*Milano,*
*XVI Convegno nazionale AIIA*

# La qualità degli studi basati sull’approccio ingegneristico e la qualifica degli operatori

Luca Nassi

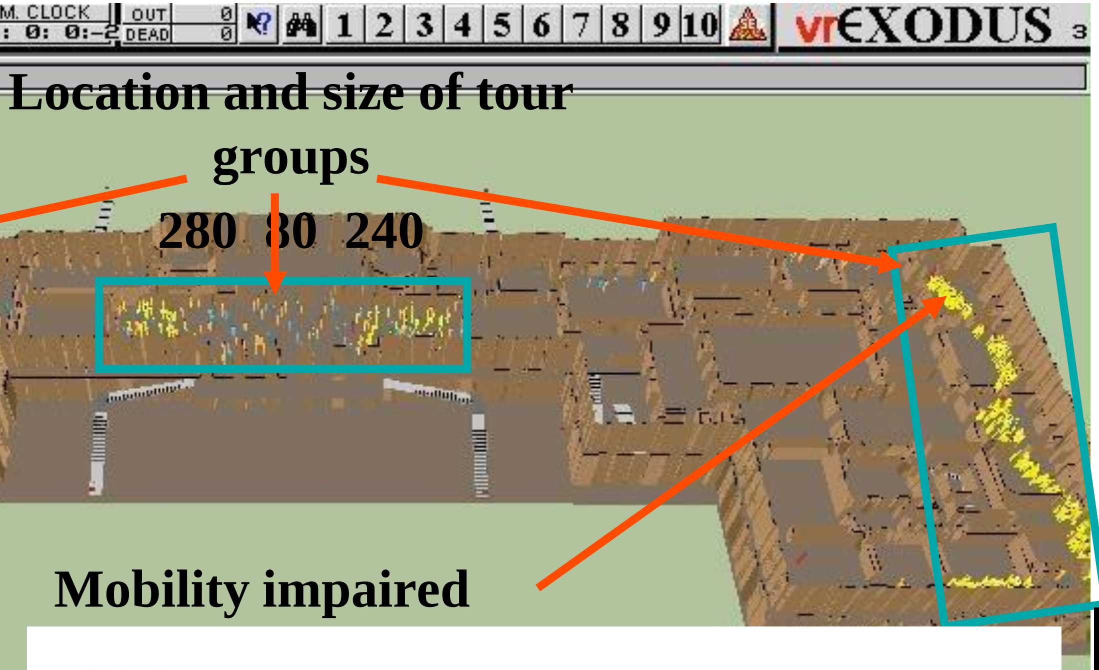
Corpo Nazionale dei Vigili del Fuoco

# In my speech

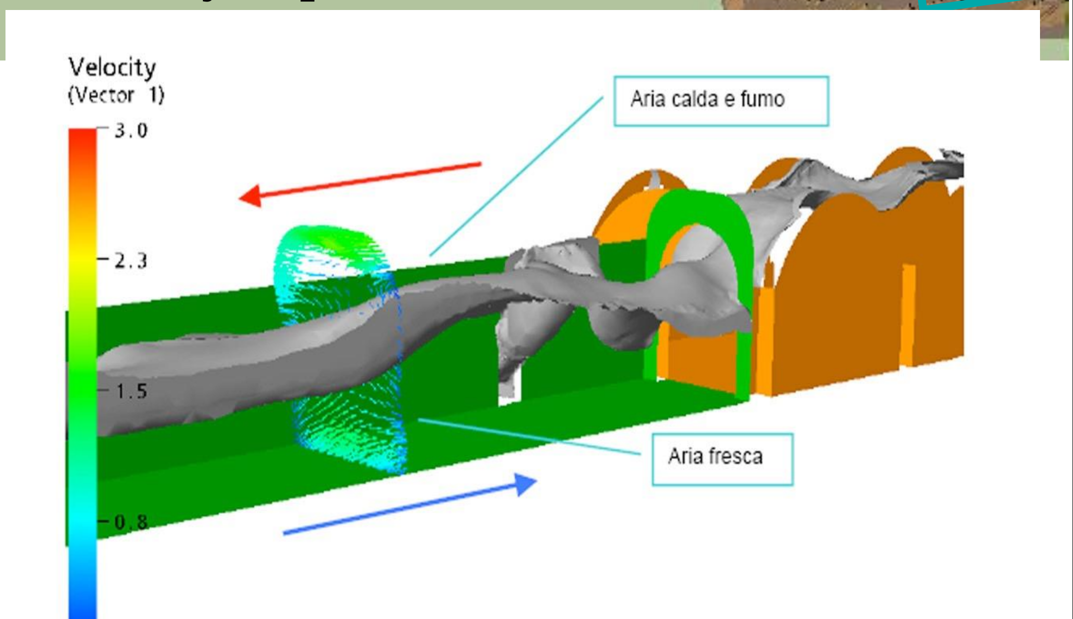
- Problemi e *(possibile)* aiuto..... CFD
- Parametri Interni ed esterni per CFD .. Approssimazioni….
- *Colorful* Fluido Dinamics ?????
- Gestione *(mantenimento ipotesi, impianti, emergenza…)*

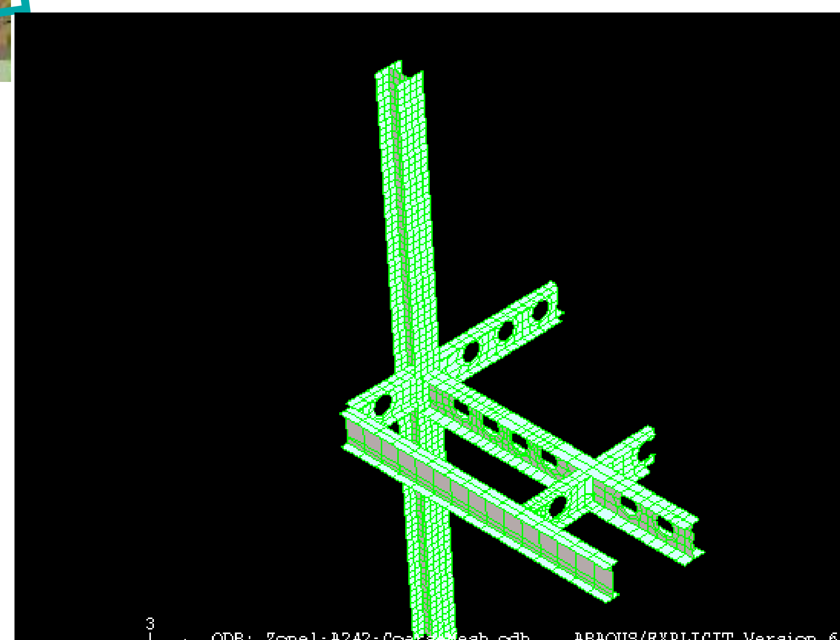

- *Dalmarnock fire tests proceedings- University of Edinburgh 2006-2007*
- *Dr. Anja Hofmann - BAM - Five - fire in Vehicles proceedings - 09-2010- Gotheburg*
- *Kai Kang - Daniel McNamee - FS-world.com fall 2010*
- *Leander Noordijk, Tony Lemaire - Modelling of fire spread in car parks - Fire&Safety magazine - fall 2010 fall 2010*
- *David Tonegran, Marcus Ryber - Increased quality and reduced uncertainty when using FDS.*
- *Kristoffer Hermansson - Quality assurance and the simulation of fires. A practical application for automated validation of user generated input data for Fire Dynamics Simulator - Report 5501, Lund 2015*

# FSE modelling - differenti prospettive




- *Sicurezza dei presenti*
- *Resistenza al fuoco delle strutture*
- *Studi per la gestione dell' emergenza*

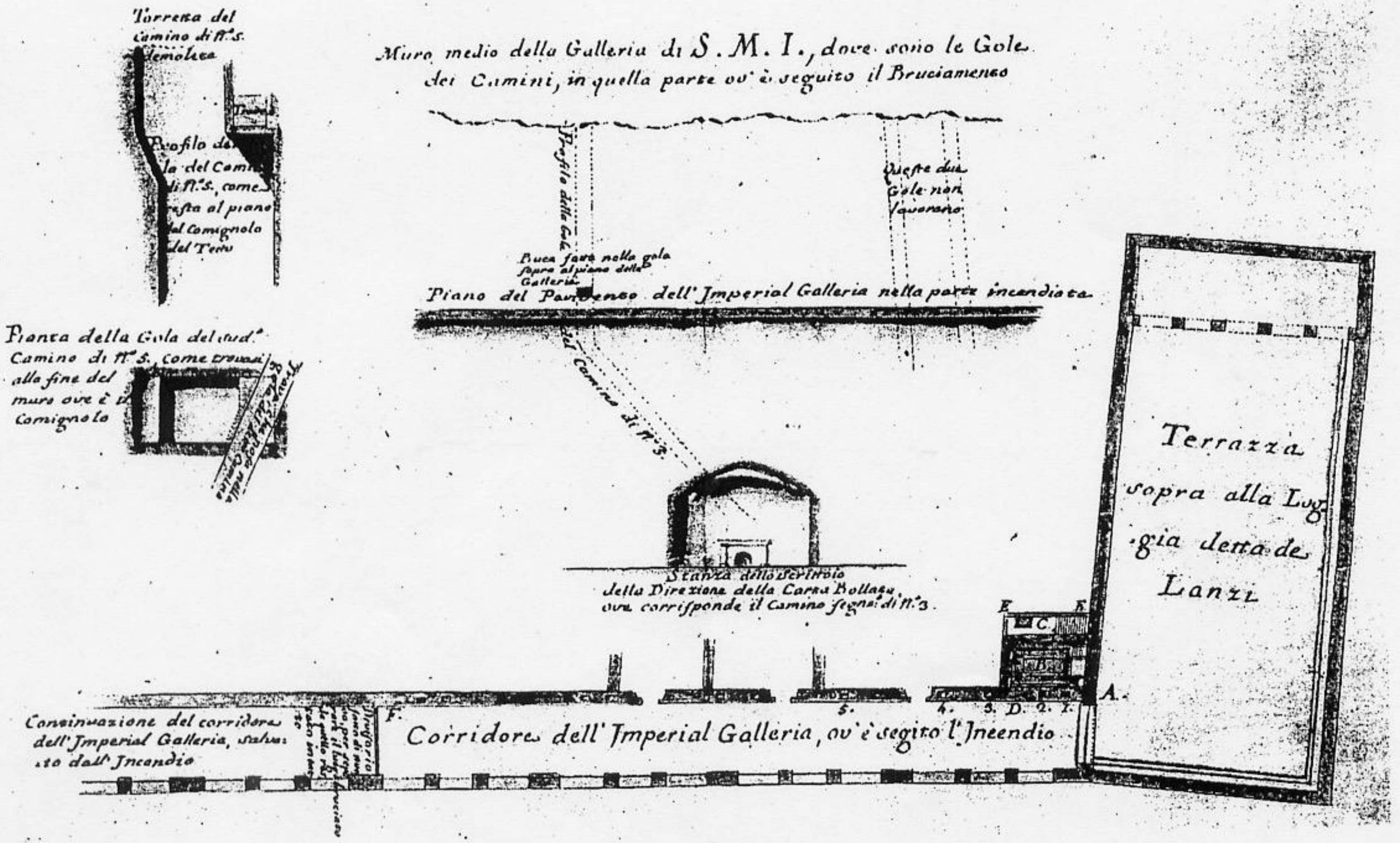


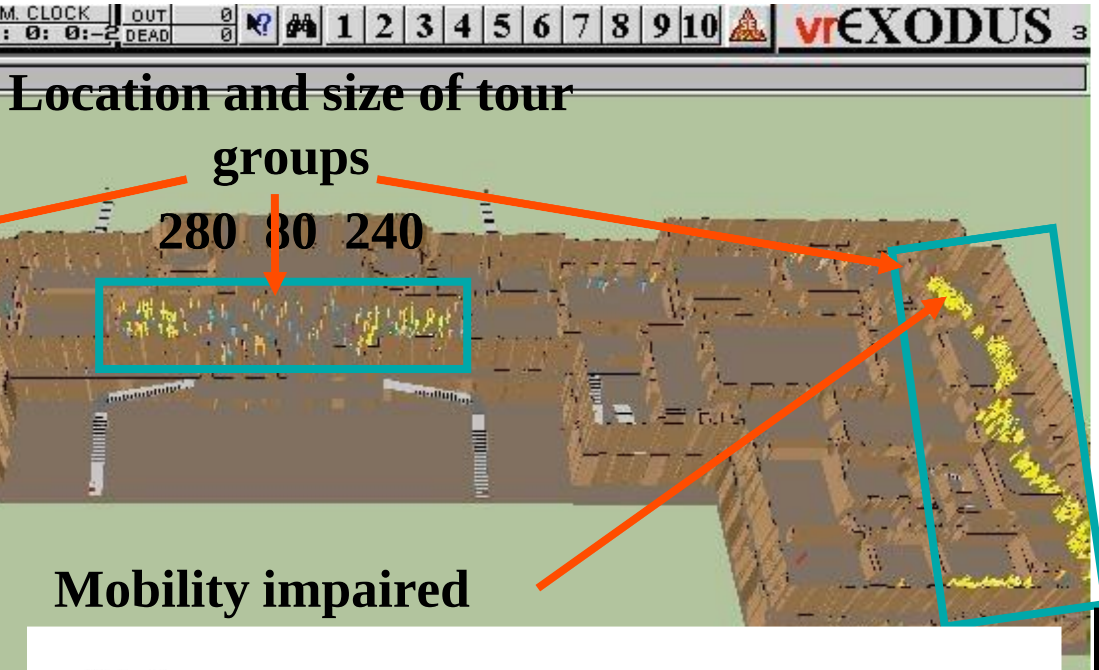
- *Vogliamo proteggere:*
- Solo le persone???
- Anche l’edificio ???
    - *Tutto??*
    - *Una Parte???*
- Anche i Contenuti ????
    - *Affreschi ???*
    - *Statue ???*
    - *Quadri ???*
    - *Libri???*
    - ………
- Anche la prosecuzione dell’attività ???
- ……….


BACCIVS·BANDINELLVS·FLORENTINVS·SANCTI·IACOBI·EQVES·FACIEBAT·

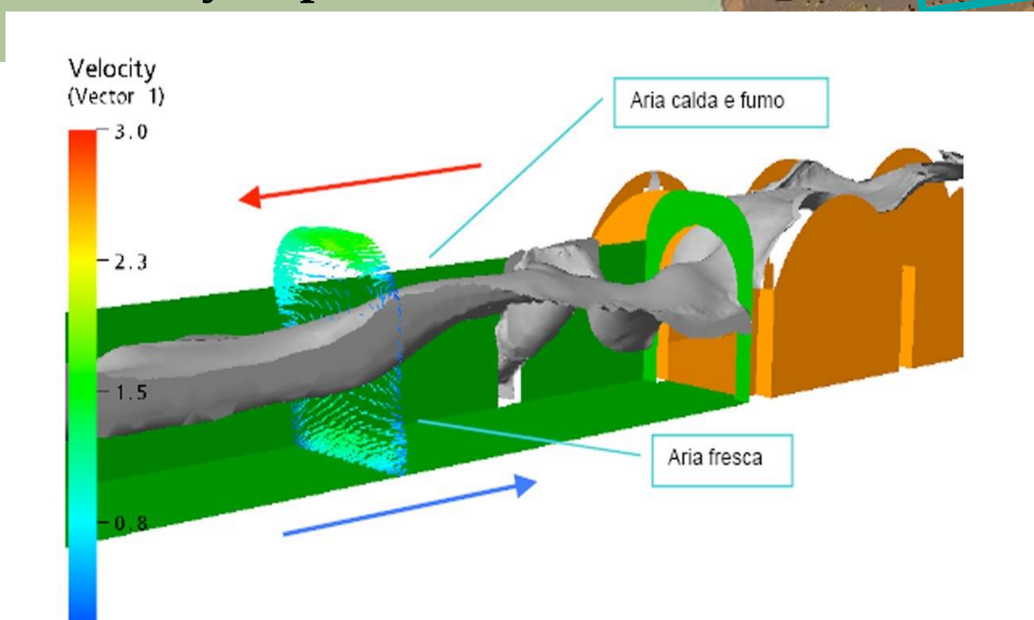
# Incendio del 12 agosto 1762

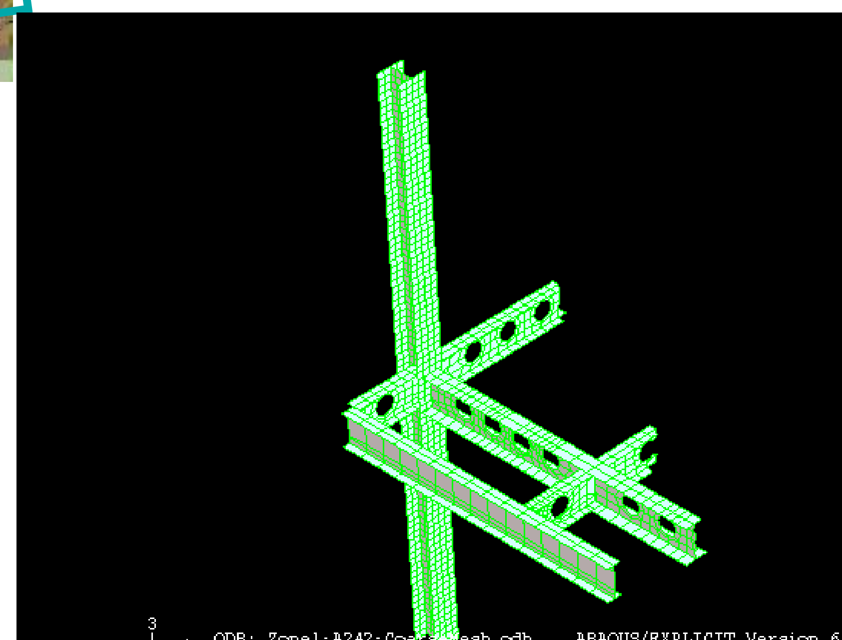


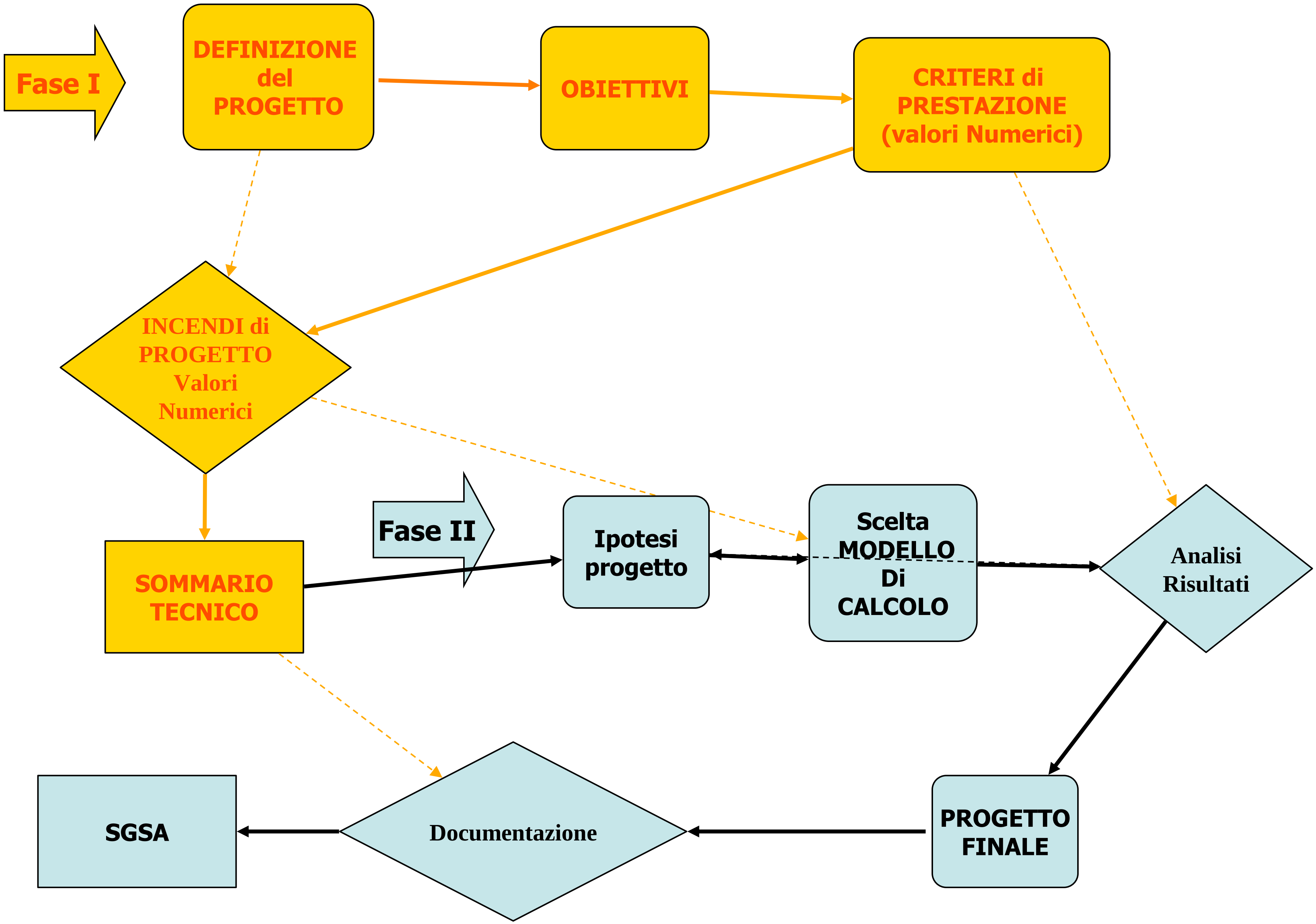
# FSE modelling - differenti prospettive



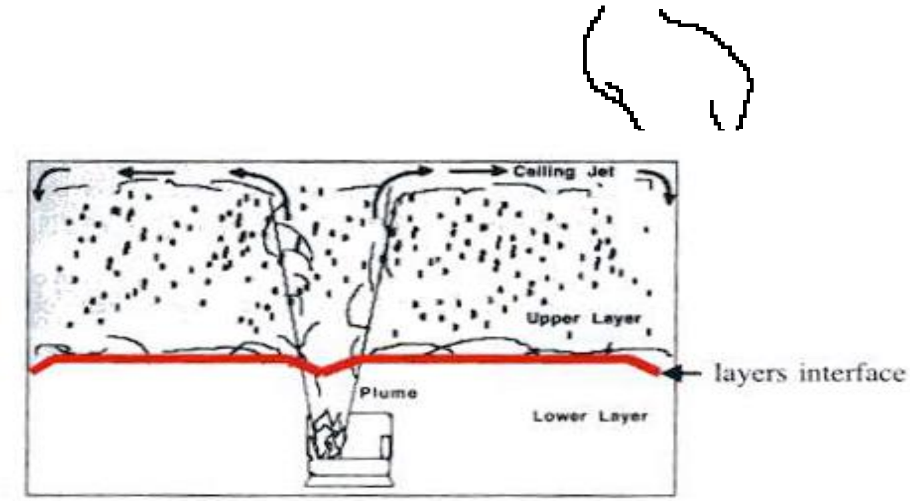

- *Sicurezza dei presenti*
- *Resistenza al fuoco delle strutture*
- *Studi per la gestione dell' emergenza*

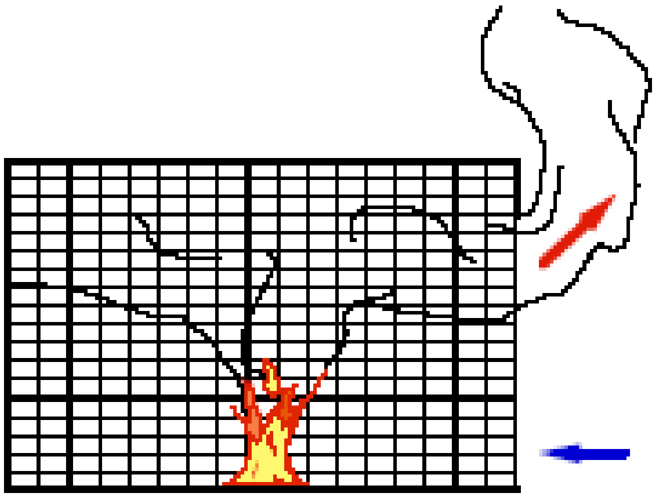



Fase I
DEFINIZIONE del PROGETTO
OBIETTIVI
CRITERI di PRESTAZIONE (valori Numerici)
INCENDI di PROGETTO Valori Numerici
SOMMARIO TECNICO
Fase II
Ipotesi progetto
Scelta MODELLO Di CALCOLO
Analisi Risultati
PROGETTO FINALE
Documentazione
SGSA

# Zone to Field Models

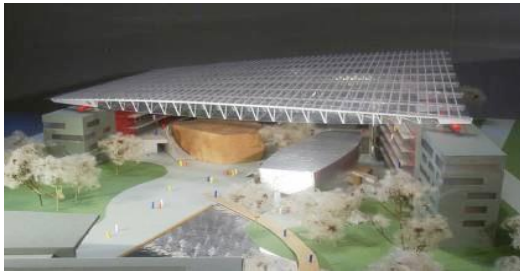


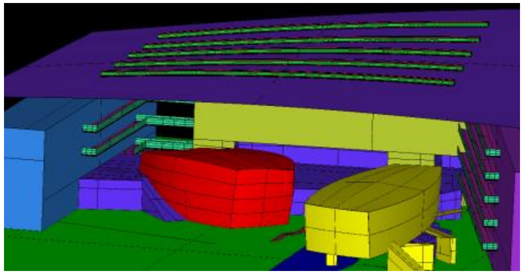
# CFD Modeling

CFD = Computational Fluid Dynamics

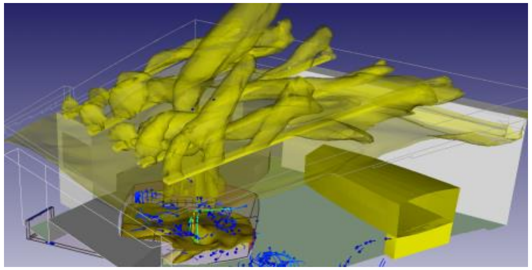
- Geometry model with details
- Generation of calculation mesh
  (e.g. 500’000 – 5‘000’000 cells)
- Transport equations are solved
- Initial and boundary conditions specified
- Interpretation of results
- Make recommendations for end-user



Geometry



Grid generation, boundary conditions



Result

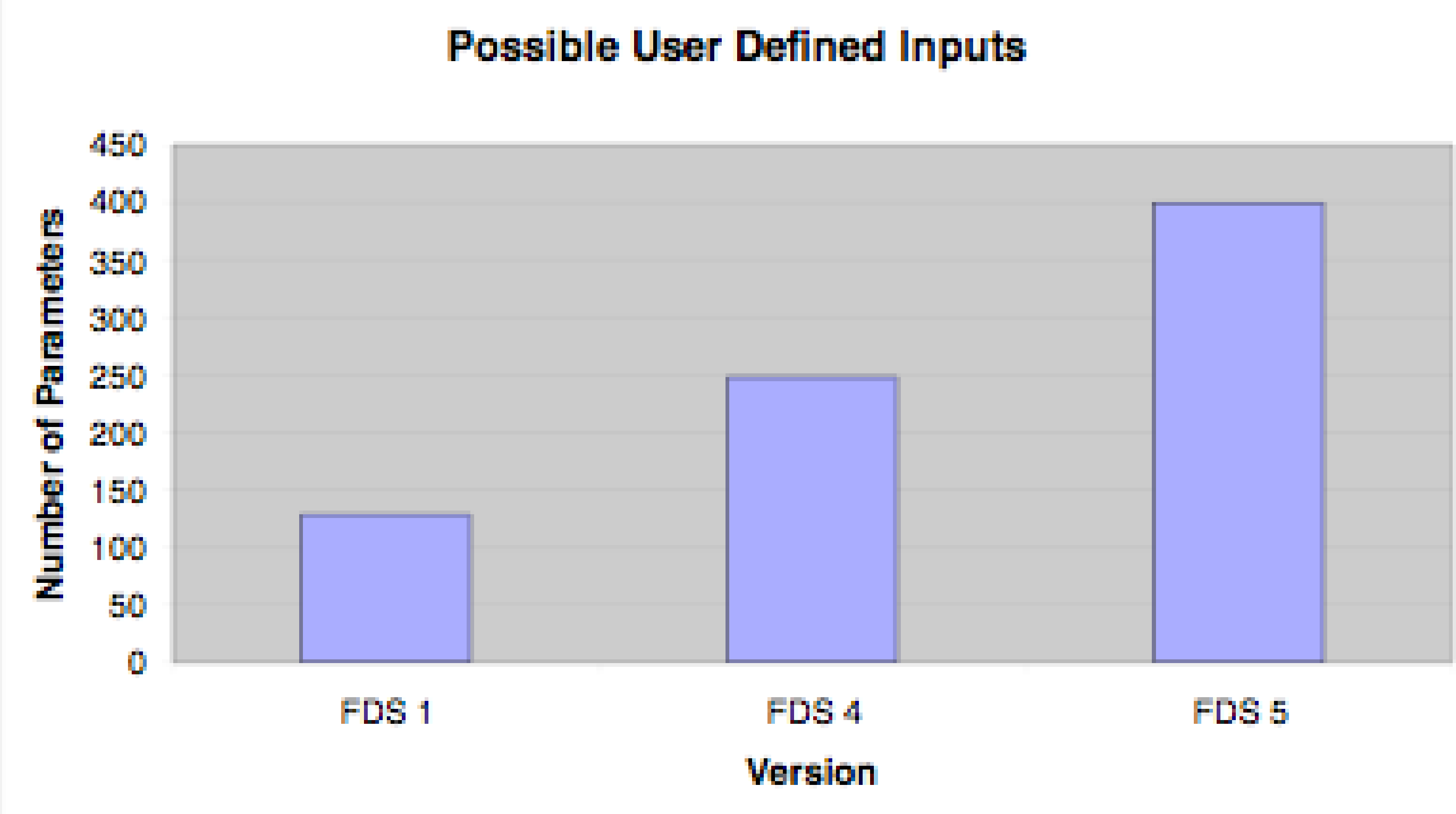



*Fig 1 – Increase of possible user defined variables in recent versions of FDS*

Each new version of FDS is increasingly more sophisticated ......more and more Knowledge is required from the user of the software...

# Internal parameters of CFD models

- Numerical Methods
  - convergence
  - stability - sensitive analisys
  - mesh - cells dimensions
  - ..........

- Validation (ex. FDS)
  - created for industrial buildings
  - well ventilated fires

- Designating a Fire (ex FDS)
  - only one gaseous fuel - mixture fraction model

# External parameters of CFD models

- Geometrical
    - dimension
    - ventilation
    - boundary conditions

- Thermophisics
    - conductivity
    - density
    - specific heat
    - ........

- Designating a Fire (ex FDS)
    - HRR, combustible definition, mass loss.......

# Burning process and fire

- Volumetric fires
  - prescribing a date HRR realesed  by a  burner
  - experimental curves

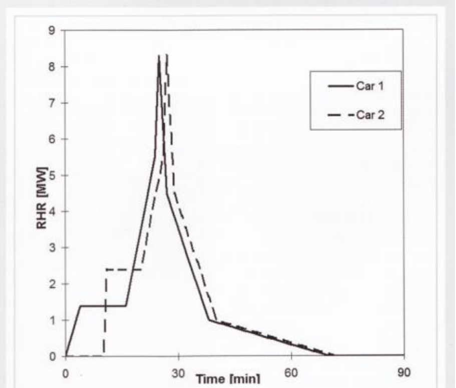
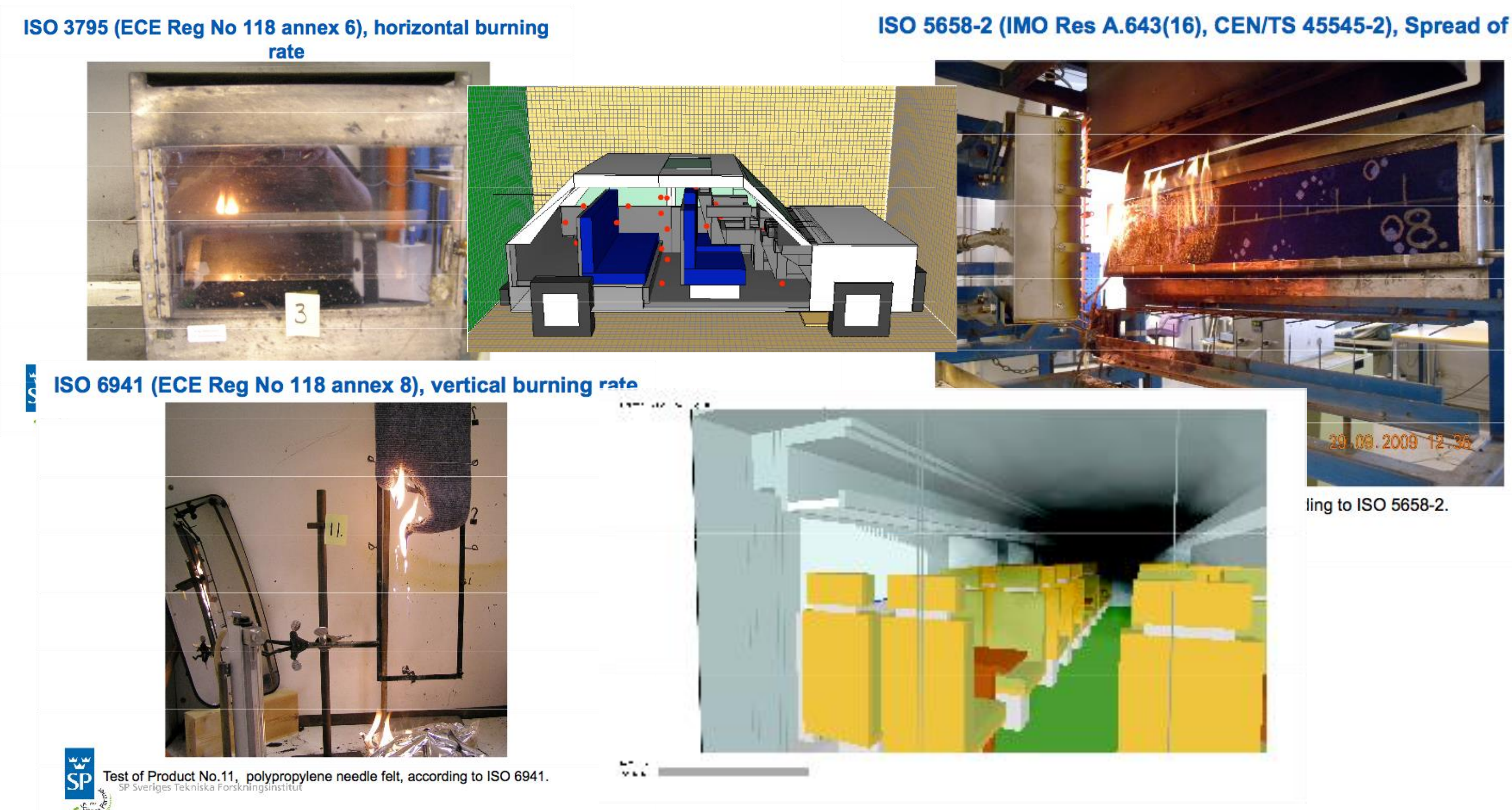
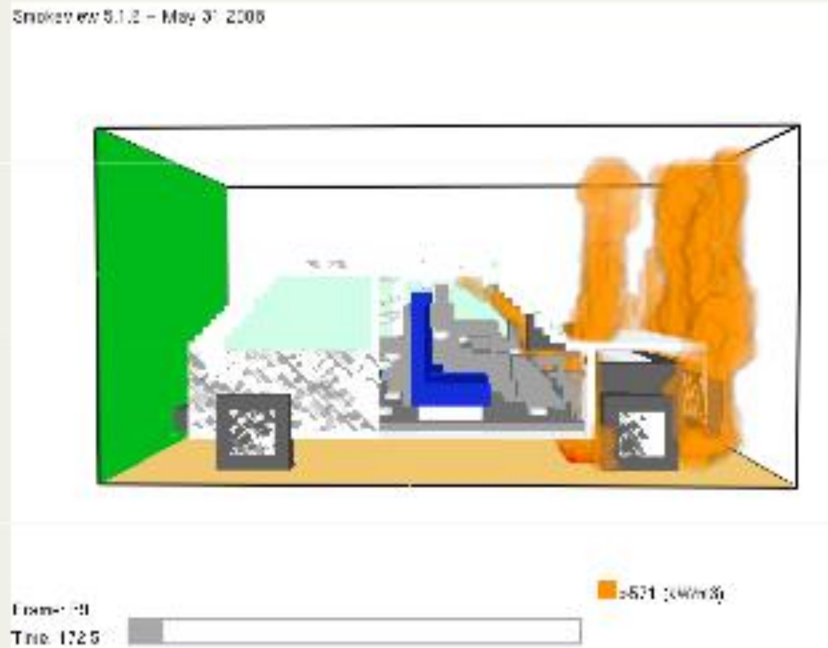



*Figure 1.* Typical heat release rates for a car initially on fire (car 1) and a car that is ignited by the first car about 10 minutes later

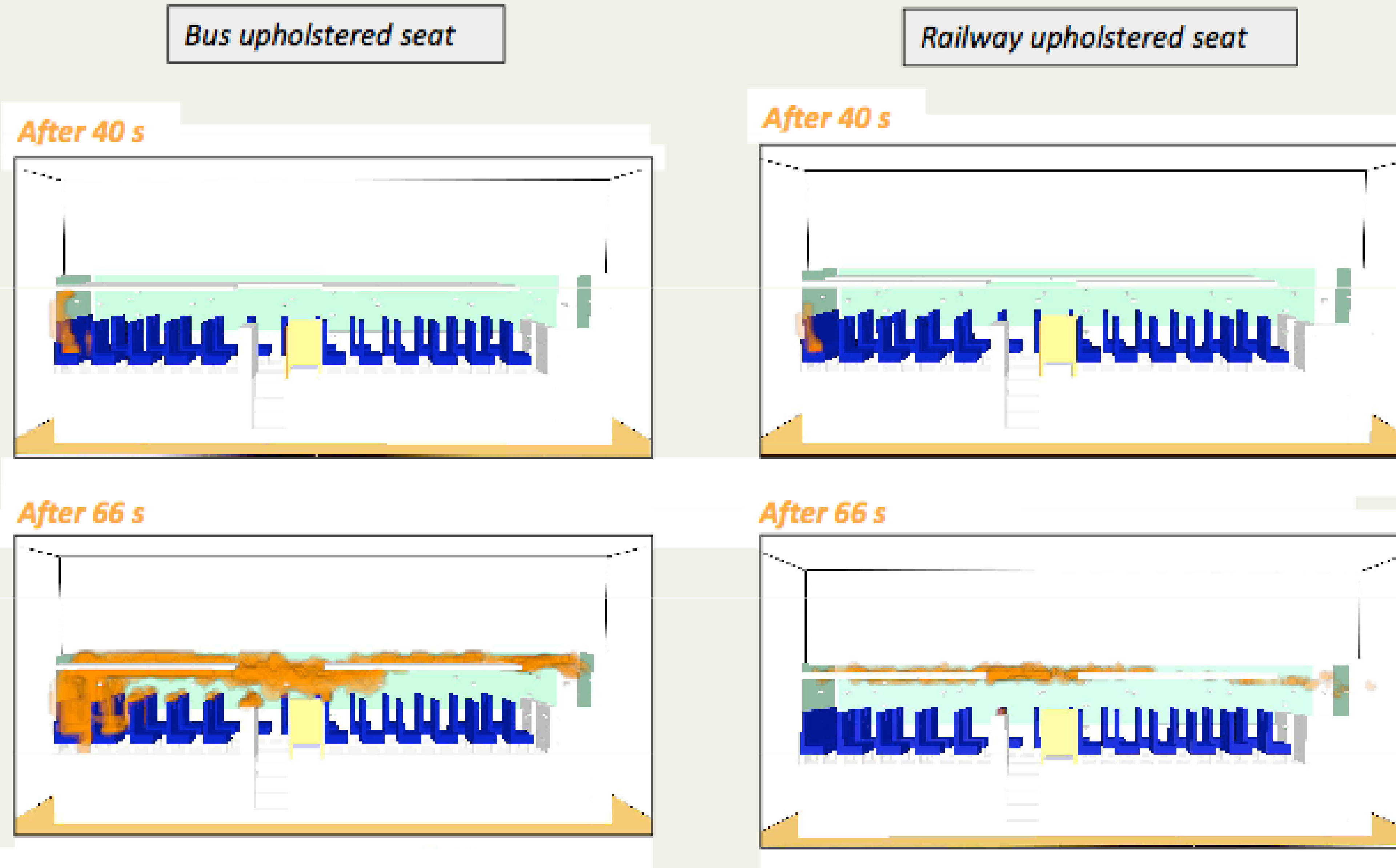
# Burning process and fire

- FDS Pyrolysis model - specify thermophysical properties of solid fuel materials and let them pyrolyze if ignited. The HRR curve is not defined a-priori by the user.



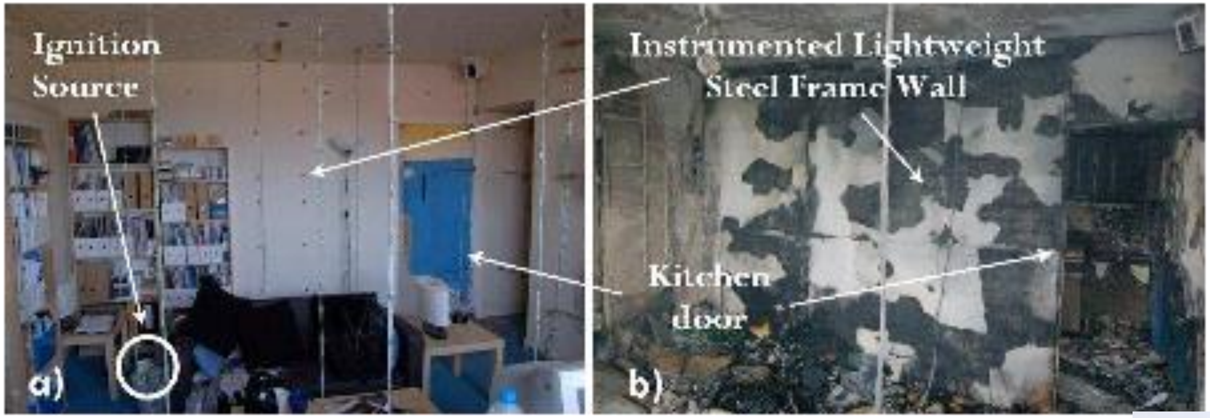


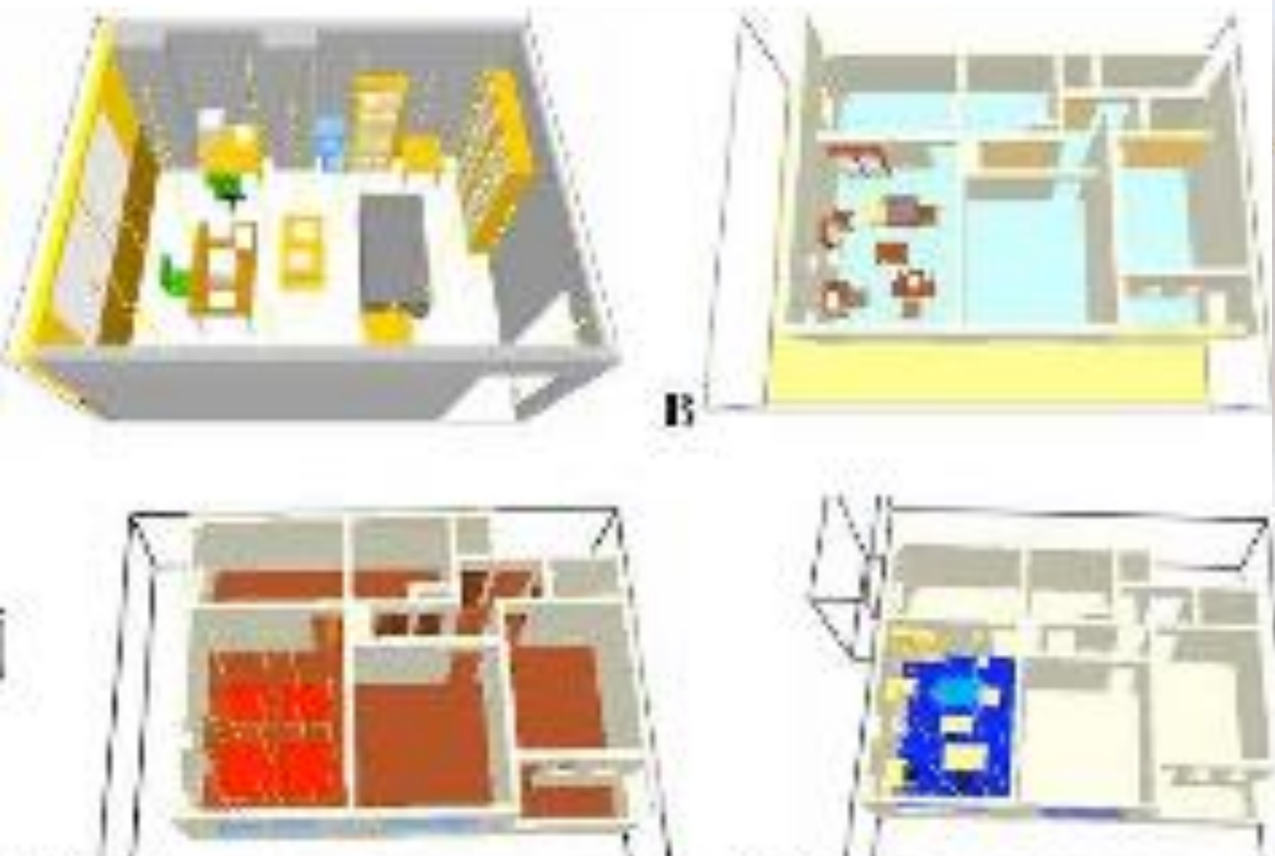
# Flames in the interior after 170 s / 172 s


Bus upholstered seat
Railway upholstered seat
After 40 s
After 40 s
After 66 s
After 66 s

The upper image is a corner burn showing the flame spread over a layered paint surface. The cell size is 10 cm. In the lower image the fire is the same size, the surface properties are the same and the images are captured at the same time in the simulation. The only difference is that the cell size is 2.5 cm. As you can see, the scenario with the higher resolution displays greater fire spread.

# Dalmarnock fire tests - University of Edinburgh 2006-2007



Combustible
furniture modeled

# Dalmarnock fire tests - A priori and a posteriori analysis

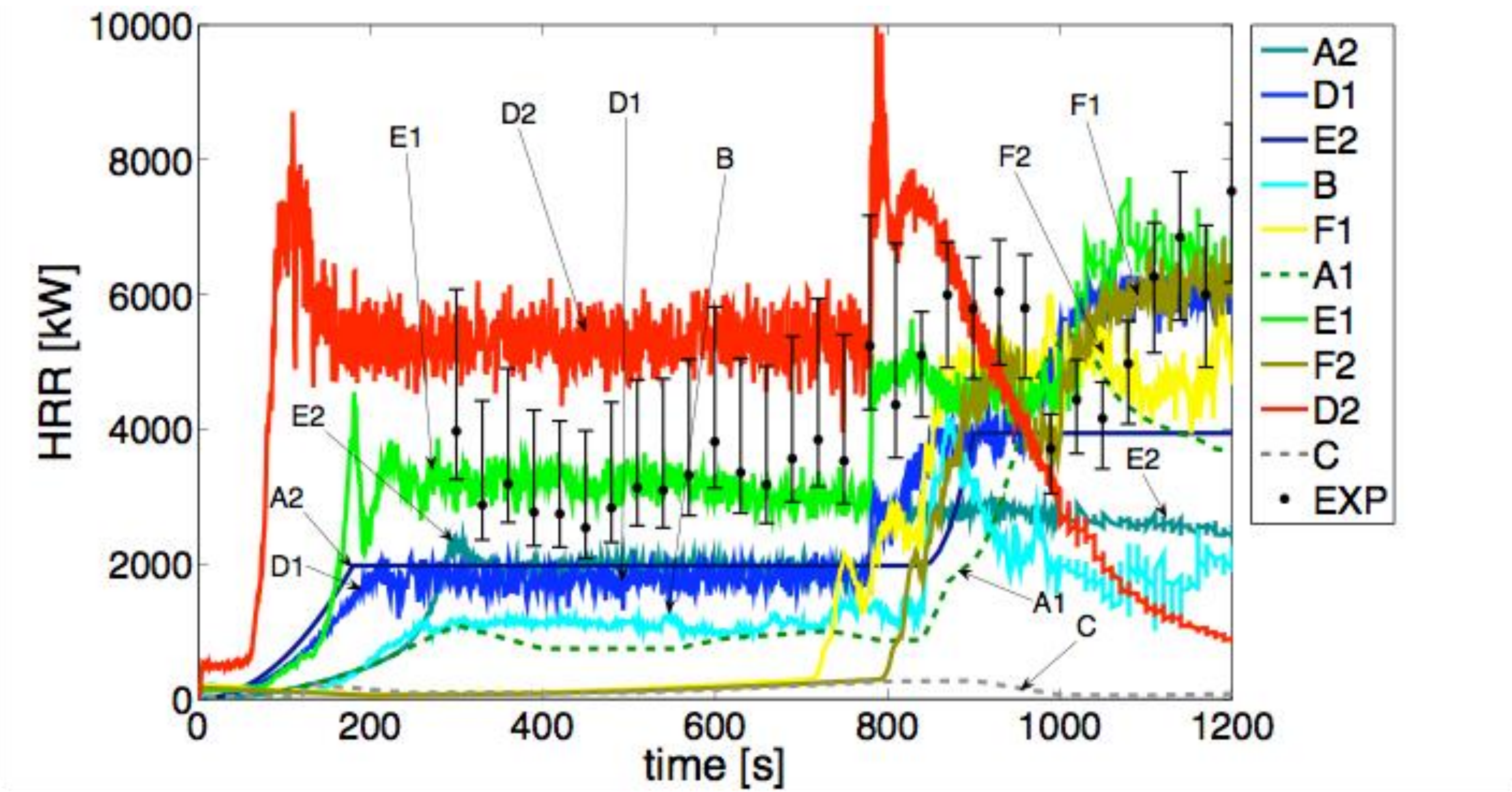



Figure 6: Evolution of the global heat release rate within the compartment. Legend for the different curves: continuous line for CFD simulations; dashed line for zone model simulations; and dotted for the experiment data with error bars.


30 seconds
NIST
00:00:47

HRR curves for single car and the time until the fire spread occurs originate from experimental research from the past years.

The model presented by Noordijk & Lemaire calculates the time until the fire spread assuming an HRR curve for a burning car and calculating the resulting Radiative Heat transfert to the other combustible surfaces

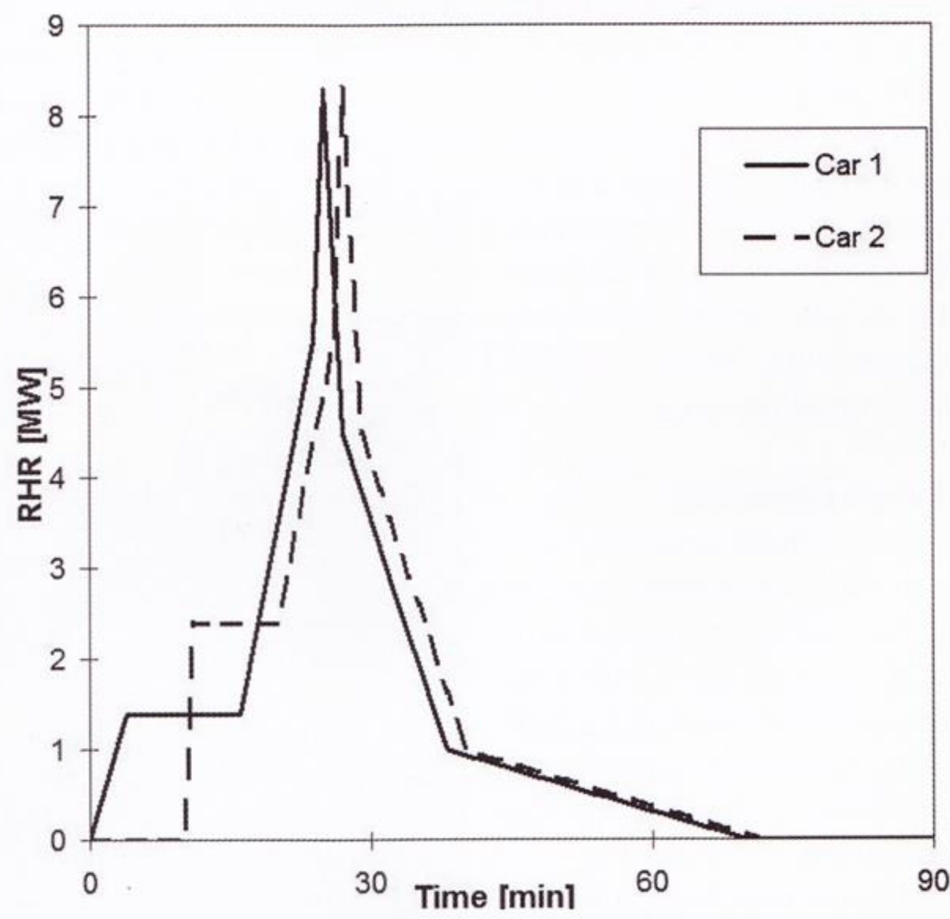


**Figure 1.** *Typical heat release rates for a car initially on fire (car 1) and a c that is ignited by the first car about 10 minutes later*

*Near Skipol Airport in this privat car park  around 30 cars were on fire at the same time (october 2002)*

Leander Noordijk, Tony Lemaire FS-world.com fall 2010

*Current, empirical assumption: at most 3-4 vehicles are at fire at the same time (??)*

*Private park of a car rental company:*

*- cars parked on a small distance of each other*
*- All new cars (more plastic parts that can be ignited more easly and producing more heat )*
*- All fuel tanks completely filled*
*- Fuel tanks made of plastic - leaking - pool fires*


# - This justify the development of a relative simple model to predict the fire spread in a car park

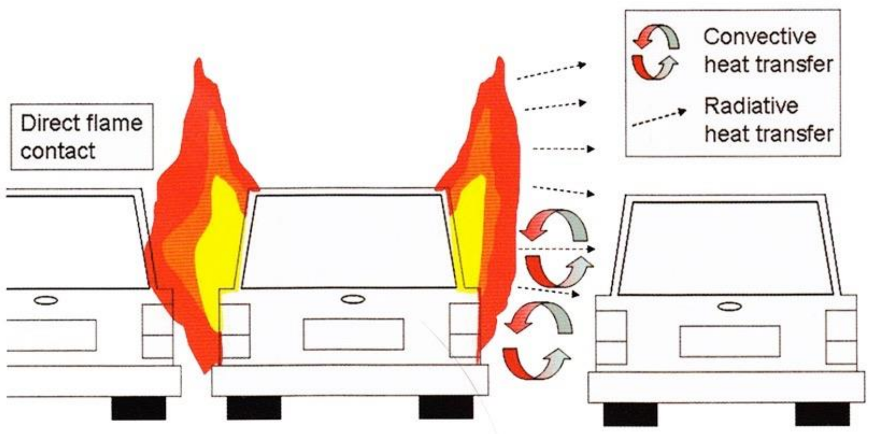



***Figure 2.*** *Mechanisms involved in fire spread from car to car*

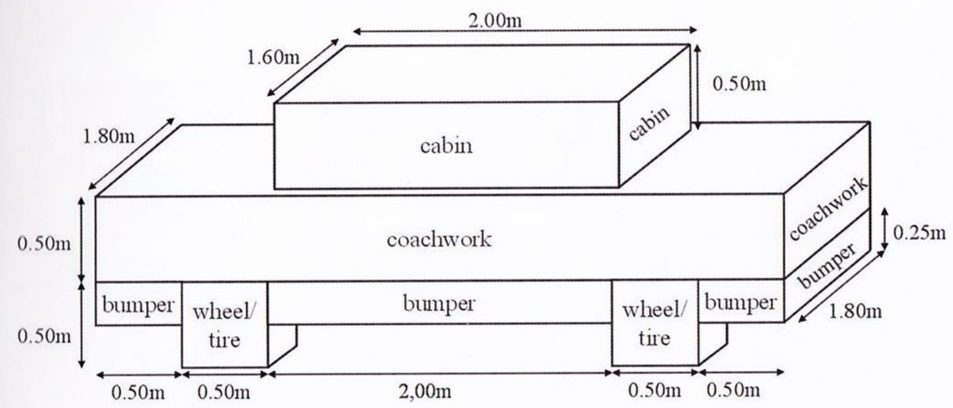



***Figure 3.*** *Modelled car geometry, which can be refined when needed*

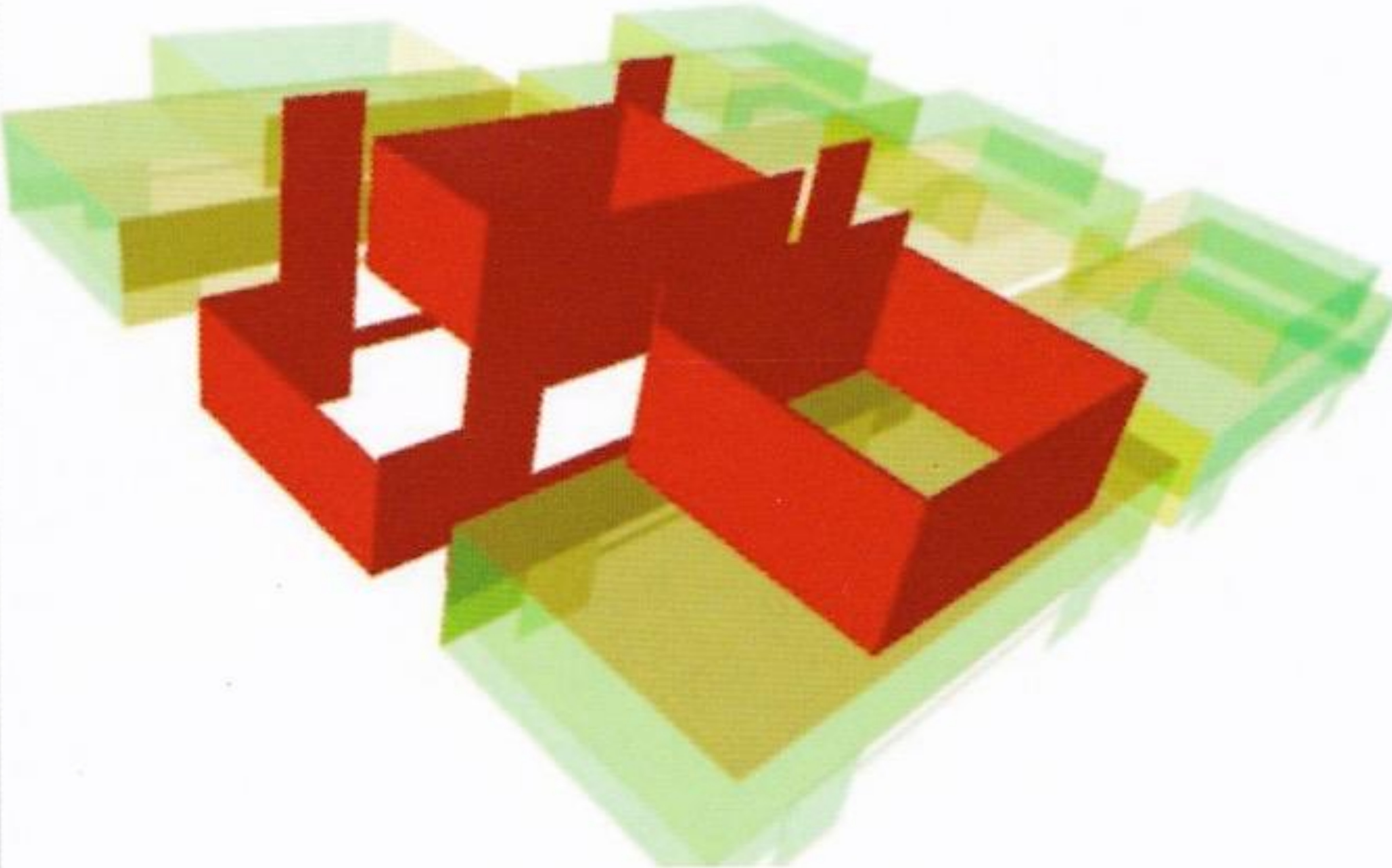


***Figure 5.*** *The dark surfaces are on fire. The height of a burning surface represents the flame height and is based on the heat release rate*

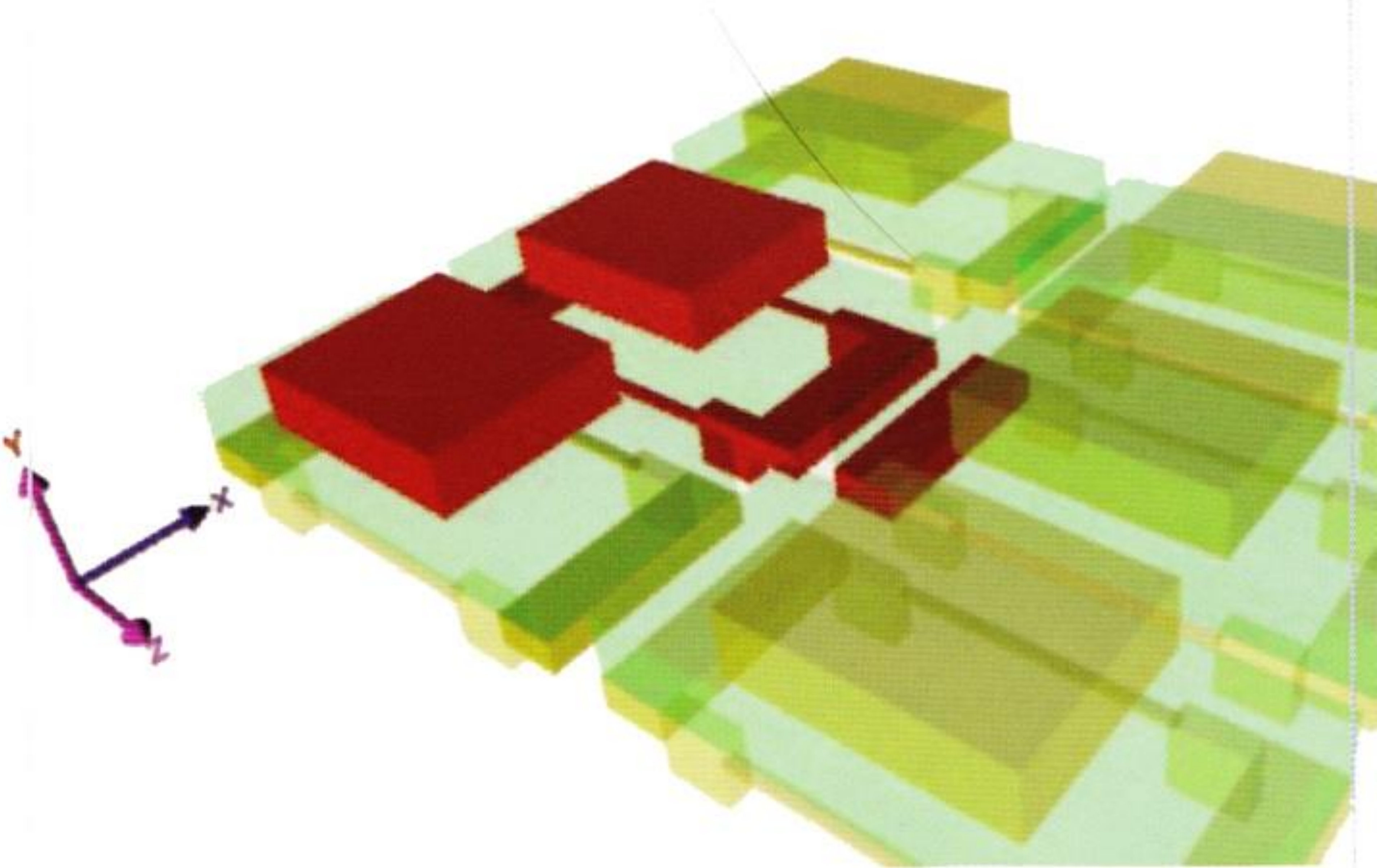



***Figure 6.*** *Result of a simulation: the top centred car has ignited the two closest cars*

A quantitative assessment on the risk on structural collapse or loss of life can be performed by running a large number of parameter value combination in a *Monte Carlo* approach

In orded to achieve this, the relevant parameters (distance between cars, lay out, filling degree of garage, size and composition of the car, etc..) need to be identified (normal or Poisson distribution mostly..)

**LIMITED COMPUTATIONAL COST**

# Working on uncertaines - FDS (modified) Parametric study on window glass breakage an fallout.

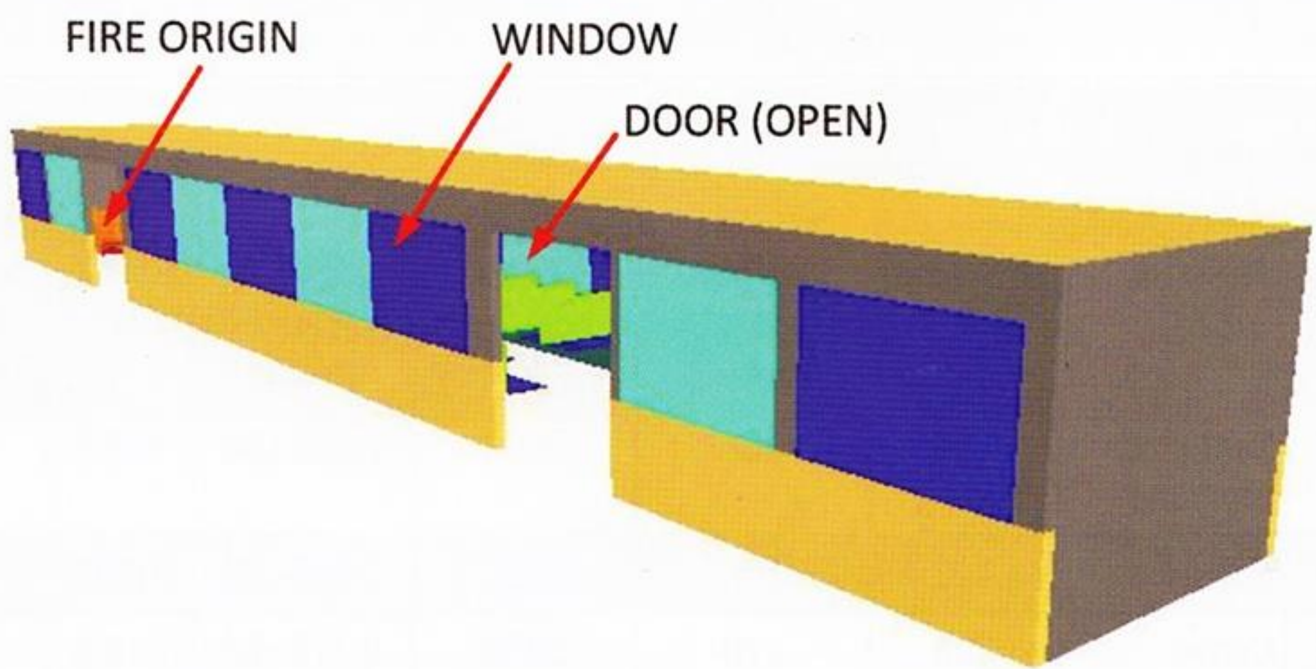



***Figure 1.** Railcar model geometry*

**(a)** *t = 410 s*

**(b)** *t = 427 s*

**(c)** *t = 444 s*

**(d)** *t = 498 s*

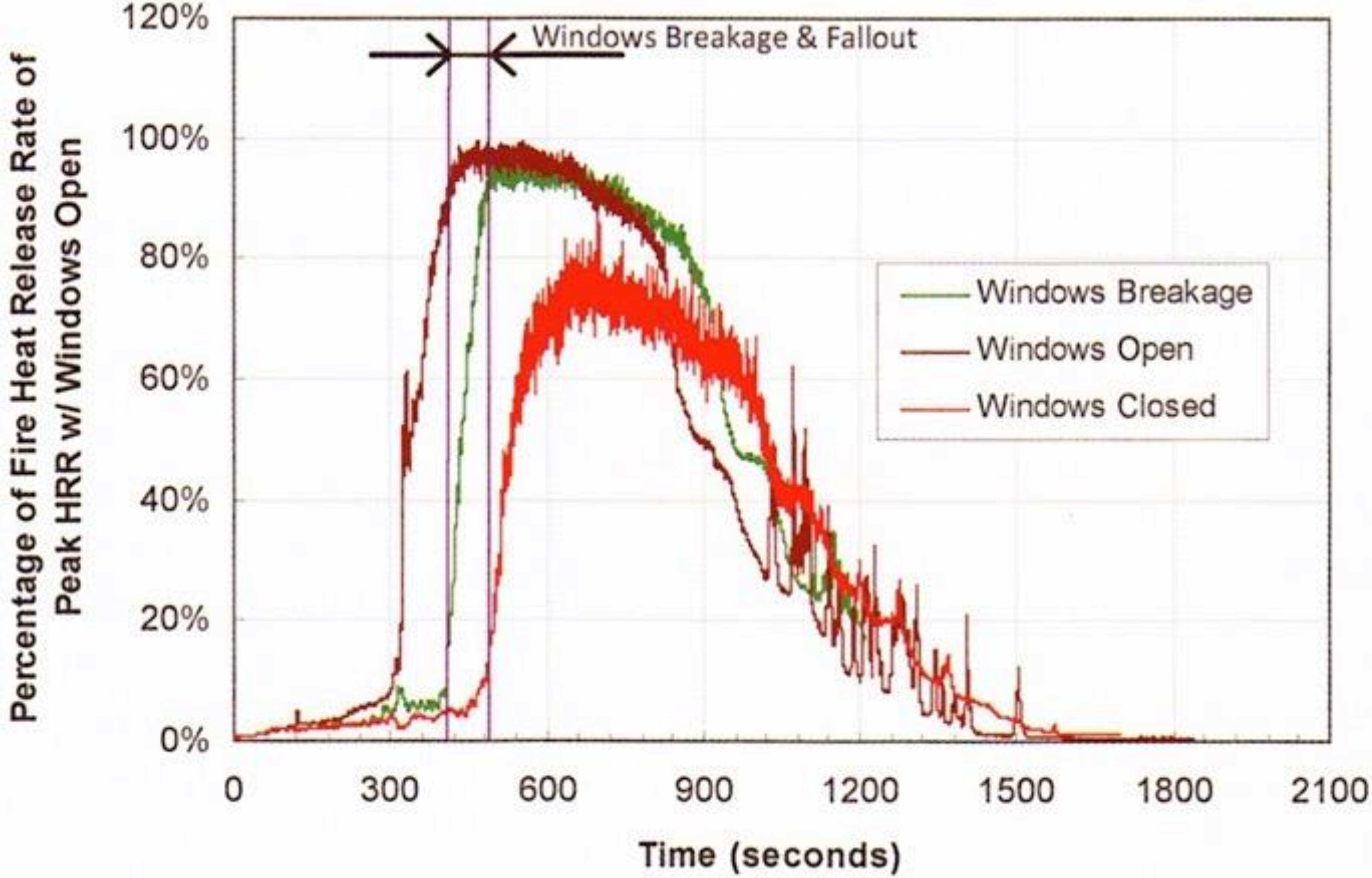
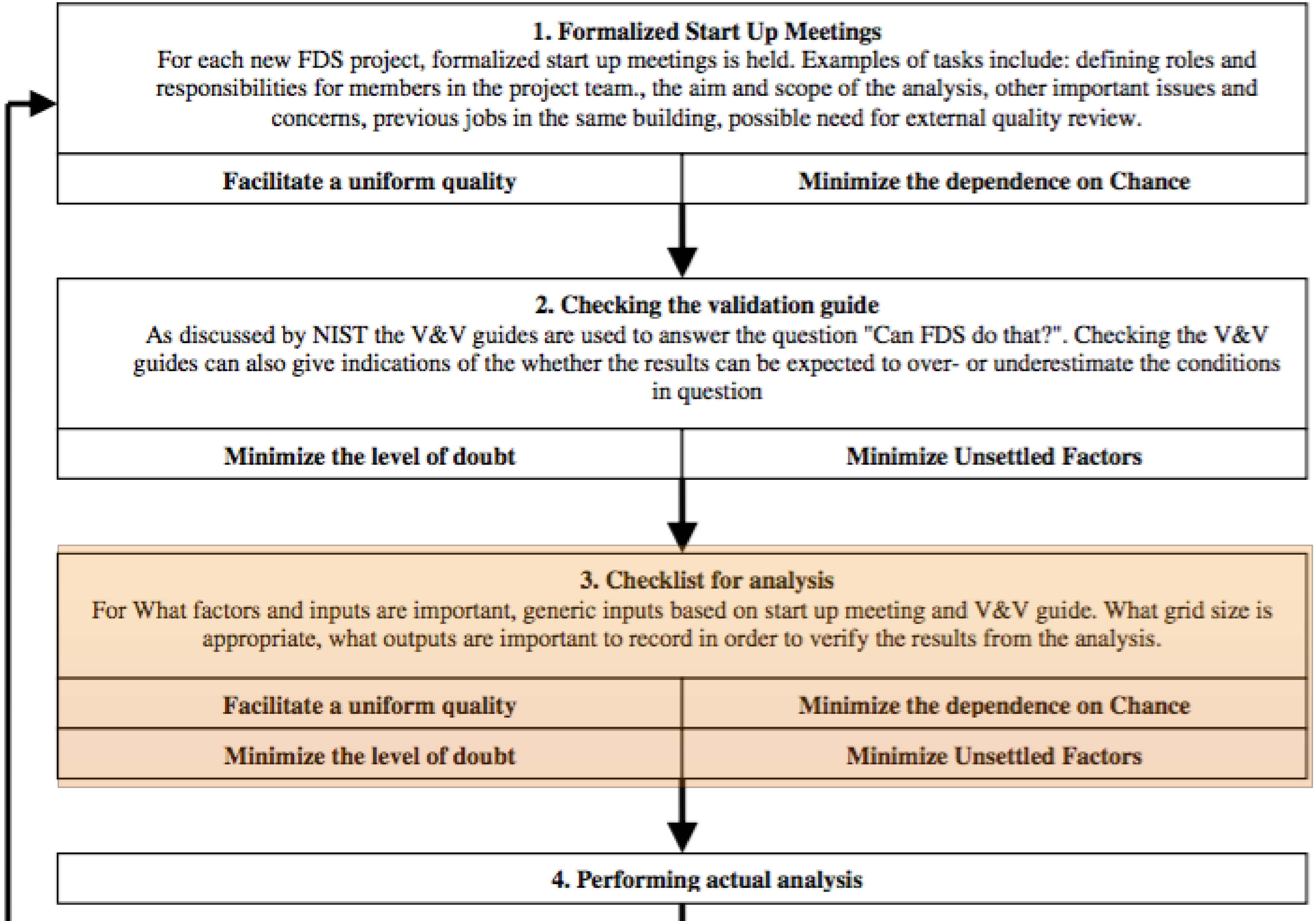
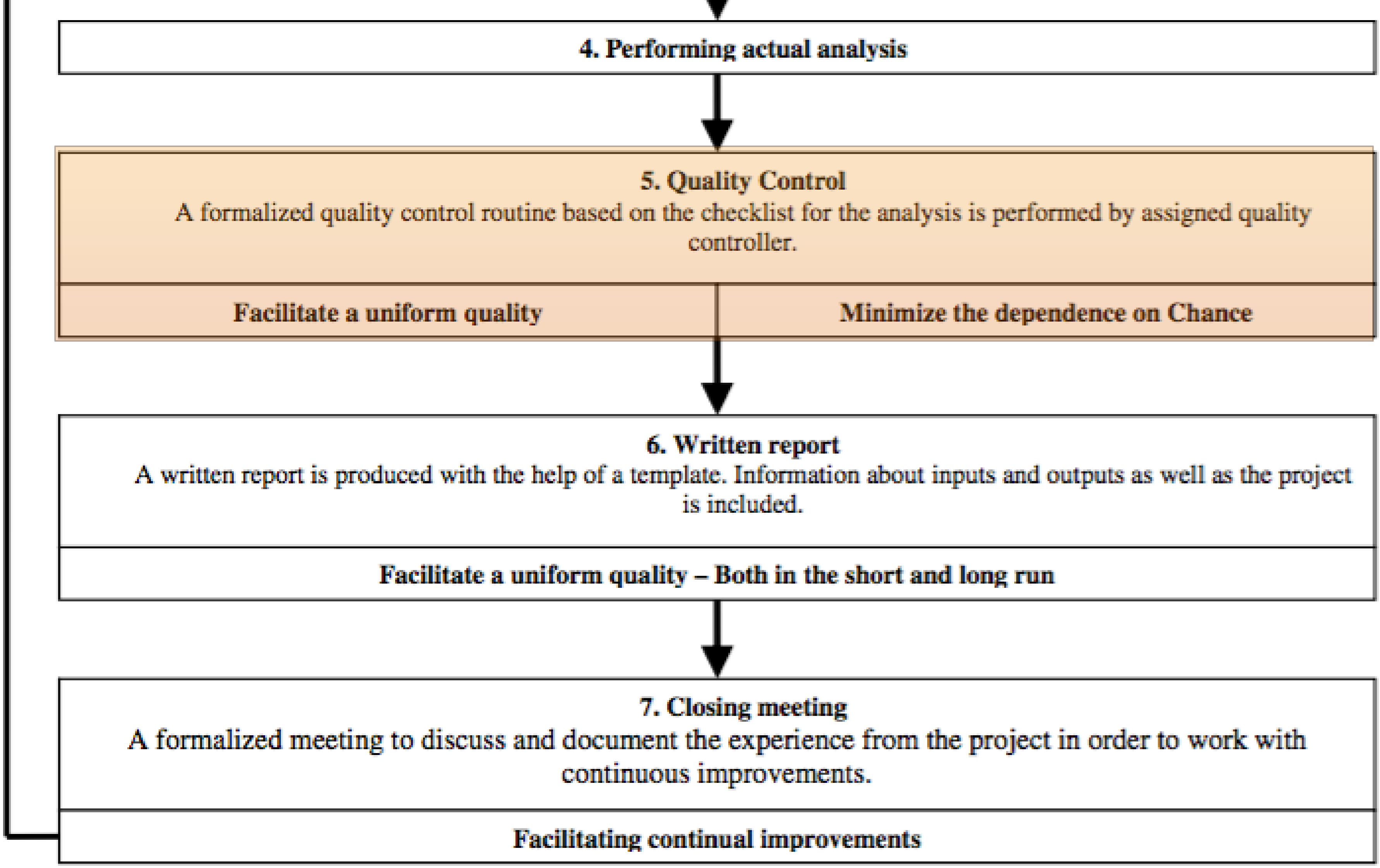



***Figure 3.*** *Comparison of predicted fire HRR as a function of time at different ventilation conditions due to windows fallout*

- *David Tonegran, Marcus Ryber - Increased quality and reduced uncertainty when using FDS.*




4. Performing actual analysis
5. Quality Control
A formalized quality control routine based on the checklist for the analysis is performed by assigned quality controller.
Facilitate a uniform quality
Minimize the dependence on Chance
6. Written report
A written report is produced with the help of a template. Information about inputs and outputs as well as the project is included.
Facilitate a uniform quality – Both in the short and long run
7. Closing meeting
A formalized meeting to discuss and document the experience from the project in order to work with continuous improvements.
Facilitating continual improvements

**Kristoffer Hermansson - Quality assurance and the simulation of fires. A practical application for automated validation of user generated input data for Fire Dynamics Simulator - Report 5501, Lund 2015**

# FDS input validator

Check FDS input data for common errors and for possible non-compliance with the Swedish building code.

# FDS input validator

Check FDS input data for common errors and for possible non-compliance with the Swedish building code.

Please note that this application is in beta status and, thus far, only intended for use with input data for FDS version 5.

**FDS input file**

Scegli file nessuno selezionato

Choose a .fds file for validation.

Add intended values

Validate

http://beta.kristofferhermansson.se/fds-validator

Instructions

- [x] Mesh cells are cubic.
- [x] The dimensions in the y- and z-directions can be written on the form 2^l*3^m*5^n.
- [x] Mesh groups are entered from finest to coarsest.
- [x] Mesh boundaries do not cross a fire.
- [x] Meshes do not overlap.
- [x] D*/dx is greater than 10.
- [x] The heat release rate has been specified as intended.
- [x] The growth rate has been specified as intended.
- [x] The heat of combustion has been specified as intended.

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- ☑ The heat of combustion has been specified as intended.

$X_{min}$ $X_{max}$

$Y_{min}$ $Y_{max}$

$Z_{min}$ $Z_{max}$

Heat Release Rate (Q)

kW

Density ($\rho_\infty$)

1.204 kg / m$^3$

Specific Heat ($c_p$)

1.005 kJ / kg-K

Ambient Temperature ($T_\infty$)

293 K

Gravity (g)

9.81 m / s$^2$

Calculate suggested cell sizes »

http://www.koverholt.com/fds-mesh-size-calc/

- [x] The necessary output data has been specified.

- [x] VENT groups do not overlap.

- [x] Non-pointwise devices do not cross mesh boundaries.

- [ ] At least one VENT group with the SURF_ID parameter set to 'OPEN' has been placed on a mesh boundary.
  No VENT group with the SURF_ID parameter set to 'OPEN' has been placed on any mesh boundary.

- [x] The radiation model is used.

| Parametro | Focolare predefinito | |
|---|---|---|
| | **per attività civile** | **per altre attività** |
| Velocità caratt. di crescita dell'incendio $t_\alpha$ | 150 s (*fast*) | 75 s (*ultra-fast*) |
| $RHR_{max}$ totale<br>$RHR_{max}$ per $m^2$ di superficie del focolare | 5 MW<br>250-500 $kW/m^2$ [1] | 50 MW<br>500 -1000 $kW/m^2$ [1] |
| Resa in particolato $Y_{soot}$ | Pre flashover: 0,07 kg/kg [2,3]<br>Post flashover: 0,14 kg/kg [2,3] | Pre flashover: 0,18 kg/kg [4]<br>Post flashover: 0,36 kg/kg [4] |
| Resa in monossido di carbonio $Y_{CO}$ | Pre flashover: 0,10 kg/kg [5]<br>Post flashover: 0,40 kg/kg [5] | |
| Calore di combustione effettivo $\Delta H_C$ | 20 MJ/kg [3] | |
| Resa in biossido di carbonio $Y_{CO2}$ | 1,5 kg/kg [3,6] | |
| Resa in acqua $Y_{H2O}$ | 0,82 kg/kg [3,6] | |
| Frazione di RHR(t) in irraggiamento<br>(*Radiative fraction*) | 35% [3] | |

[1] Da impiegare in alternativa all'$RHR_{max}$ totale, considerando la massima superficie del focolare, pari al compartimento antincendio nel caso di carico di incendio uniformemente distribuito, ma che può essere un valore inferiore nel caso d'incendio localizzato.
[2] Robbins A P, Wade C A, Study Report No.185 *"Soot Yield Values for Modelling Purposes – Residential Occupancies"*, BRANZ, 2008
[3] *"C/VM2 Verification method: Framework for fire safety design"*, New Zealand Building Code
[4] *"SFPE handbook of fire protection engineering"*, NFPA, 4th ed., 2008. Tabella 3-4.16, pag. 3-142, da *polyurethane flexible foams*.
[5] Stec A A, Hull T R, *"Fire Toxicity"*, Woodhead Pub., 2010. § 2.4 con $\Phi = 1,25$ (*underventilated fire*)
[6] In alternativa alle rese $Y_{CO2}$ e $Y_{H2O}$, si può imporre nel codice di calcolo il combustibile generico $CH_2O_{0,5}$.

*Tabella M.2-2: Focolari predefiniti*

| Modello | Prestazione | Soglia di prestazione | Riferimento |
|---|---|---|---|
| Oscuramento della visibilità da fumo | Visibilità minima di pannelli riflettenti, non retroilluminati, valutata ad altezza 1,80 m dal piano di calpestio | Occupanti: 10 m<br>Occupanti in locali di superficie lorda < 100m$^2$: 5 m | ISO 13571-2012. |
| | | Soccorritori: 5 m<br>Soccorritori n locali di superficie lorda < 100m$^2$: 2,5 m | [1] |
| Gas tossici | FED, *fractional effective dose* e FEC, *fractional effective concentration* per esposizione a gas tossici e gas irritanti, valutata ad altezza 1,80 m dal piano di calpestio | Occupanti: 0,1 | ISO 13571-2012, limitando a 1,1% gli occupanti incapacitati al raggiungimento della soglia |
| | | Soccorritori: nessuna valutazione | -- |
| Calore | Temperatura massima di esposizione | Occupanti: 60°C | ISO 13571-2012 |
| | | Soccorritori: 80°C | [1] |
| Calore | Irraggiamento termico massimo da tutte le sorgenti (incendio, effluenti dell'incendio, struttura) di esposizione degli occupanti | Occupanti: 2,5 kW/m$^2$ | ISO 13571-2012, per esposizioni maggiori di 30 minuti, senza modifica significativa dei tempi di esodo (2,5 kW/m$^2$). |
| | | Soccorritori: 3 kW/m$^2$ | [1] |
| [1] Ai fini di questa tabella, per *soccorritori* si intendono i componenti delle squadre aziendali opportunamente protetti ed addestrati alla lotta antincendio, all'uso dei dispositivi di protezione delle vie aeree, ad operare in condizioni di scarsa visibilità. Ulteriori indicazioni possono essere desunte ad esempio da documenti dell'Australian Fire Authorities Council (AFAC) per *hazardous conditions.* | | | |

*Tabella M.3-2: Esempio di soglie di prestazione impiegabili con il metodo di calcolo avanzato*

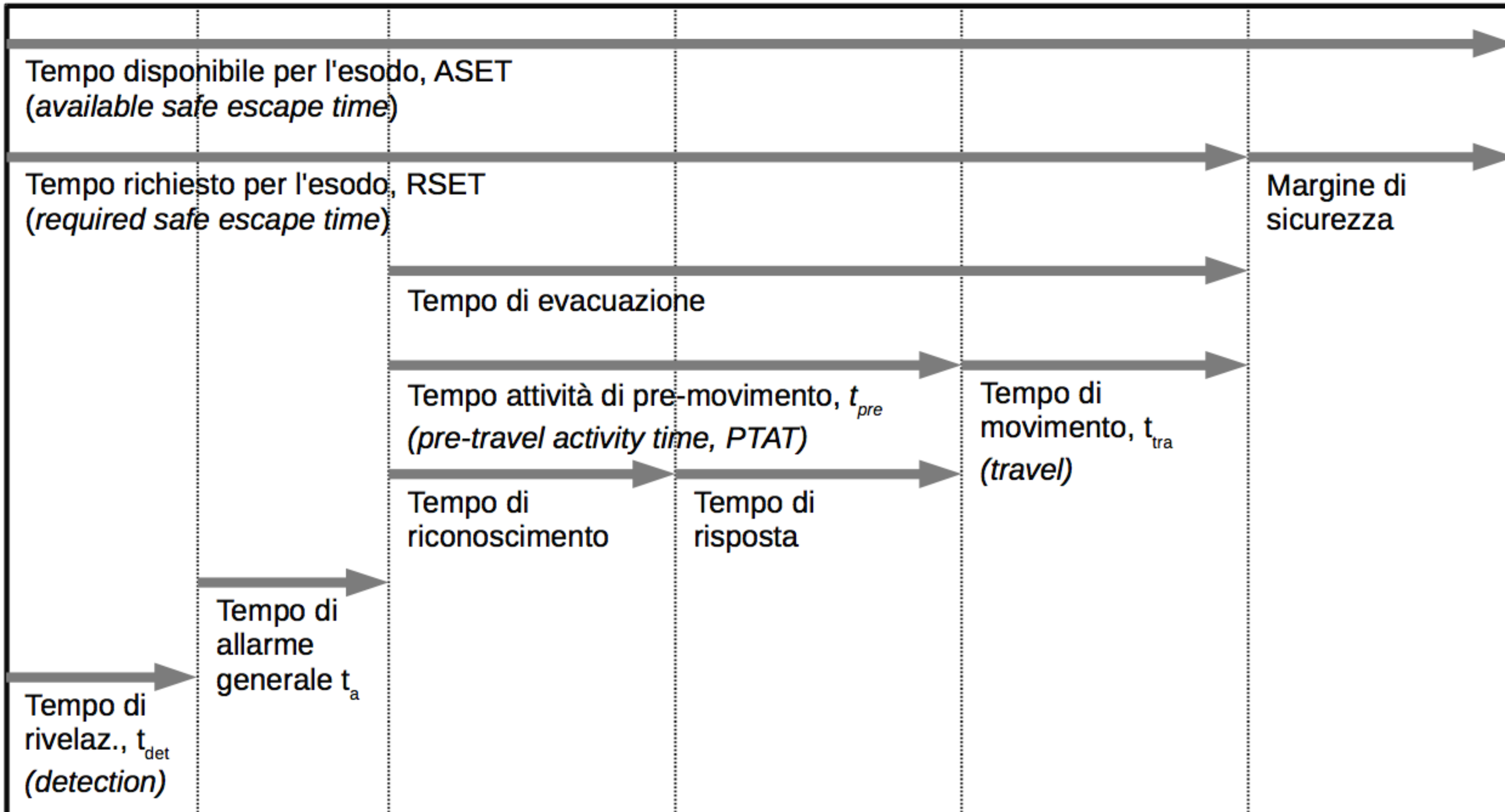



*Illustrazione M.3-1: Confronto tra ASET ed RSET* evacuazione riportato nel registro dei controlli.

| Parametri di descrizione dell'attività tratto da ISO TR 16738 | Tempi di attività di pre-movimento ISO TR 16738 | |
|---|---|---|
| | $\Delta t_{pre\ (1st)}$ primi occupanti in fuga | $\Delta t_{pre\ (99th)}$ ultimi occupanti in fuga |
| Esempio 1: albergo di media complessità<br>• *occupanti: Ciii, sleeping and unfamiliar;*<br>• sistema di allarme: rivelazione automatica ed allarme generale mediato dall'intervento di verifica dei dipendenti;<br>• complessità geometrica edificio: *edificio multipiano e layout semplice;*<br>• gestione della sicurezza: *ordinaria*. | 20' | 40' |
| **Esempio 2: grande attività produttiva**<br>• occupanti: *A, awake and familiar;*<br>• sistema di allarme: rivelazione automatica ed allarme generale mediato dall'intervento di verifica dei dipendenti;<br>• complessità geometrica edificio: edificio multipiano e layout complesso;<br>• gestione della sicurezza: *ordinaria*. | 1' 30" | 3' 30" |
| **Esempio 3: residenza sanitaria assistenziale**<br>• occupanti: *D, sleeping and unfamiliar;*<br>• sistema di allarme: rivelazione automatica ed allarme generale mediato dall'intervento di verifica dei dipendenti;<br>• complessità geometrica edificio: edificio multipiano e layout semplice;<br>• gestione della sicurezza: *ordinaria*;<br>• presenza di addetti in quantità sufficiente a gestire l'evacuazione dei diversamente abili. | 5' | 10' |

*Tabella M.3-1: Esempi di valutazione del tempo di pre-movimento, tratto da ISO TR 16738*

## *Mai Dimenticare la parte Gestionale ed i CONTROLLI !!!*


sal

# Conclusioni ……….

- Molte variabili da definire e da presidiare
  - Interne
  - Esterne

- Molte approssimazioni, metodo deterministico
  - Necessità di metodologie di uso
  - Utenti consapevoli e formati

- Sistema di Gestione
  - mantenimento delle condizioni di progetto
  - FORMAZIONE, CONTROLLI, PROVE…

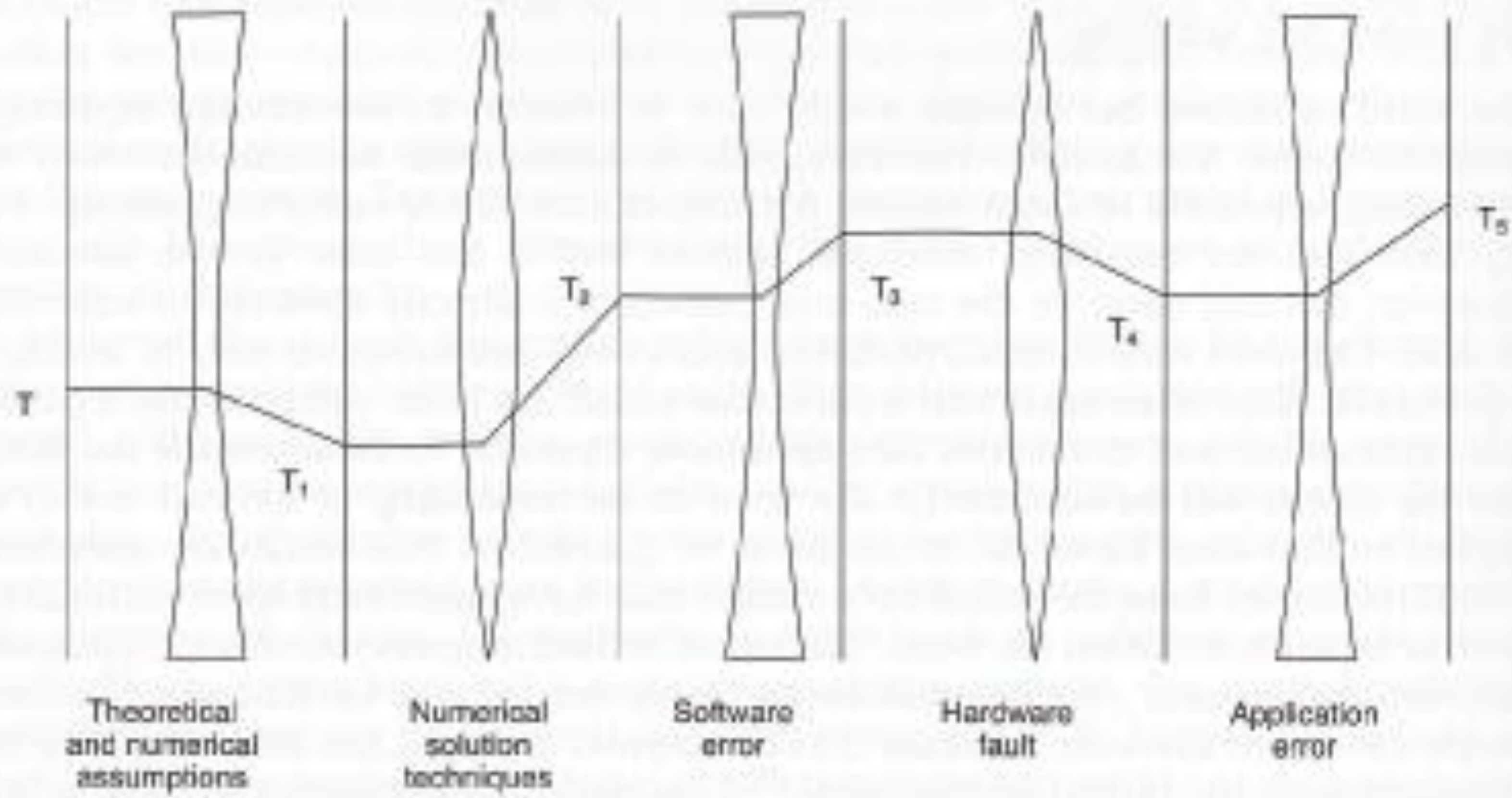
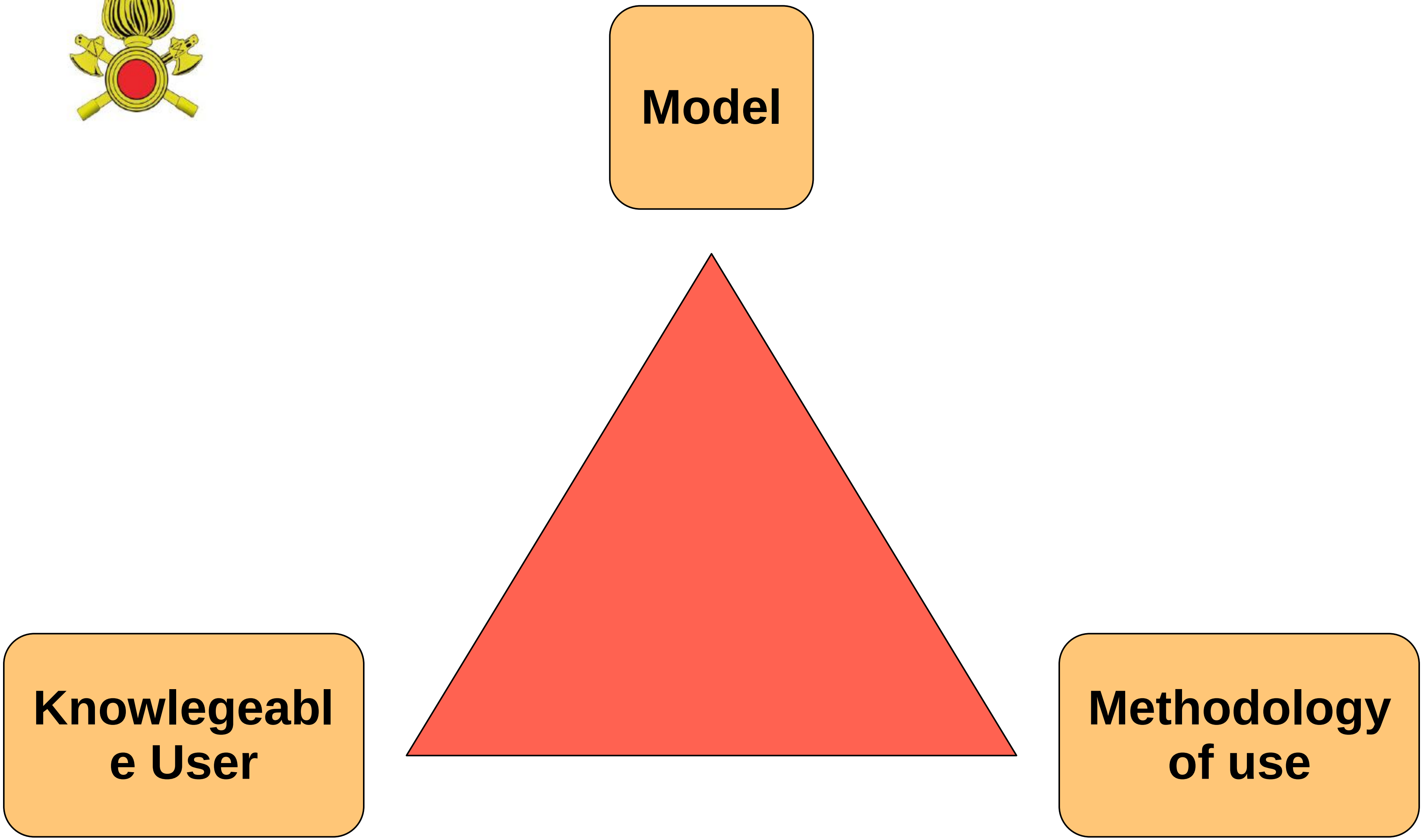



*Figure 14.4. Categories of error (represented via a lens analogy)*


Model
Knowlegeable User
Methodology of use

# Ma NON dimentichiamo le soluzioni SEMPLICI !!!!

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