STRUCTURES IN FIRE FORUM

Travelling or Parametric fire curves?

A data-driven model for building fire risk assessment in performance-based design

Date: 10th April 2026

Time: 15:30 – 16:00

Location: University of Sheffield, 32 Leavygreave Rd S3 7RD

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LONDON / BIRMINGHAM / OXFORD / EASTBOURNE / IRELAND / MANCHESTER

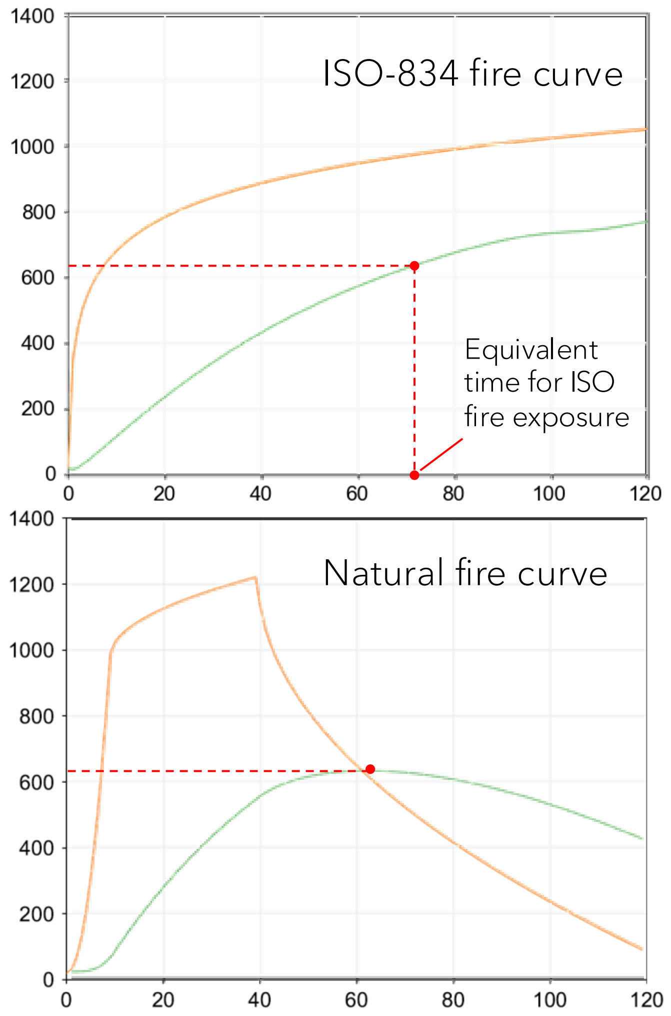
Contents

Problem description

Time equivalent method

Table B2 Minimum periods of fire resistance

Purpose group of building	Minimum periods of fire resistance[1] (minutes) in a:						
	Basement storey* including floor over		Ground or upper storey				
	Depth (m) of the lowest basement		Height (m) of top floor above ground, in a buil… separated part of a building				
	More than 10	Up to 10	Up to 5	Up to 11	Up to 18	Up to 30	More than 30
1. Residential:							
a. Block of flats							
– without sprinkler system	90 min	60 min	30 min†	60 min+§	Not permitted[2]	Not permitted[2]	Not permitted[2]
– with sprinkler system[3]	90 min	60 min	30 min†	60 min+§	60 min+§	90 min+	120 min+
b. and c. Dwellinghouse	Not applicable[4]	30 min*†	30 min†	60 min[5]	60 min[5]	Not applicable[4]	Not applicable[4]
2. Residential							
a. Institutional	90 min	60 min	30 min†	60 min	60 min	90 min	120 min‡
b. Other residential	90 min	60 min	30 min†	60 min	60 min	90 min	120 min‡
3. Office:							
– without sprinkler system	90 min	60 min	30 min†	60 min	60 min	90 min	Not permitted[6]
– with sprinkler system[3]	60 min	60 min	30 min†	30 min†	30 min†	60 min	120 min‡
4. Shop and commercial:							
– without sprinkler system	90 min	60 min	60 min	60 min	60 min	90 min	Not permitted[6]
– with sprinkler system[3]	60 min	60 min	30 min†	60 min	60 min	60 min	120 min‡



Structural fire resistances are defined based on the ISO fire curve. The time equivalent method in structural fire design converts a real, natural fire scenario into an equivalent duration of a standard fire (e.g., ISO 834) to determine required fire resistance.

Compartment fire models

Question: which natural fire model should be used for calculating the structural fire resistance?

Compartment fire models

BS EN 1991-1-2:2002
EN 1991-1-2:2002 (E)

Annex A
(informative)

Parametric temperature-time curves

The European Union
EDICT OF GOVERNMENT

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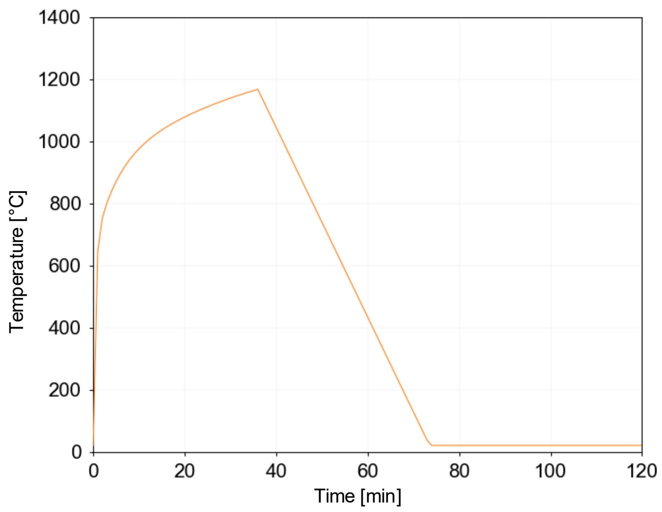
EN 1991-1-2 (2002) (English): Eurocode 1: Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire [Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC]

(1) The following temperature-time curves are valid for fire compartments up to 500 m^2 of floor area, without openings in the roof and for a maximum compartment height of 4 m. It is assumed that the fire load of the compartment is completely burnt out.

(2) If fire load densities are specified without specific consideration to the combustion behaviour (see annex E), then this approach should be limited to fire compartments with mainly cellulosic type fire loads.

(3) The temperature-time curves in the heating phase are given by:

$$\Theta_g = 20 + 1\,325\ (1 - 0{,}324\,e^{-0{,}2\,t^*} - 0{,}204\,e^{-1{,}7\,t^*} - 0{,}472\,e^{-19\,t^*}) \qquad \text{(A.1)}$$



Eurocode 1991-1-2: parametric fire curves

Fire Safety Journal 54 (2012) 96–112
Contents lists available at SciVerse ScienceDirect
Fire Safety Journal
journal homepage: www.elsevier.com/locate/firesaf

ELSEVIER

Travelling fires for structural design-Part II: Design methodology

Jamie Stern-Gottfried [a,b], Guillermo Rein [a,*]

Received: 18 February 2019 | Revised: 15 January 2020 | Accepted: 6 February 2020
DOI: 10.1002/fam.2810

SPECIAL ISSUE PAPER

WILEY

An extended travelling fire method framework for performance-based structural design

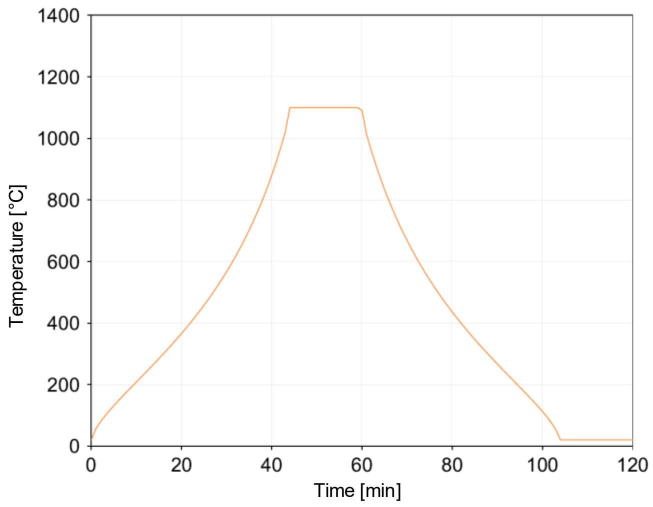
Xu Dai[1] | Stephen Welch[1] | Olivier Vassart[2] | Kamila Cábová[3] | Liming Jiang[4] | Jamie Maclean[1] | George Charles Clifton[5] | Asif Usmani[4]

ELSEVIER

Engineering Structures
Volume 33, Issue 5, May 2011, Pages 1635-1642

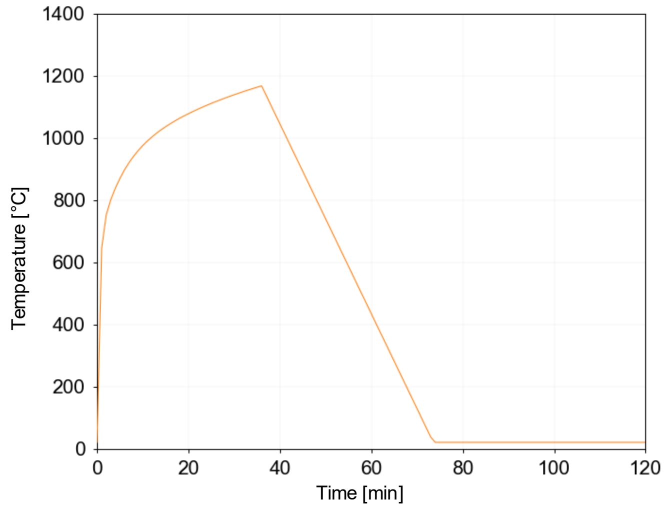
The influence of travelling fires on a concrete frame

Angus Law [1], Jamie Stern-Gottfried [1], Martin Gillie, Guillermo Rein



Travelling fire model

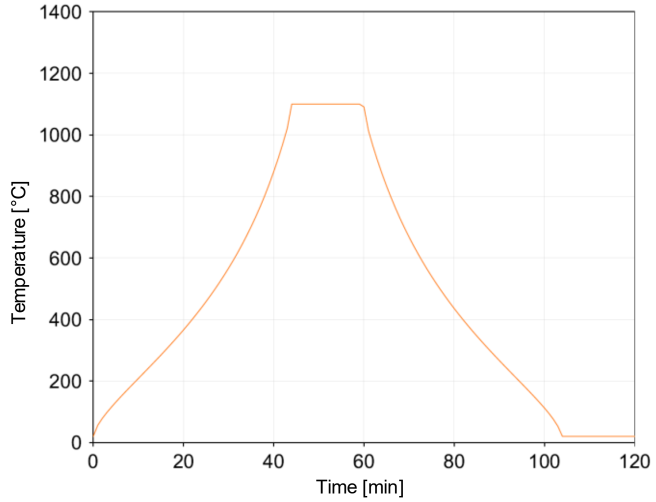
Compartment fire models



Eurocode 1991-1-2: parametric fire curves

- **Compartment floor area**
- **Compartment height**
- **Fire load density**
- Ventilation factor
- Thermal inertia
- Fire growth rate

When should we use EN or TF model?



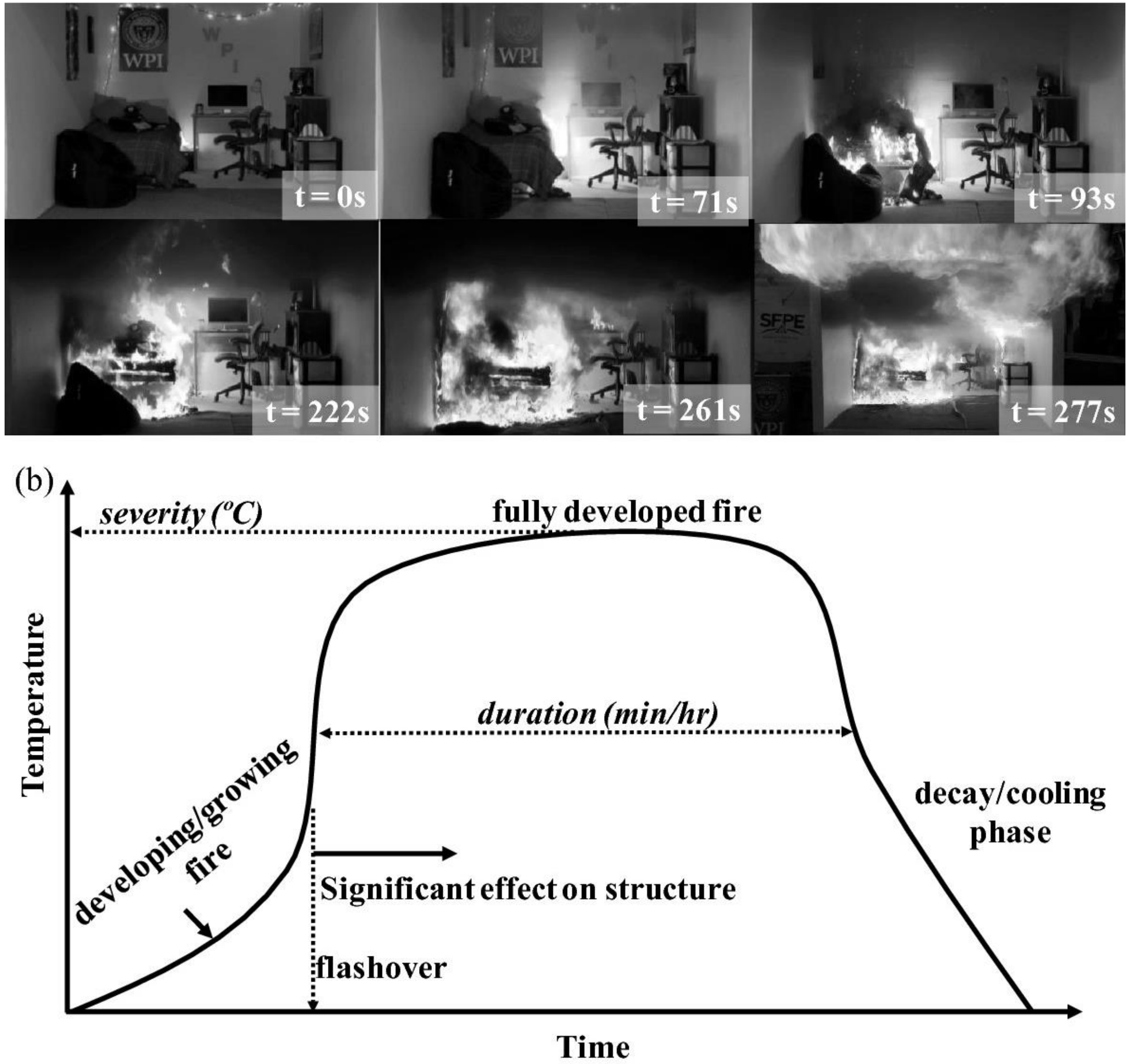
Travelling fire model

- **Compartment floor area**
- **Compartment height**
- **Fire load density**
- Fire spread rate
- Heat release rate

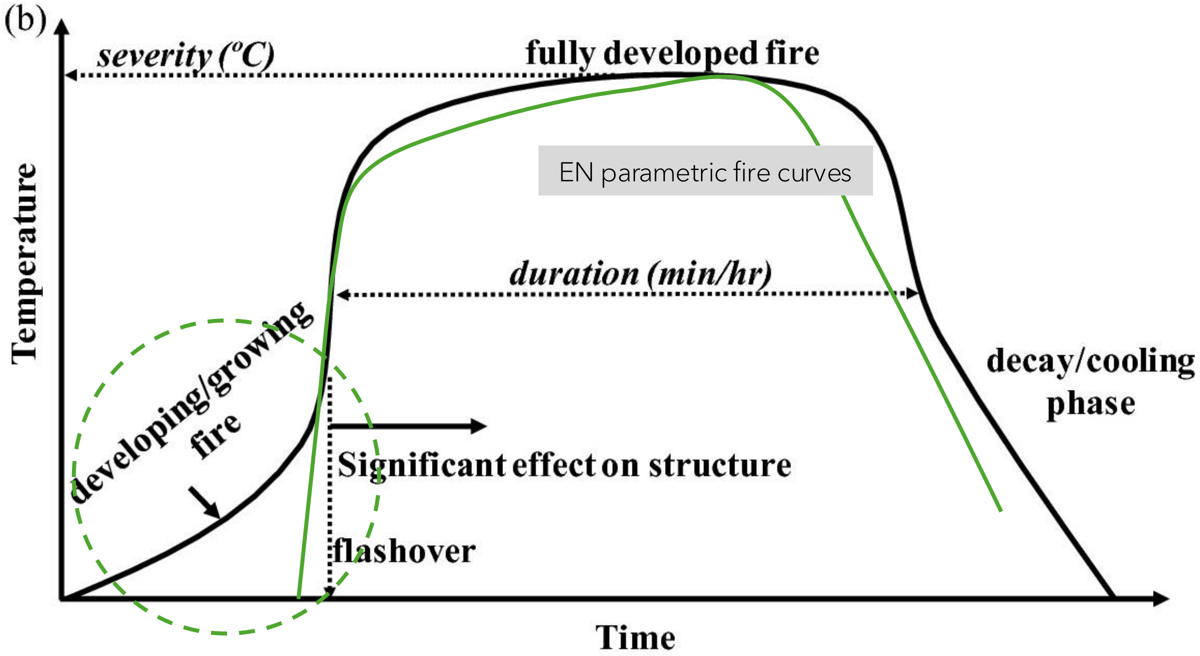
Check with the full-scale tests!

Fire curves comparison

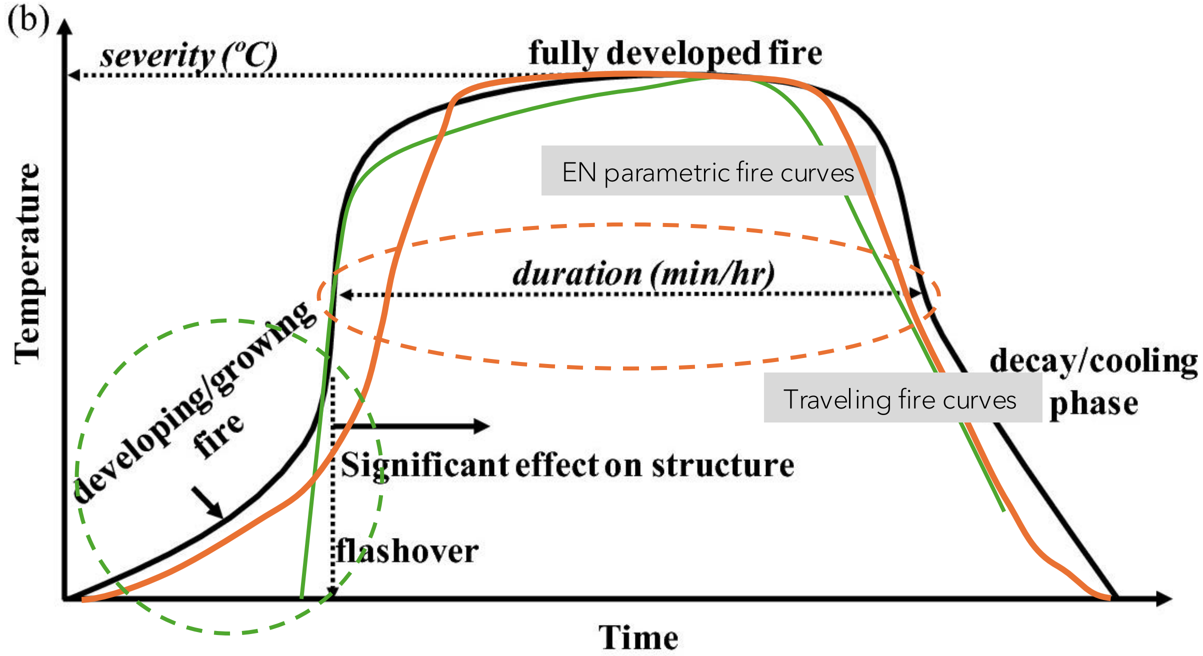
Identify the best-performing model



Identify the best-performing model



Identify the best-performing model

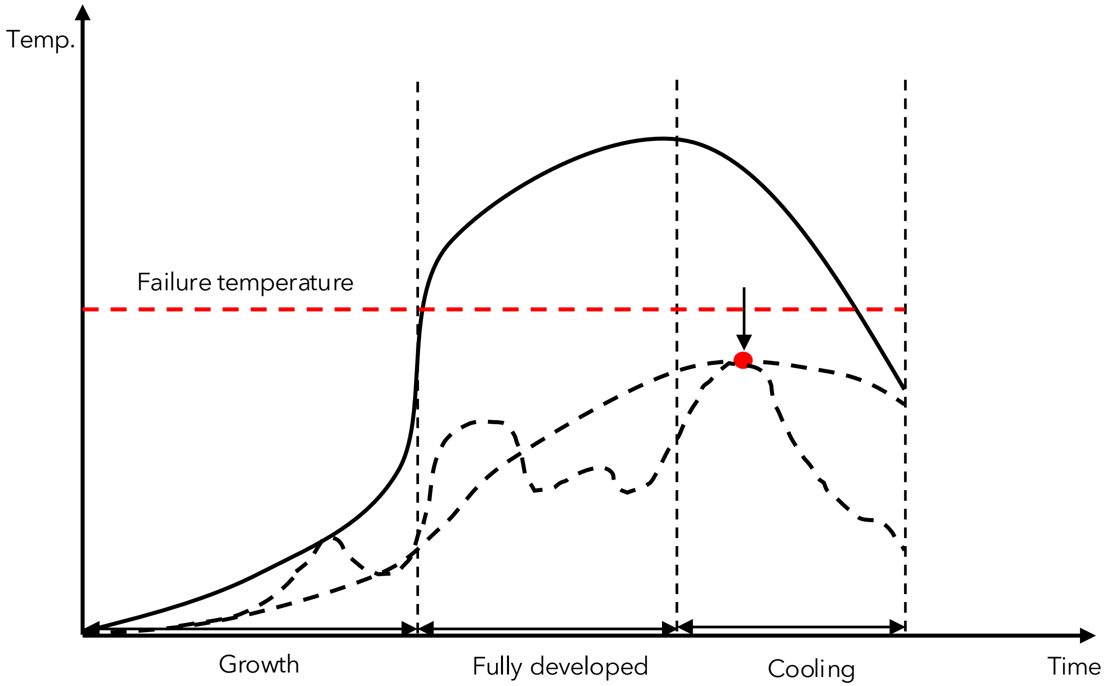


Which model is the best?

Which parameter should we look at?

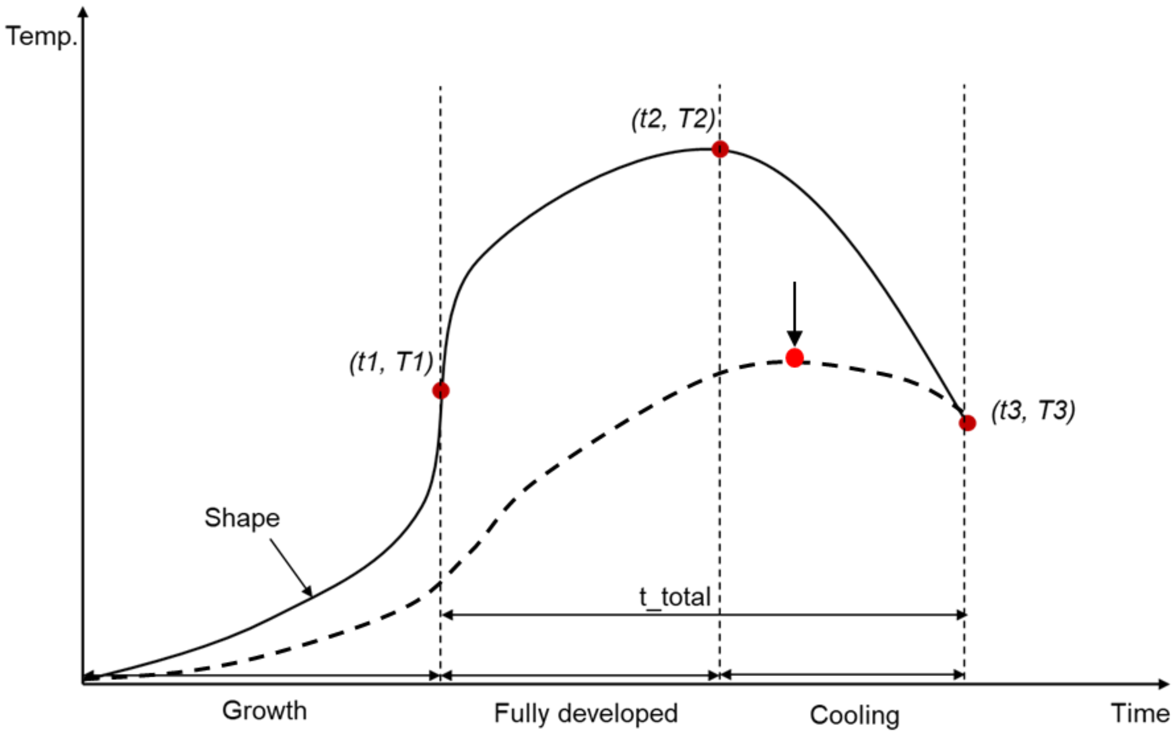
Identify key parameters

From structural fire engineering perspective:



Which **fire parameter** contributes the most to the **peak steel temperature changes**?

Sensitivity study



Parameters	Referenced value	Range of data variation
Flashover time (t_1) [min]	10	[5, 15]
Flashover temperature (T_1) [°C]	500	[350, 650]
Curve shape [-]	Linear	[Linear, quadratic]
Peak temperature (T_2) [°C]	1000	[750, 1250]
Time to peak temperature ($t_2 - t_1$) [min]	80	[60, 100]
Cooling temperature (T_3) [°C]	500	[350, 650]
Total fire duration ($t_3 - t_2$) [min]	100	[80, 120]

Define referenced fire and steel curves

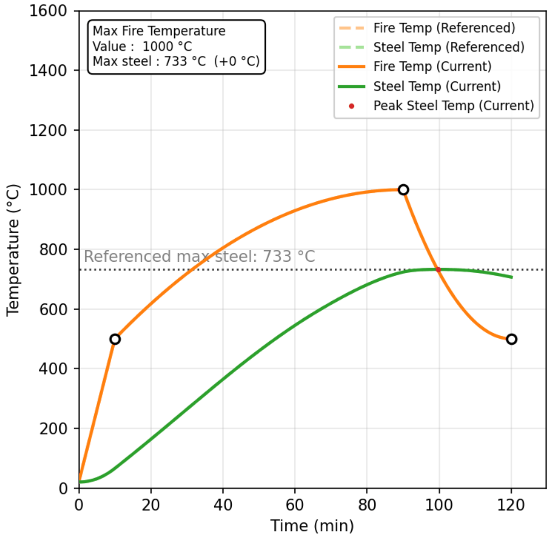
↓

Vary each parameter for around ±50%

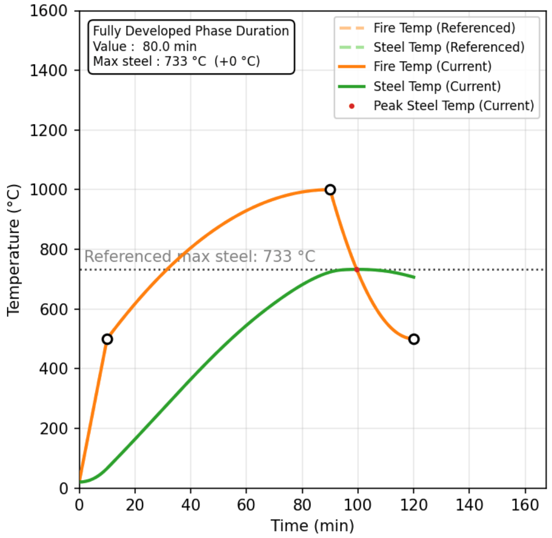
↓

Check the variation of the peak steel temperature

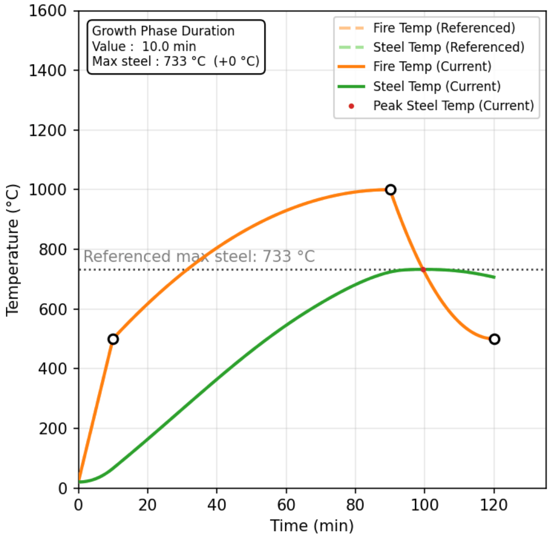
Identify key parameters



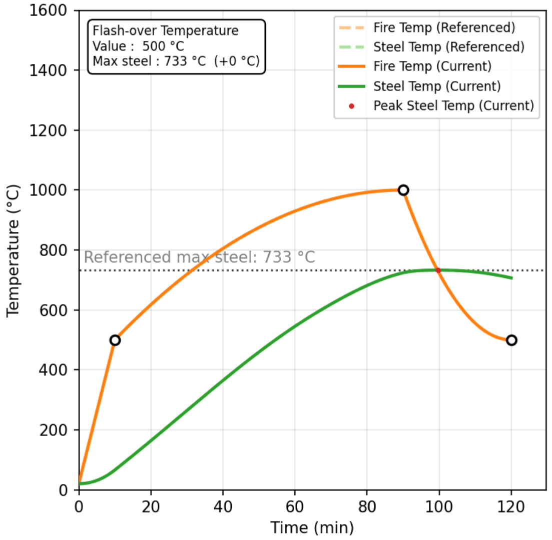
Peak fire temperature



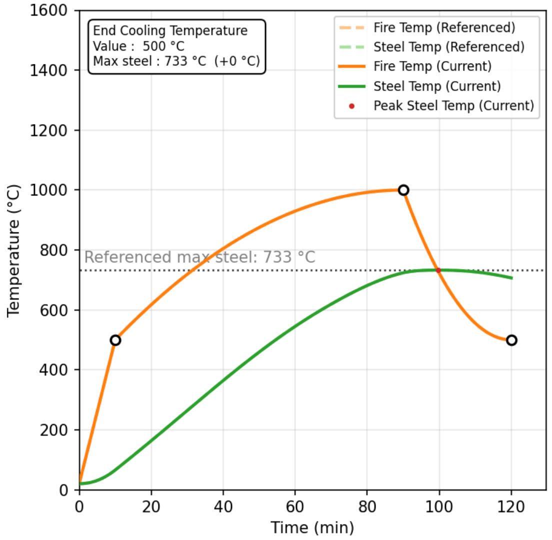
Total fire duration



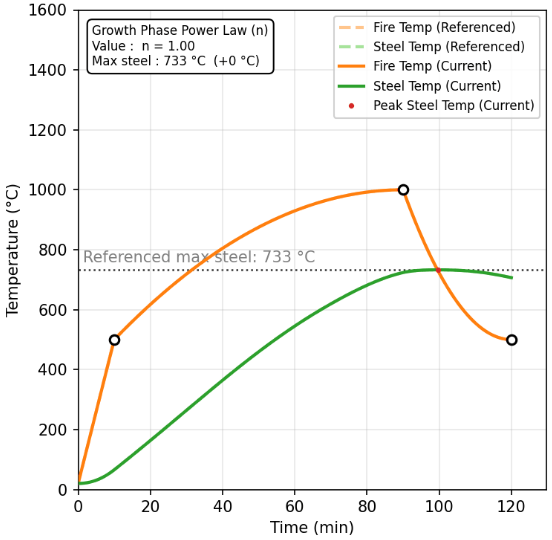
Fire growth time



Flashover temperature

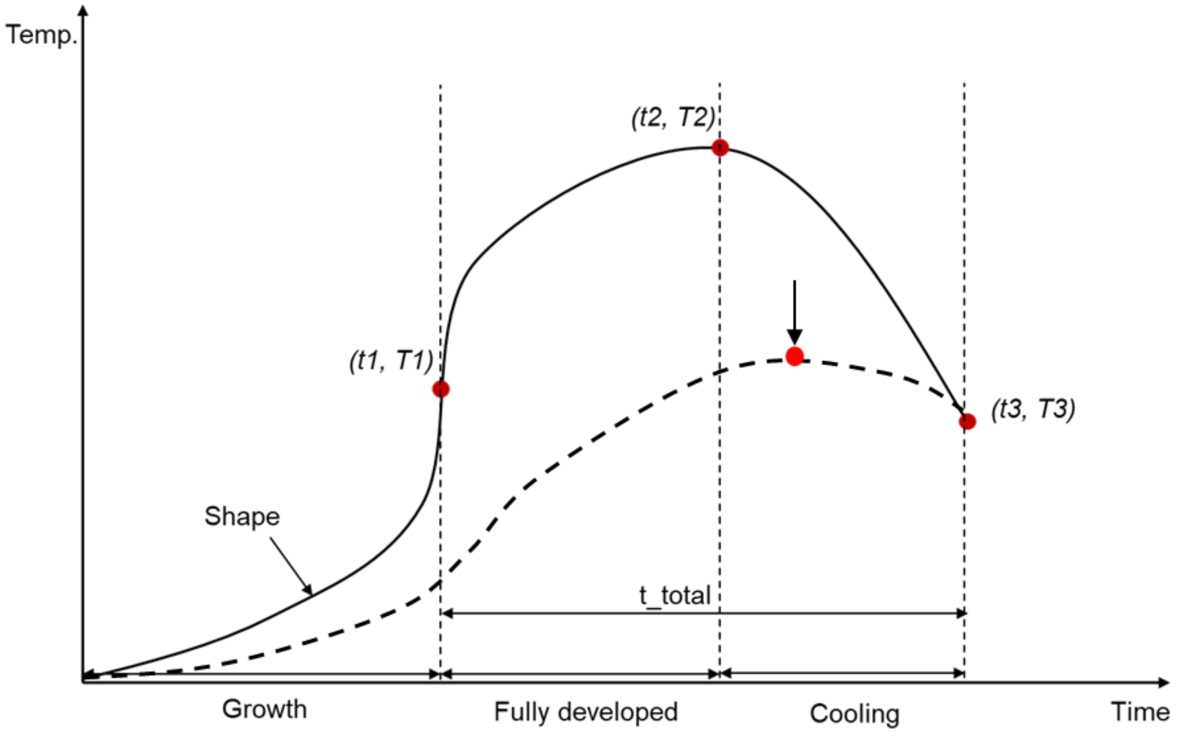


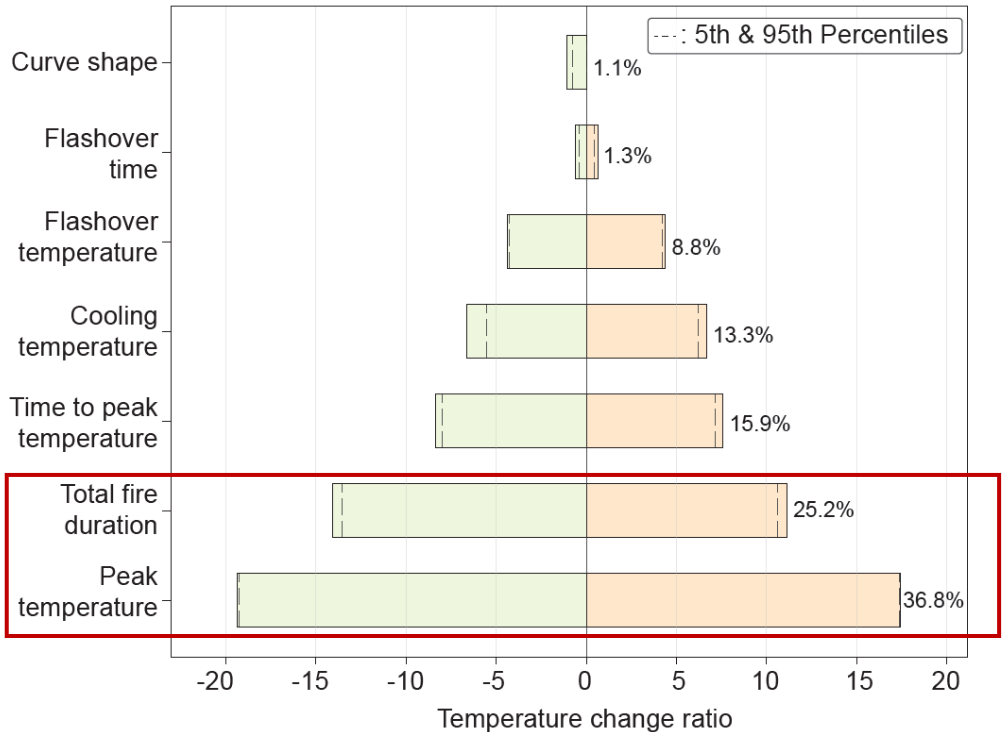
Cooling temperature



Fire growth curve

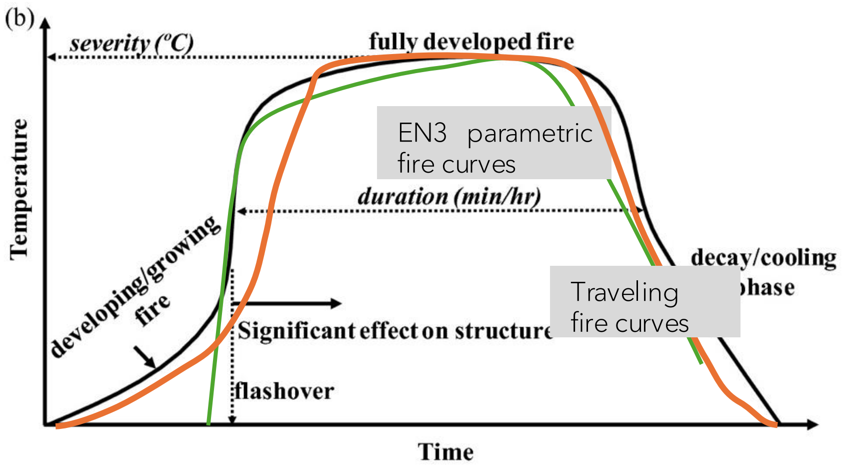
Identify key parameters (sensitivity)





- The **Peak temperature** and **Total fire duration** are the most important factors in determining the **peak steel temperature** (> 20 %).
- Importance: $\frac{Total\ fire\ duration}{Peak\ temperature} = \frac{0.252}{0.368}$

Identify best-performing model

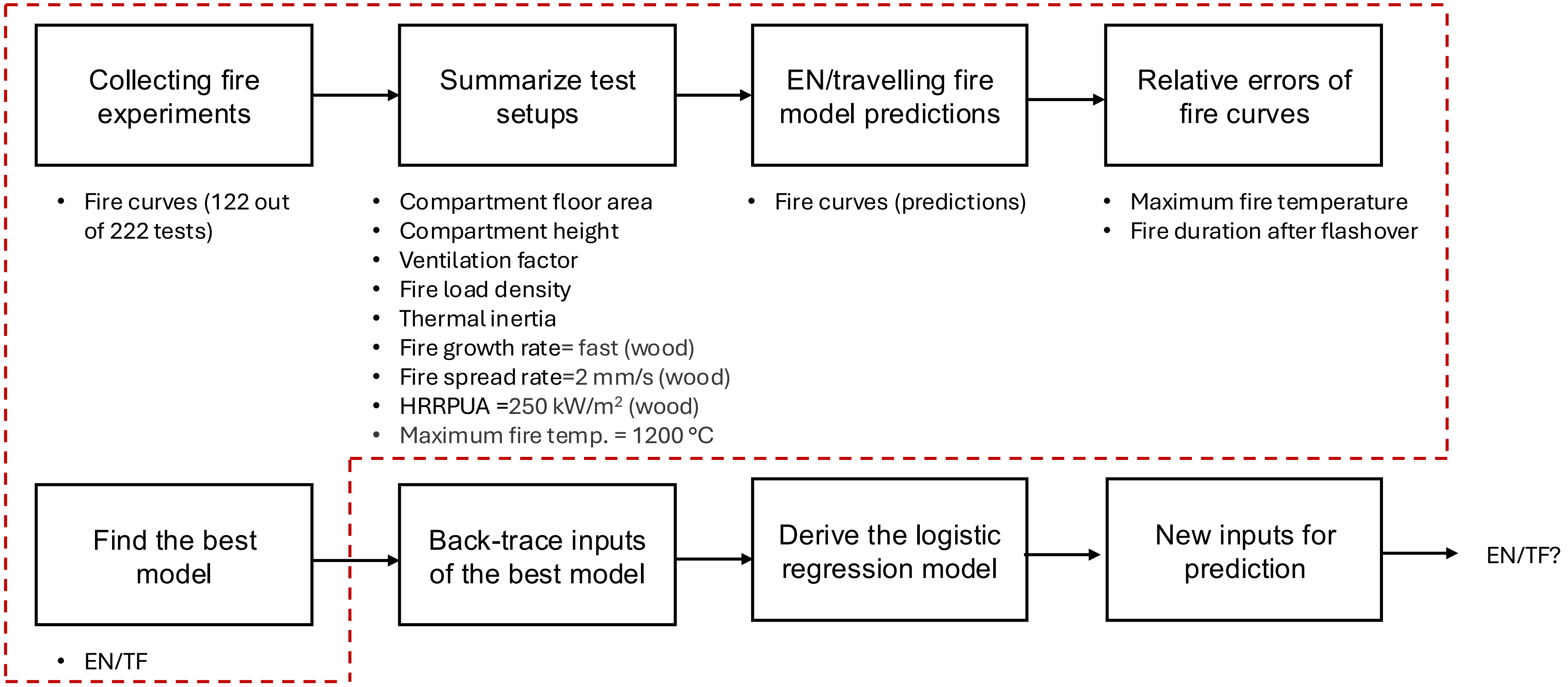


$$\frac{Total\ fire\ duration}{Peak\ temperature} = \frac{0.252}{0.368}$$

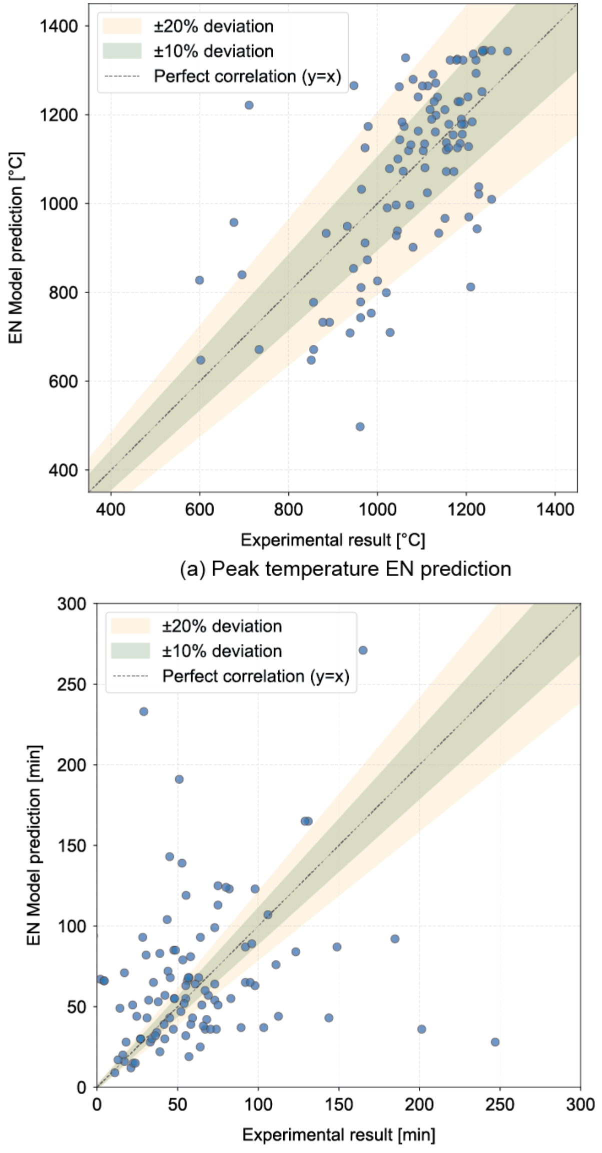
Name	Test	EN parametric fire		Travelling fire	
		Value	Relative error [-]	Value	Relative error [-]
Total fire duration [min]	100	95	(95 – 100) / 100 = -0.05	80	(80 – 100) / 100 = -0.2
Peak temperature [°C]	1000	950	(950 - 1000)/1000 = -0.05	1050	(1050 - 1000)/1000 = 0.05
Total relative error [-]	-	/	0.252*(-0.05) + 0.368*(-0.05) = -0.031	/	0.252*(-0.2) + 0.368*(0.05) = -0.032
Winner (best perfoming model)			✓		

Development of the logistic regression model

Methodology

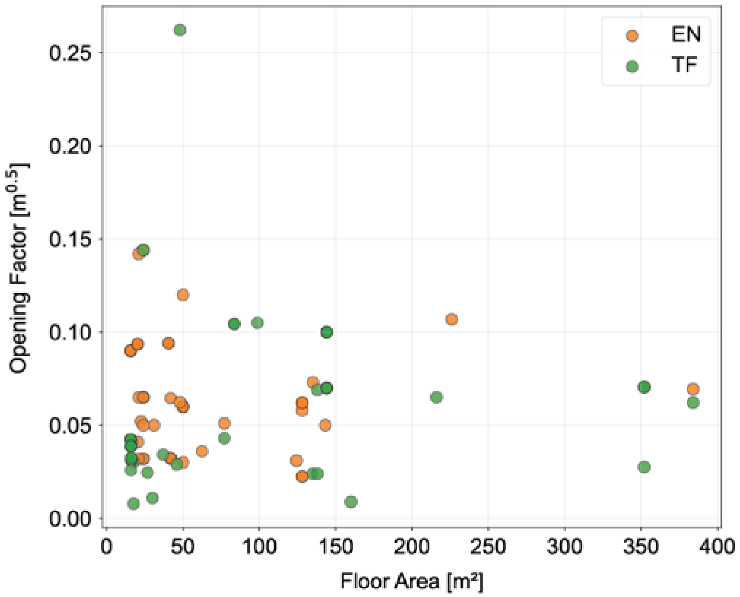


Full-scale experiments



(a) Peak temperature EN prediction
(b) Peak temperature TF prediction
(c) Total fire duration EN prediction
(d) Total fire duration TF prediction

- Database description:
  - 122 out of 222 full-scale tests in total
  - Test setups are summarized
  - Average temperature-time curves are collected
- Selecting criteria:
  - Compartment floor area > 20 [m^2];
  - Fire load density > 50 [MJ/ m^2];
  - Ventilation factor > 0.02;
  - Peak temperature > 500 [°C];
  - Include (part of) cooling phase.

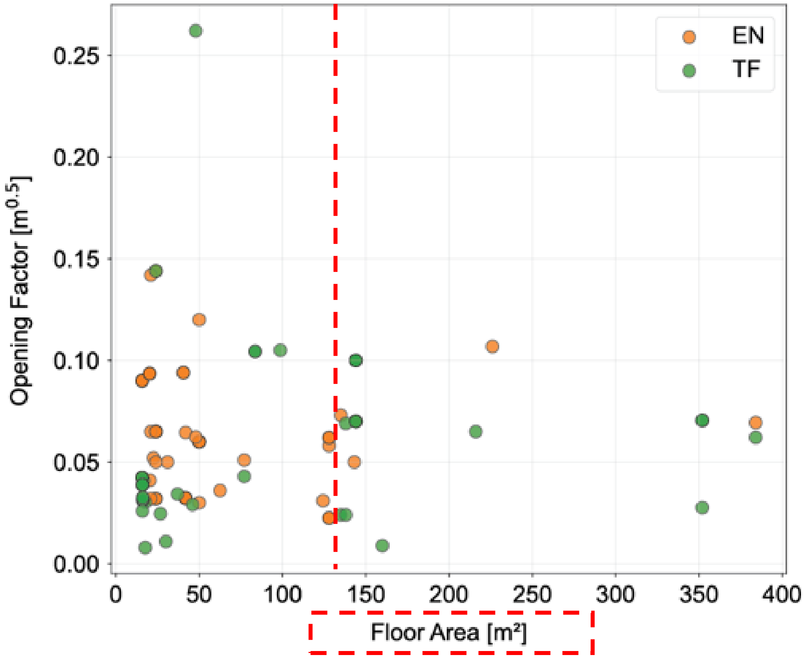


Logistic regression model

- Compartment floor area
- Opening factor
- Compartment height
- Thermal inertia
- Fire load density

Inputs

Logistic Regression Model



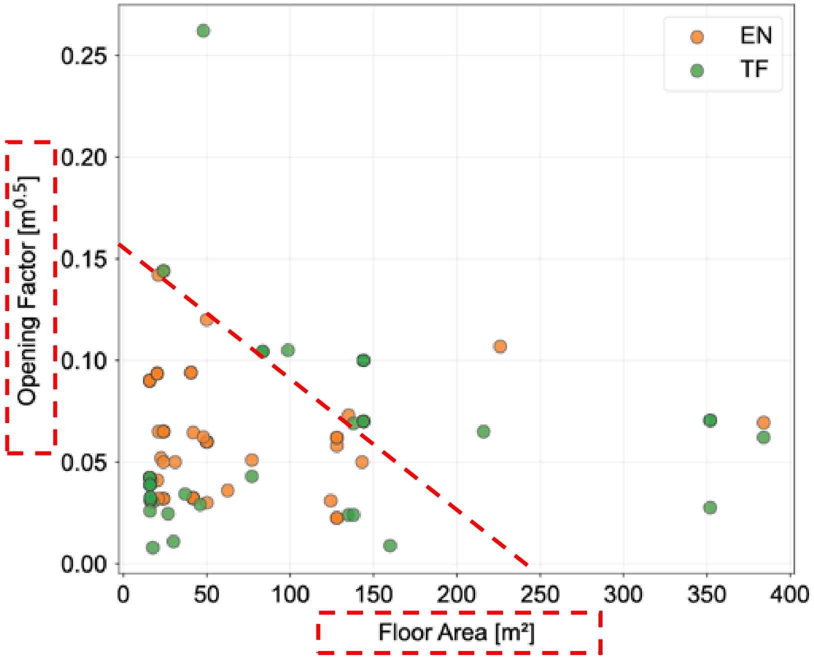
EN/travelling fire model

Logistic regression model

- Compartment floor area
- Opening factor
- Compartment height
- Thermal inertia
- Fire load density

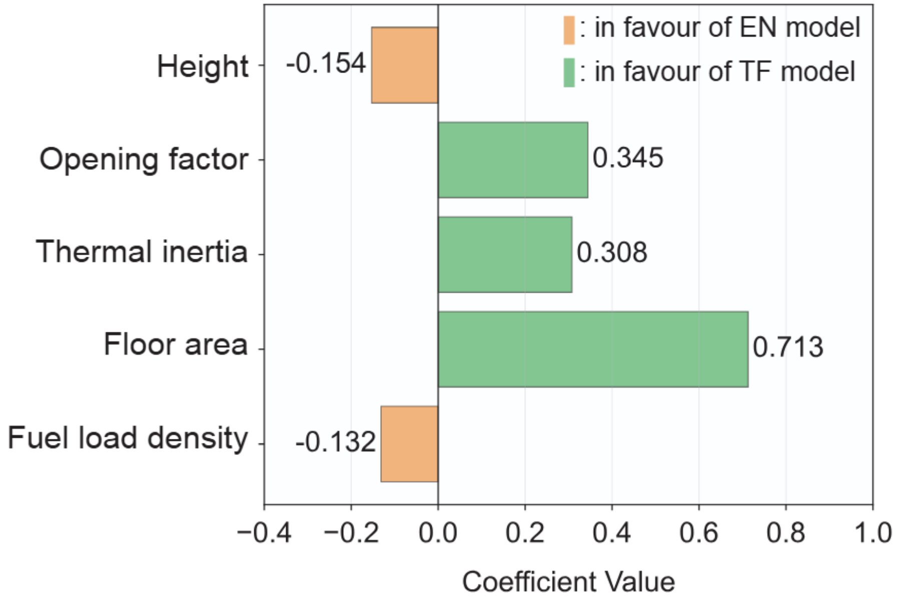
Inputs

Logistic Regression Model



EN/travelling fire model

LR model results



Feature importance in classifying EN and TF:

1. Floor area
2. Opening factor
3. Thermal inertia

Step-1: fire model inputs:

- Floor area: A_f
- Opening factor: O
- Thermal inertia: b
- Fuel load density: q
- Compartment height: H_c

Step-2: calculate linear predictor z:

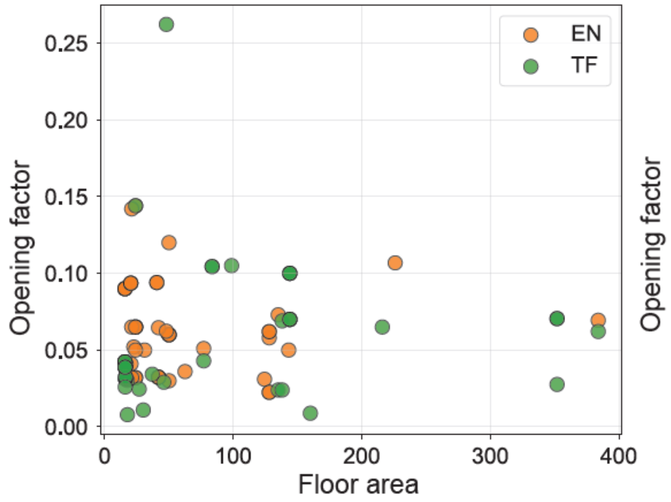
$$z = -0.111 + \frac{616.07 - q}{1905} + \frac{A_f - 89.92}{123.7} + \frac{b - 846.64}{1424.8} + \frac{O - 0.066}{0.1} + \frac{2.95 - H_c}{2.98}$$

Step-3: transform z to a logistic (sigmoid) function:

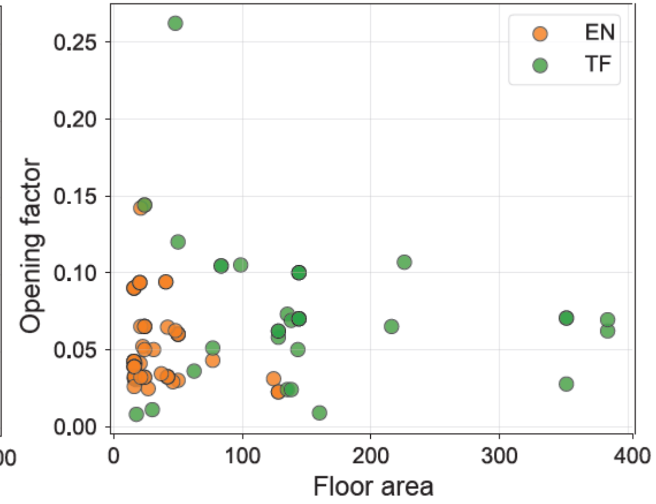
$$p = \frac{1}{1 + e^{-z}}$$

If $P \geq 0.5$ → TF model; else EN model.

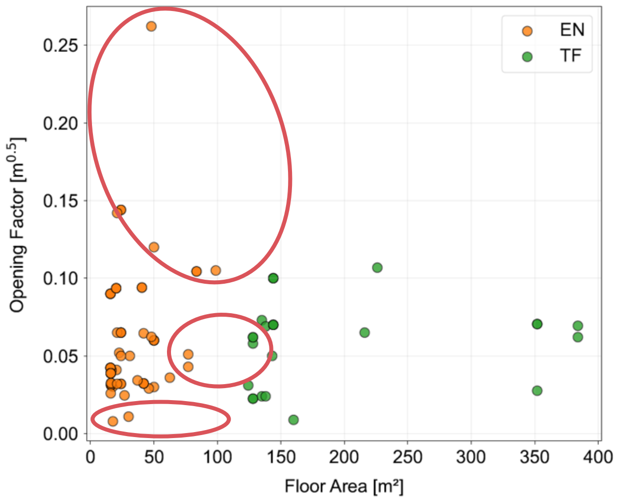
LR model performance



Experimental results

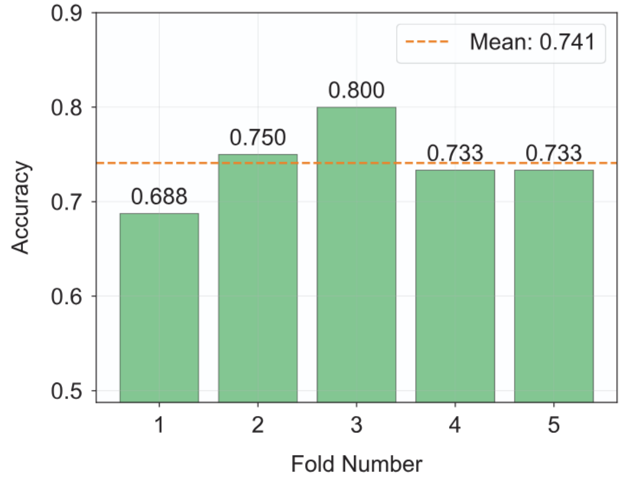


Logistic regression model prediction

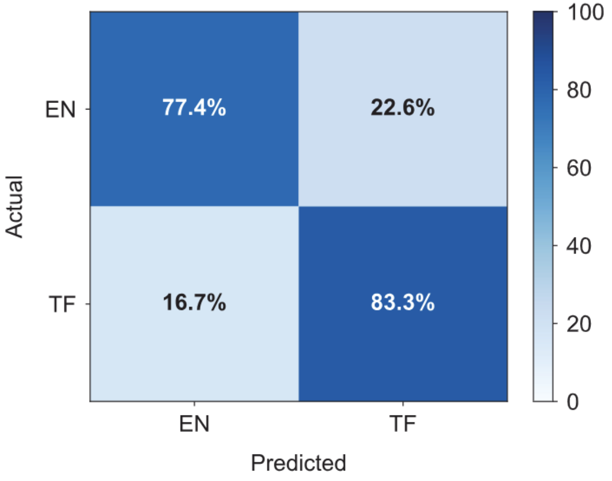


Traditional 100 [m^2] method

(1) Experiments v.s. LR predictions



(a) Cross-validation results



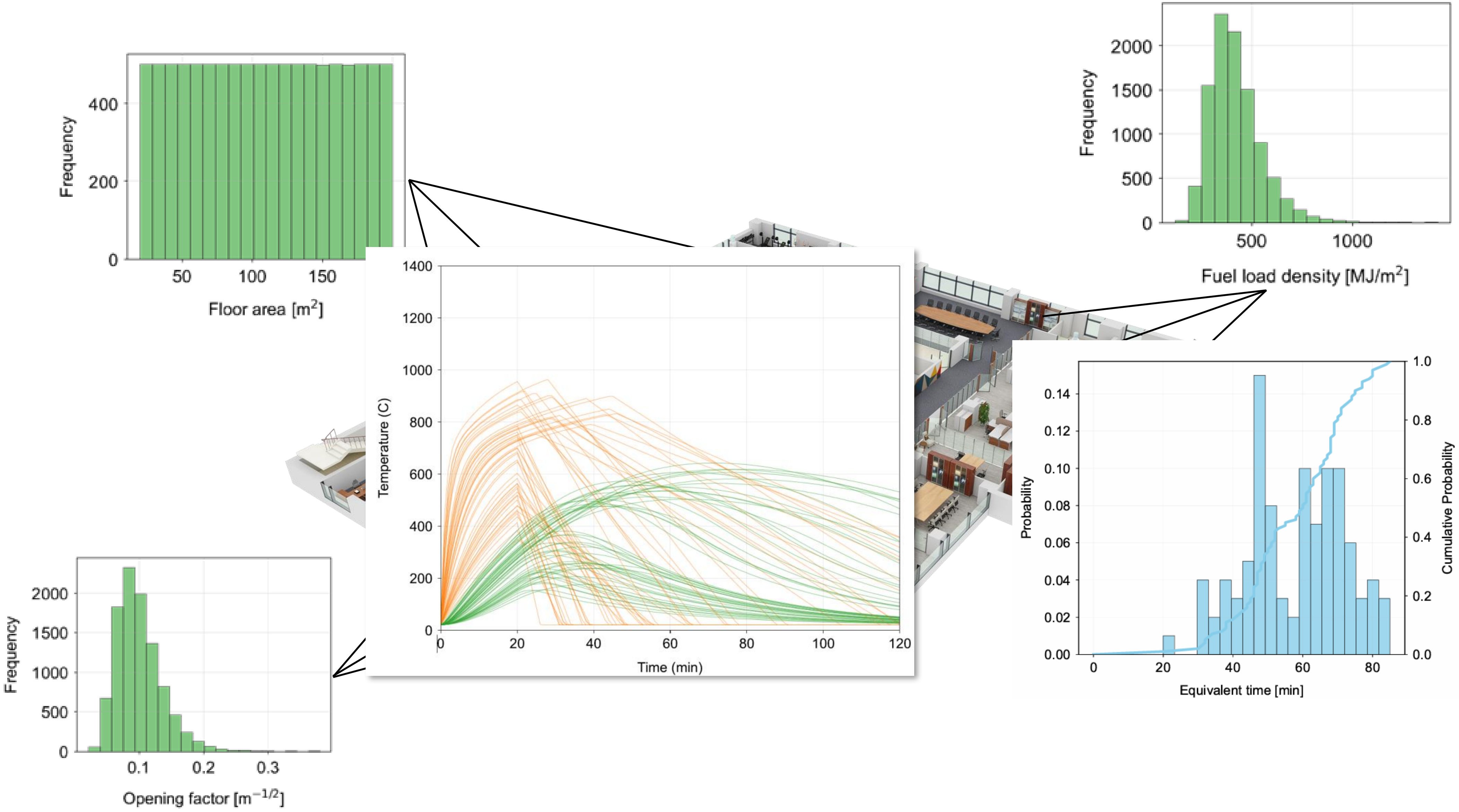
(b) Confusion matrix

(2) LR model performance

- Accuracy of the trained model: 74.1±5.3%
- Accuracy in predicting EN model: 77.4%
- Accuracy in predicting TF model: 83.3%

Implementation of the model in PRA

Risk-based approach



Risk-based approach

paper: kirby *et al*

A new approach to specifying fire resistance periods

Synopsis
A Task Group under the auspices of the British Standards Institution was formed to develop a new approach for specifying fire resistance requirements for building design for inclusion in the new DD 9999 'Code of practice *for fire safety design, construction and the use of buildings*'.
The task group which was made up of researchers and fire safety engineering practitioners, developed a set of fire resistance periods for each occupancy group and taking into account, the effectiveness of sprinklers in reducing fire severity where active fire protection measures may be employed. A single table of fire

structural failure.

The aim of this paper is to present an overview of the work carried out by the Task Group that has led to a new set of fire resistance periods being proposed for consideration in the development of DD 9999.

Development of the analytical approach

Fig 1 provides an overview of the analytical processes carried out by the Task Group. This process involved the following main steps:

- Engineering calculations based upon a Time Equivalent approach to specifying fire resistance.

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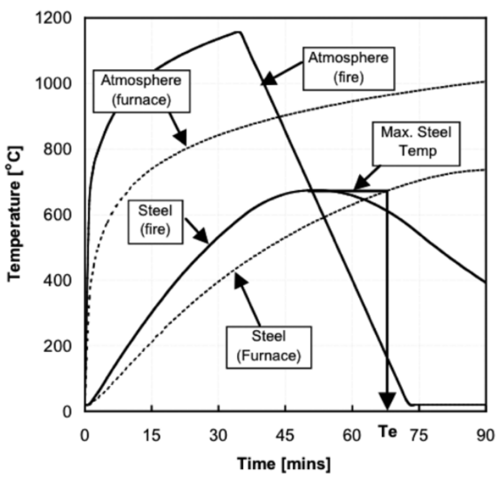

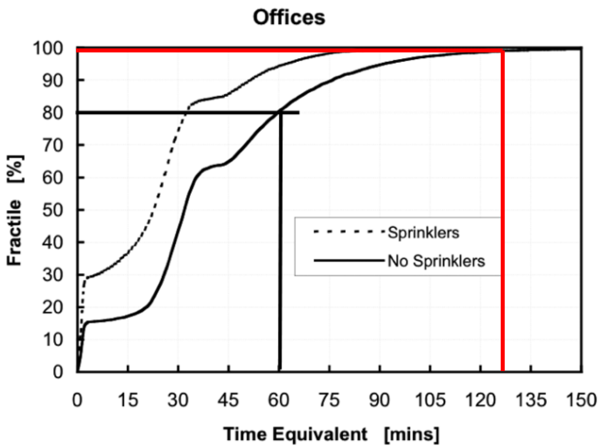

Fire Technology, 51, 771–784, 2015

DOI: 10.1007/s10694-014-0410-9

A Risk Based Framework for Time Equivalence and Fire Resistance

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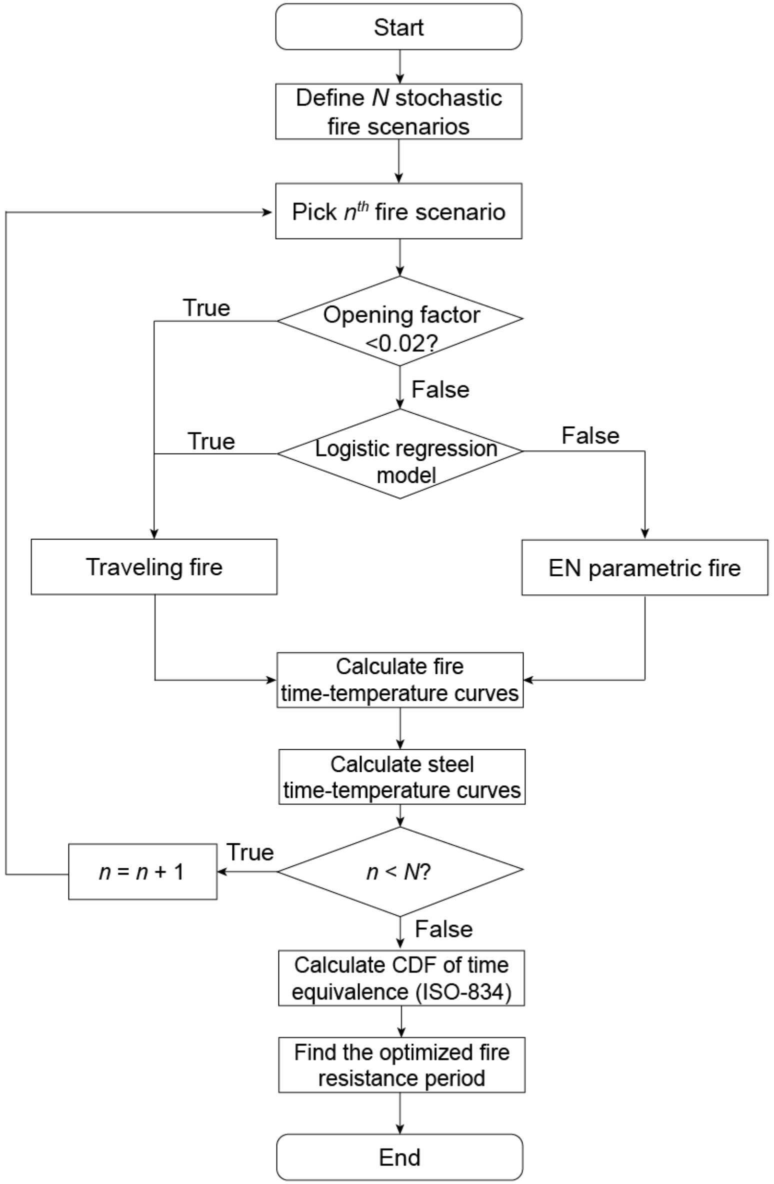
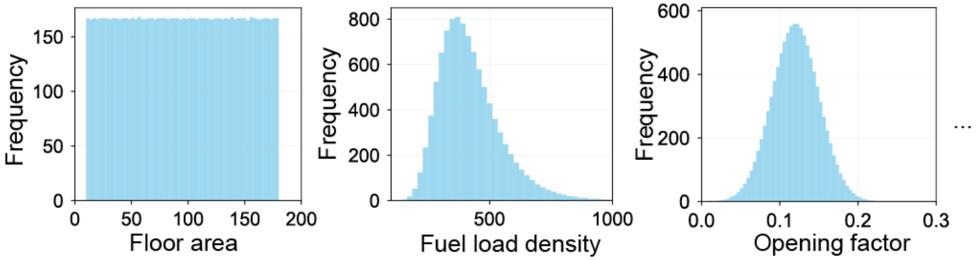
Received: 30 January 2014/**Accepted:** 26 April 2014

Table 1
Design Structural Reliability

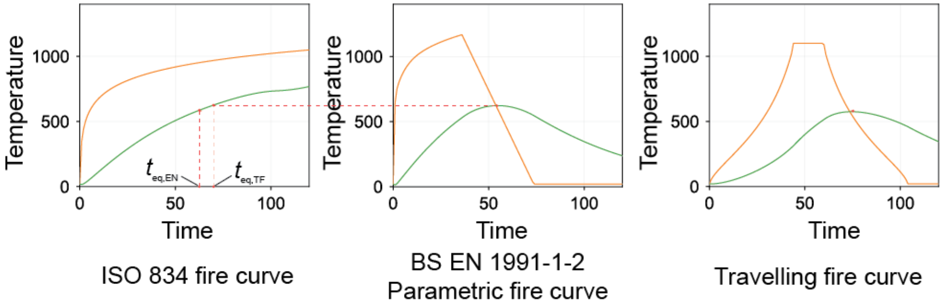
Building height (m)	Design reliability	Structural reliability with: 75% Reliable sprinklers	90% Reliable sprinklers	95% Reliable sprinklers
10	35%	N/A	N/A	N/A
20	84%	35%	N/A	N/A
30	93%	71%	28%	N/A
40	96%	84%	60%	19%
50	97%	90%	74%	48%
60	98%	93%	82%	64%
80	99%	96%	90%	80%

Implementation in PRA

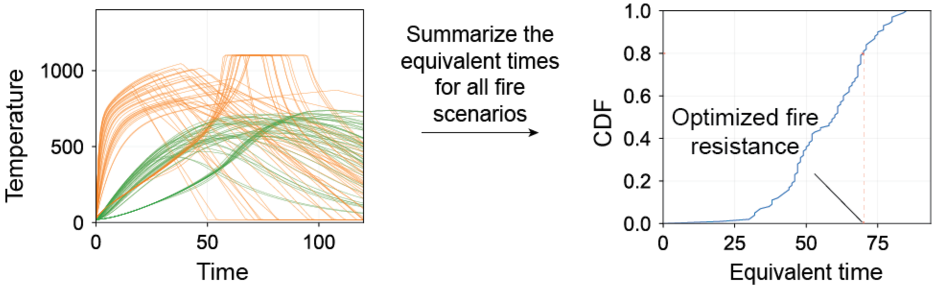




Stochastic values are generated using the Latin Hypercube Sampling (LHS) method to ensure all possible scenarios are considered.



For each scenario, converts the real (natural) fire into an equivalent duration (t_{eq}) under the standard ISO fire curve via the peak steel temperature.



With the designed structural reliability (a function of building height) from the Cumulative Density Function (CDF) plot, the optimized structural resistance period can be determined.

Acknowledgement

Yong Wang, Professor

Civil Engineering and Management,
University of Manchester

Charlie Hopkin, PhD

Director,
Ashton Fire

Lee Cunningham, Reader

Civil Engineering and Management,
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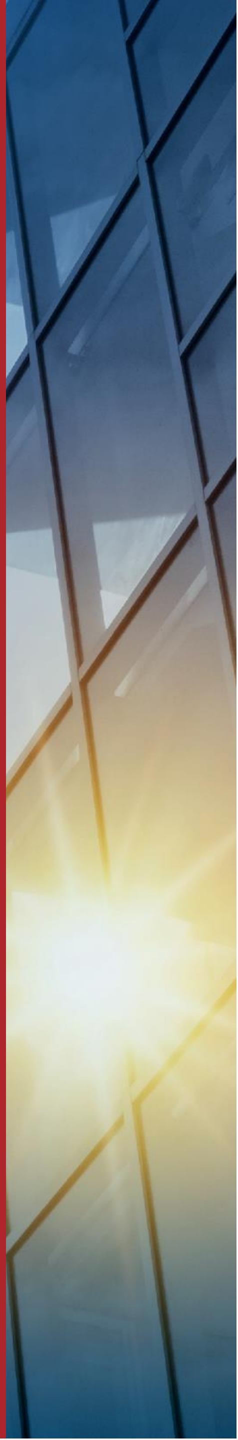

Structures in Fire Forum

Thanks!

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LR model:

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