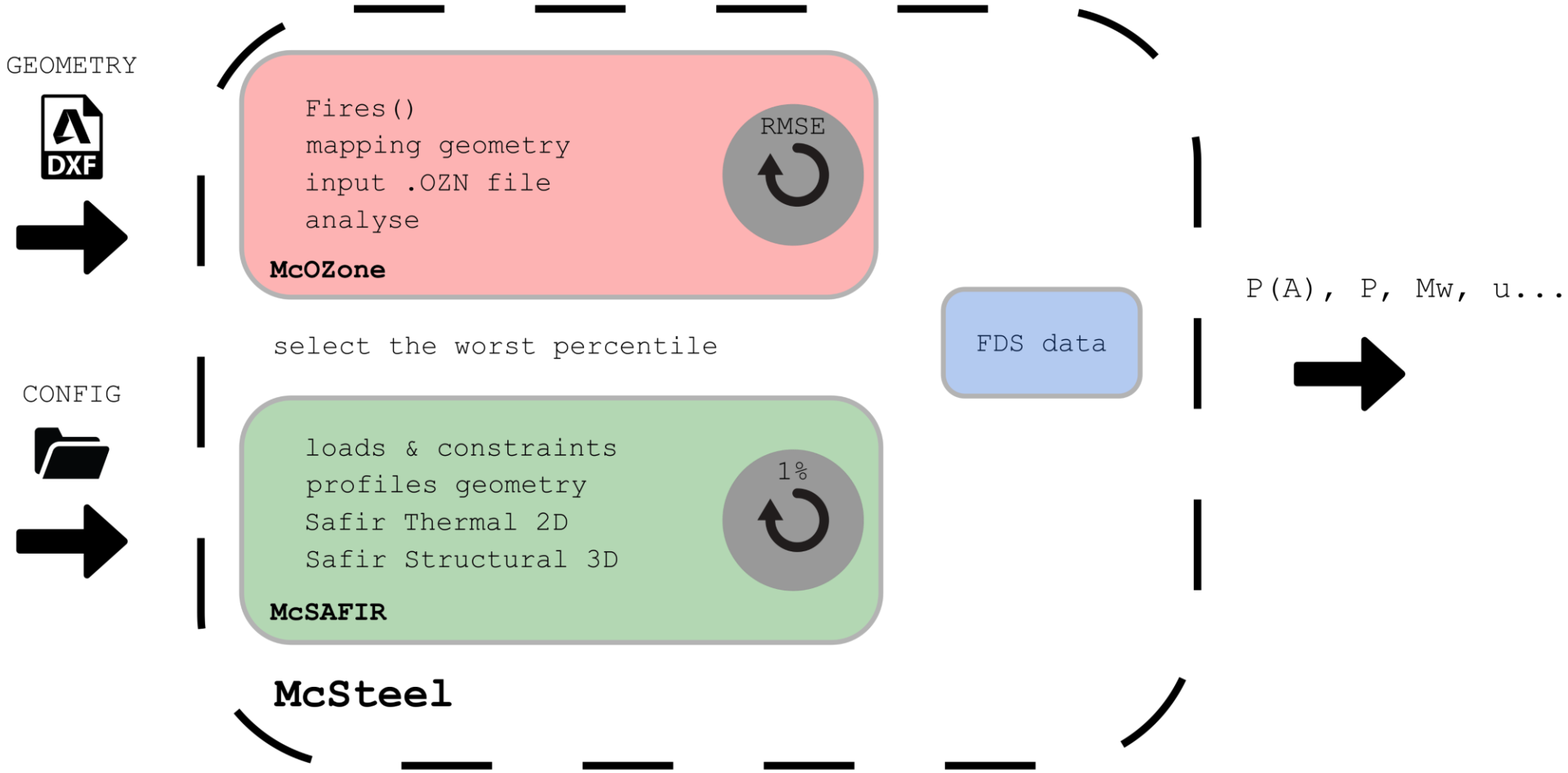




Source: steel profile window (Ozone)

Source: https://www.uee.uliege.be/cms/c_2383458/en/safir

McSteel



Source: own study

„These days, there's not much you can understand about what is going on around you if you do not understand the uncertainty attached to pretty much every phenomenon."

- J.N. Tsitsiklis

THANK YOU !

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