Infrastructure Fire Engineering:

Why all that analysis and why all that detail

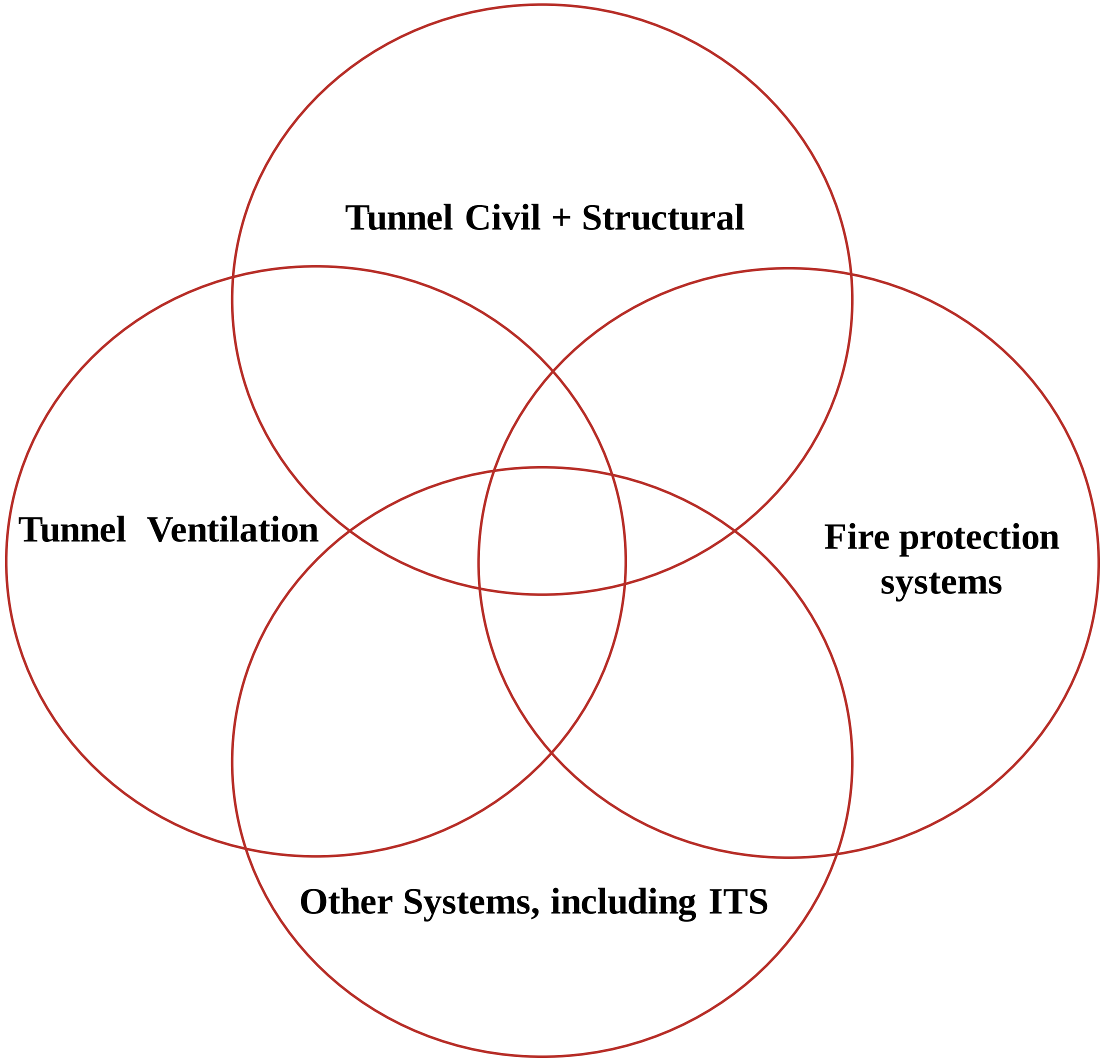
Dr Joe Paveley

Technical Executive, Tunnel Systems Manager

WSP

Content

- What scope fire engineering
- Fire scenarios
- Fire, smoke and ventilation
- Emergency operations.



3

Fire safety strategy developed by:

- Precedence
- Codes
- Community (i.e. site locations)
- Contract technical criteria

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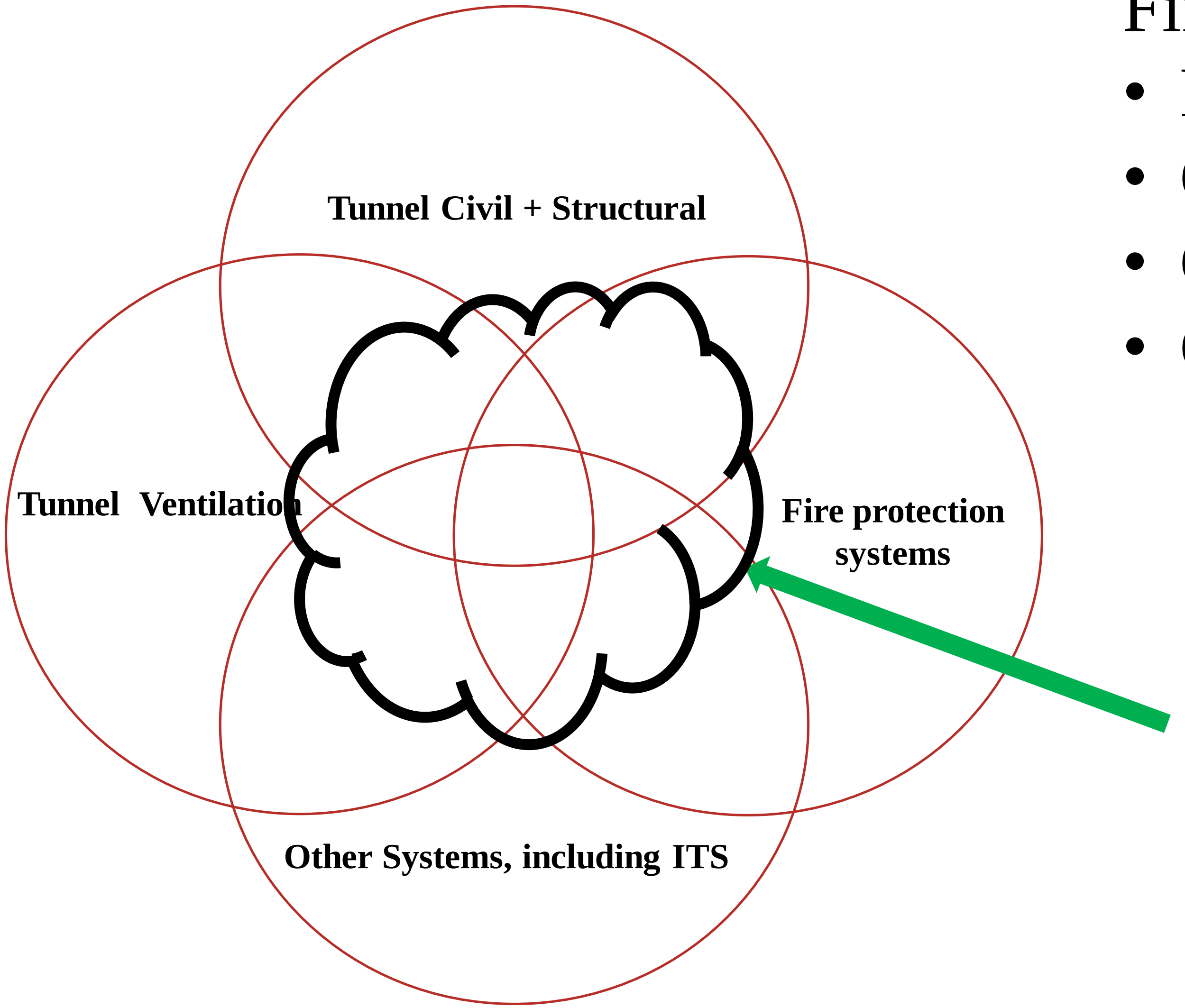


What role fire engineering?

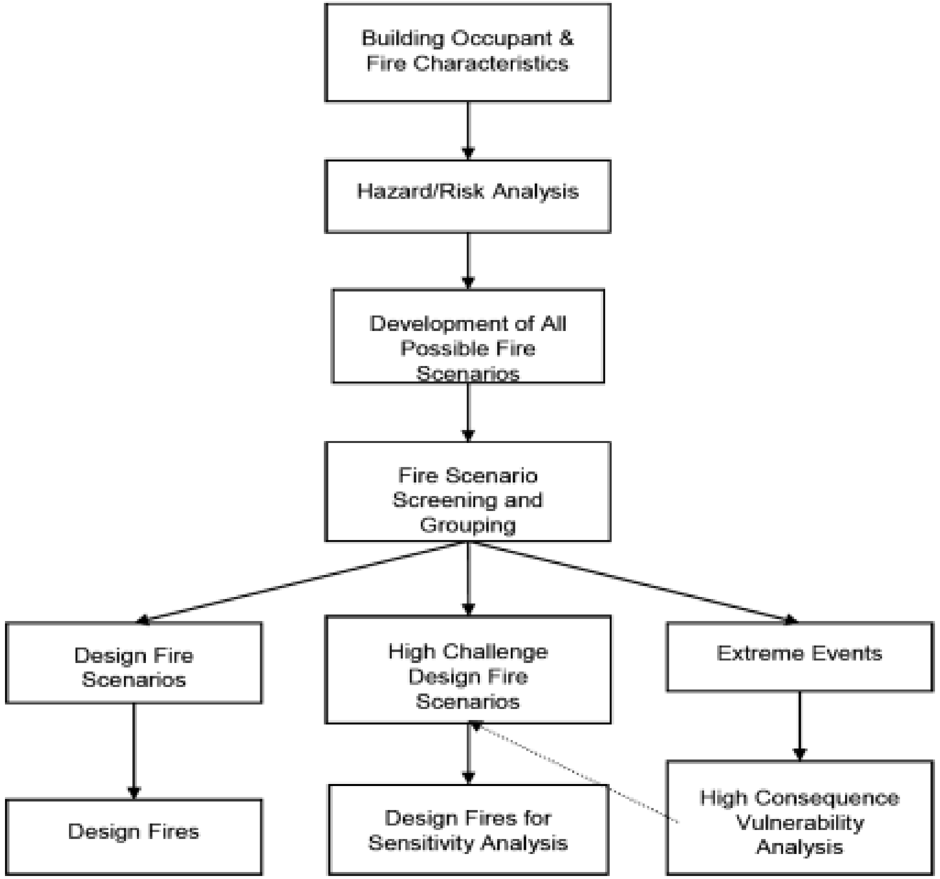
Fire Safety Engineering Changing Role

- Increasing performance based input
  - New modelling tools
  - Fire risk analysis
  - Operations
- Legislation
  - Rail Safety National Law
    - SFaiRP
  - Road regulations
- Fires
  - Kings Cross Fire 1987
  - Lacrosse Fire.

Fire Scenarios

Fire Scenarios

Design Fire Scenario	X	Design Egress Scenario	=	Combined Design Scenario (Minimum Safety factor of 1.5)
Design Fire Scenario	X	High Challenge Egress Scenario	=	Combined High Challenge Scenario (Minimun Safety factor of 1.0)
High Challenge Fire Scenario	X	Design Egress Scenario	=	Combined High Challenge Scenario (Minimun Safety factor of 1.0)
High Challenge Fire Scenario	X	High Challenge Egress Scenario	=	Combined Extreme Event Scenario (SFAIRP)
Extreme Event Fire Scenario	X	Design Egress Scenario	=	Combined Extreme Event Scenario (SFAIRP)
Extreme Event Fire Scenario	X	High Challenge Egress Scenario	=	Combined Extreme Event Scenario (SFAIRP)

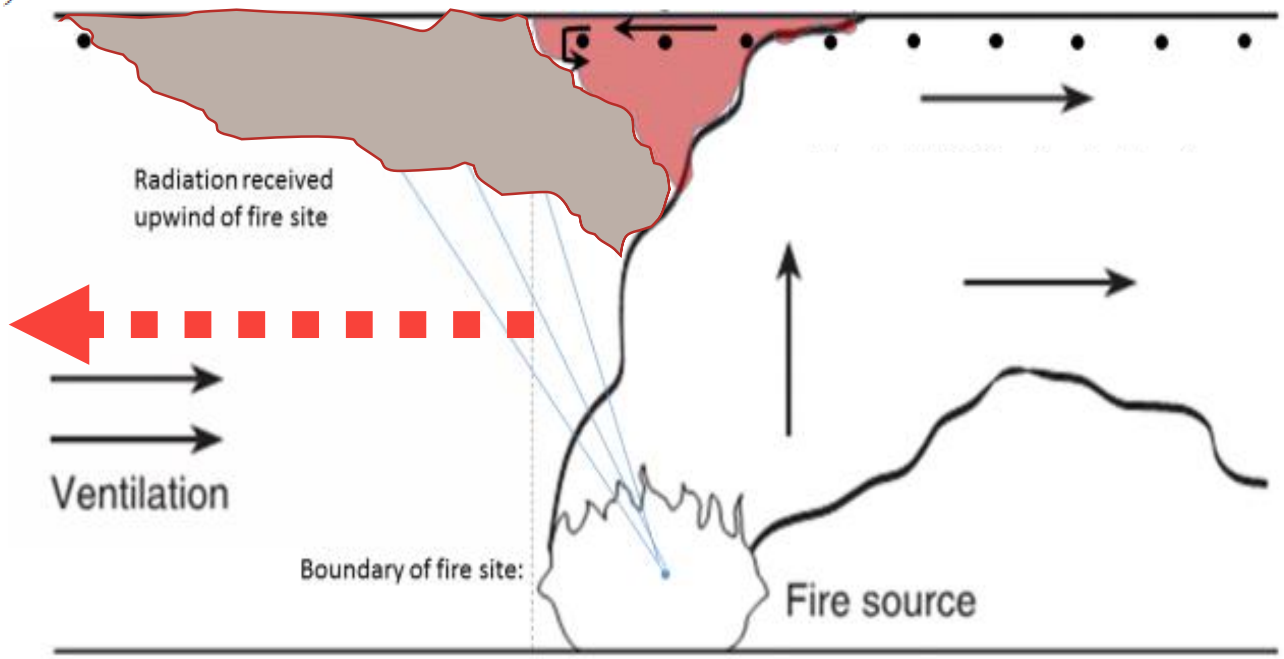


Tunnel Ventilation and Critical Velocity

Backlayering

- Froude number calculation
- NFPA 502 (2020)

$$\frac{u}{\sqrt{gH}} = \begin{cases} 0.81\left(\dfrac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}}\right)^{1/3}\left(\dfrac{H}{W}\right)^{1/12} e^{\left(-\frac{L_b}{18.5H}\right)}, & \dfrac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}} \le 0.15\left(\dfrac{H}{W}\right)^{-1/4} \\ 0.43 e^{\left(-\frac{L_b}{18.5H}\right)}, & \dfrac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}} > 0.15\left(\dfrac{H}{W}\right)^{-1/4} \end{cases}$$



- zero backlayering

OR

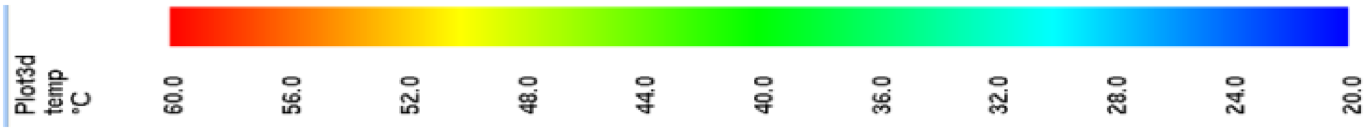
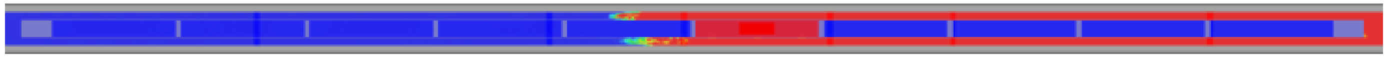
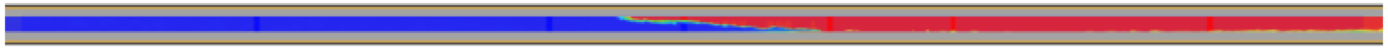
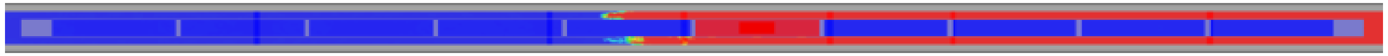
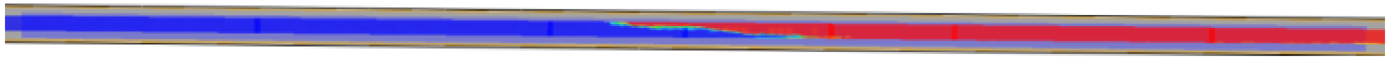
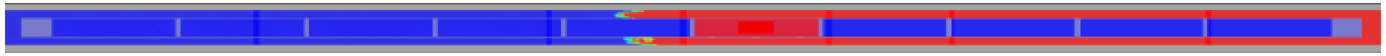
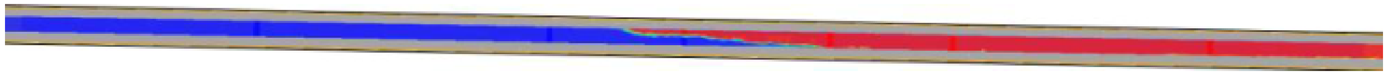
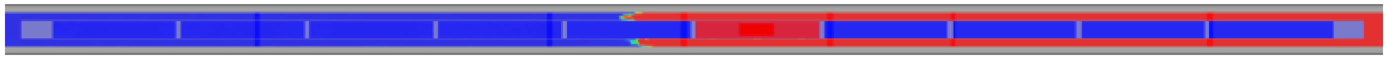
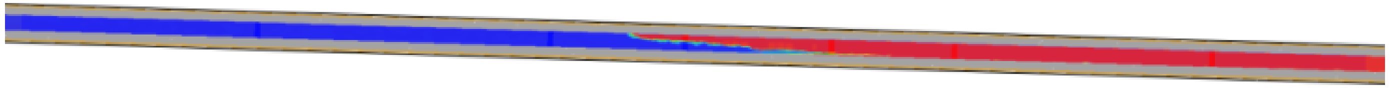
- Backlayering confinement.

Analysis

What is acceptable?

- Length
- Temperature
- Visibility

- Acceptable backlayering
  - everything good?

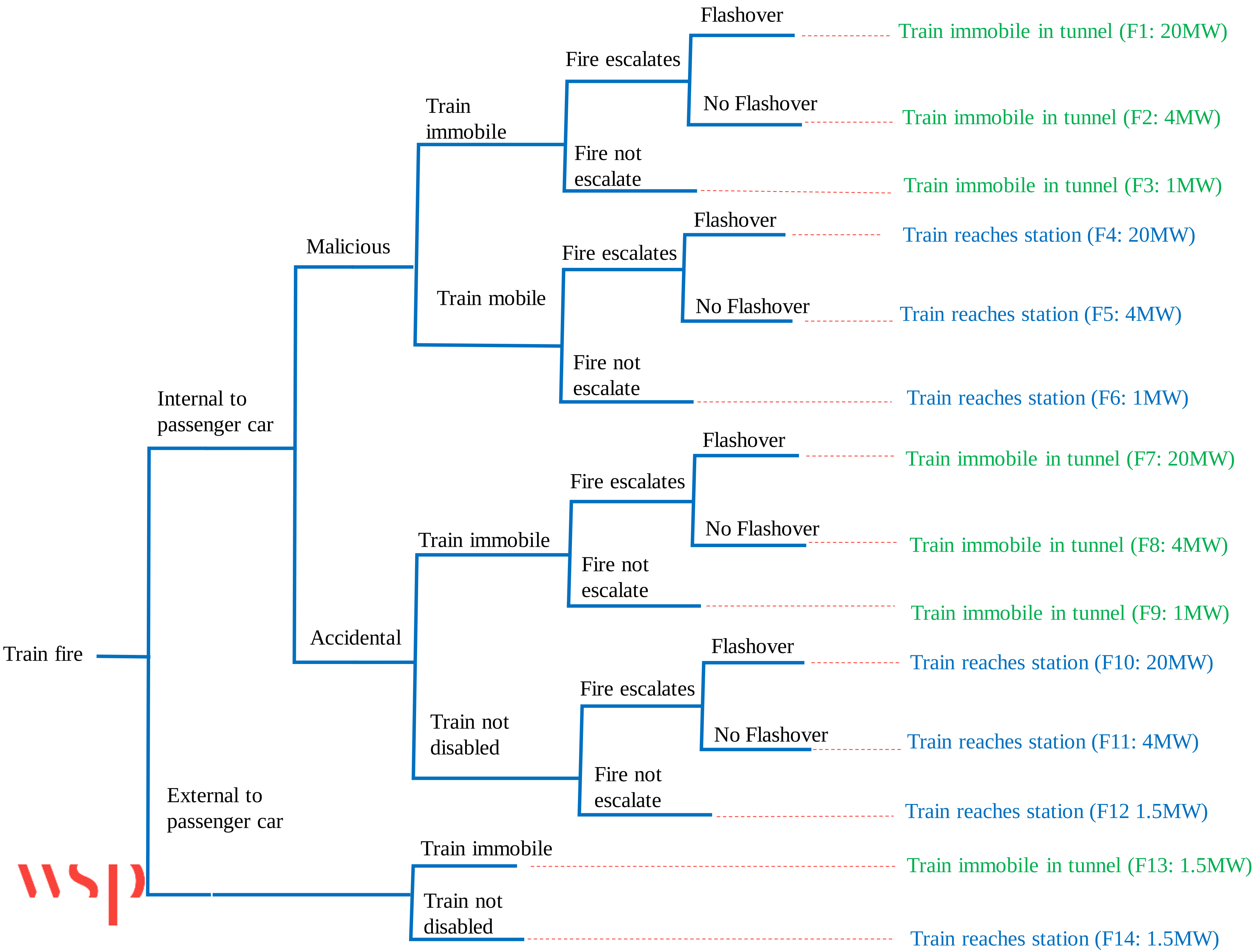
SIMULATION PARAMETERS	VIEW	TEMPERATURE CONTOUR
		
Tunnel gradient: 0 %	Plan	
Annulus velocity: 2.4 m/s	Section	
Tunnel gradient: 1.0 %	Plan	
Annulus velocity: 2.5 m/s	Section	
Tunnel gradient: 2.0 %	Plan	
Annulus velocity: 2.6 m/s	Section	
Tunnel gradient: 3.0 %	Plan	
Annulus velocity: 2.7 m/s	Section	

So Backlayering OK – Nothing else?

"Tenability downstream of a train fire in a tunnel is not typically analysed for metros, as that risk is normally managed by controlling the fire performance of the rollingstock and its running capability. With the cross passage spacing set, and within the practical limits of TVS capacity, there are limited options that can be done practically to improve tenability downstream."

However…………

i. Extreme Scenarios need assessment if high consequence
ii. Design and High Challenge fires?
    i. What is the risk associated with evacuation downstream?
    ii. What can be done to improve
    iii. Are there operational options.


Train fire
Internal to passenger car
External to passenger car
Malicious
Accidental
Train immobile
Train mobile
Train immobile
Train not disabled
Train immobile
Train not disabled
Fire escalates
Fire not escalate
Flashover
No Flashover
Train immobile in tunnel (F1: 20MW)
Train immobile in tunnel (F2: 4MW)
Train immobile in tunnel (F3: 1MW)
Train reaches station (F4: 20MW)
Train reaches station (F5: 4MW)
Train reaches station (F6: 1MW)
Train immobile in tunnel (F7: 20MW)
Train immobile in tunnel (F8: 4MW)
Train immobile in tunnel (F9: 1MW)
Train reaches station (F10: 20MW)
Train reaches station (F11: 4MW)
Train reaches station (F12 1.5MW)
Train immobile in tunnel (F13: 1.5MW)
Train reaches station (F14: 1.5MW)

Tenability Analysis

ISO 13344 & 13571 FED approach

NFPA 130

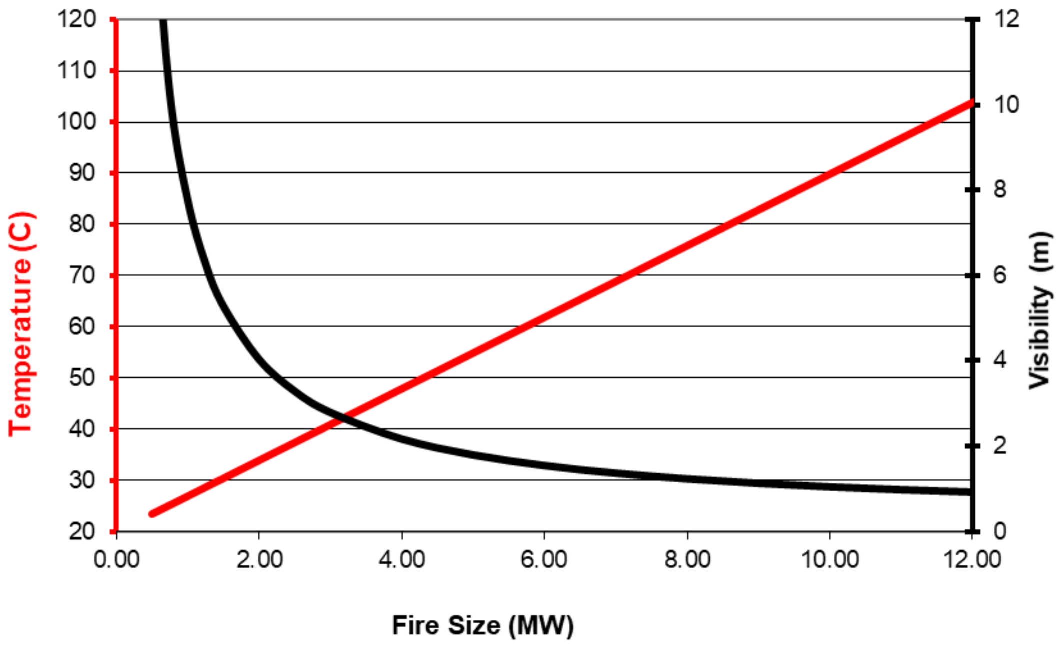
In a 1.5 MW fire:

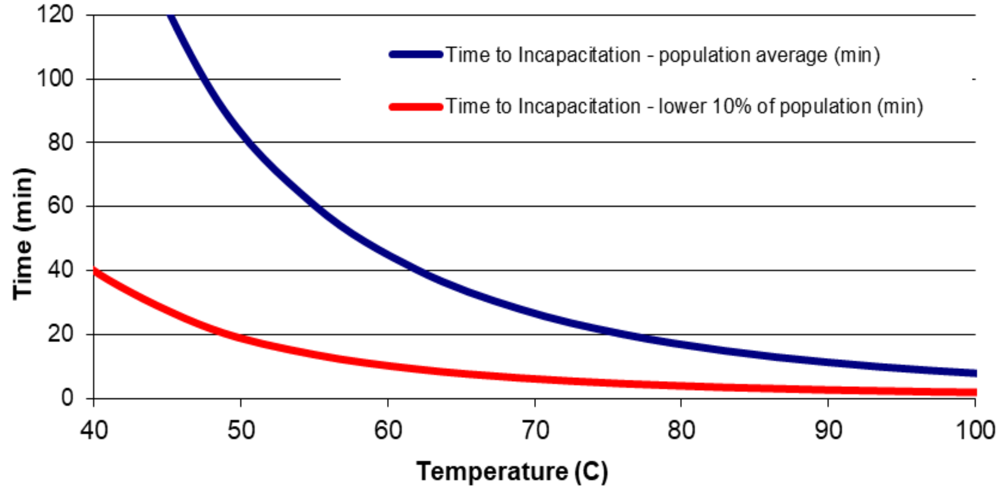
- Low visibility
  - Travel at 0.3 m/s
- Low temperatures (<< 40^{0}C)

In a 4.0 MW fire:

- Low visibility
  - Travel at 0.3 m/s
- Moderate temp (<< 50^{0}C)

Can carry out analysis for lower FED values.





	1.5 MW fire		I	II	III	IV	V	VI	VII	VIII
	Passenger/Public Safety	Fatality					1	10	100	1000
		Major Injury				1	10	100	1000	
		Minor Injury (Class 1)			1	10	100	1000		
	>100,000 years	<0.00001/yr				L	L	L	L	M
A	10,000 years to 100,000 years	0.0001-0.00001/yr				L	L	L	M	M
B	1000 years to 10,000 years	0.001-0.0001/yr	L	L	L	L	L	M	M	M
C	100 years to 1000 years	0.01-0.001/yr	L	L	L	L	M	M		
D	10 years to 100 years	0.1-0.01/yr	L	L	L	M	M	M		
E	1 year to 10 years	1-0.1/yr	L	L	M	M	M	H		
F	1 month to 1 year	10-1/yr	L	M	M	M	H	H		
G	Few times per month	100-10/yr	M	M	M	H	H	H		
H	Few times per day	100-1000/yr	M	M	H	H	H	H	H	H

Risk for off peak occupant load

Risk for peak and crush occupant load

	4MW fire		I	II	III	IV	V	VI	VII	VIII
	Passenger/Public Safety	Fatality					1	10	100	1000
		Major Injury				1	10	100	1000	
		Minor Injury (Class 1)			1	10	100	1000		
	>100,000 years	<0.00001/yr				L	L	L	L	M
A	10,000 years to 100,000 years	0.0001-0.00001/yr				L	L	L	M	M
B	1000 years to 10,000 years	0.001-0.0001/yr	L	L	L	L	L	M	M	M
C	100 years to 1000 years	0.01-0.001/yr	L	L	L	L	M	M		
D	10 years to 100 years	0.1-0.01/yr	L	L	L	M	M	M		
E	1 year to 10 years	1-0.1/yr	L	L	M	M	M	H		
F	1 month to 1 year	10-1/yr	L	M	M	M	H	H		
G	Few times per month	100-10/yr	M	M	M	H	H	H		
H	Few times per day	100-1000/yr	M	M	H	H	H	H	H	H

Risk for off-peak occupant load

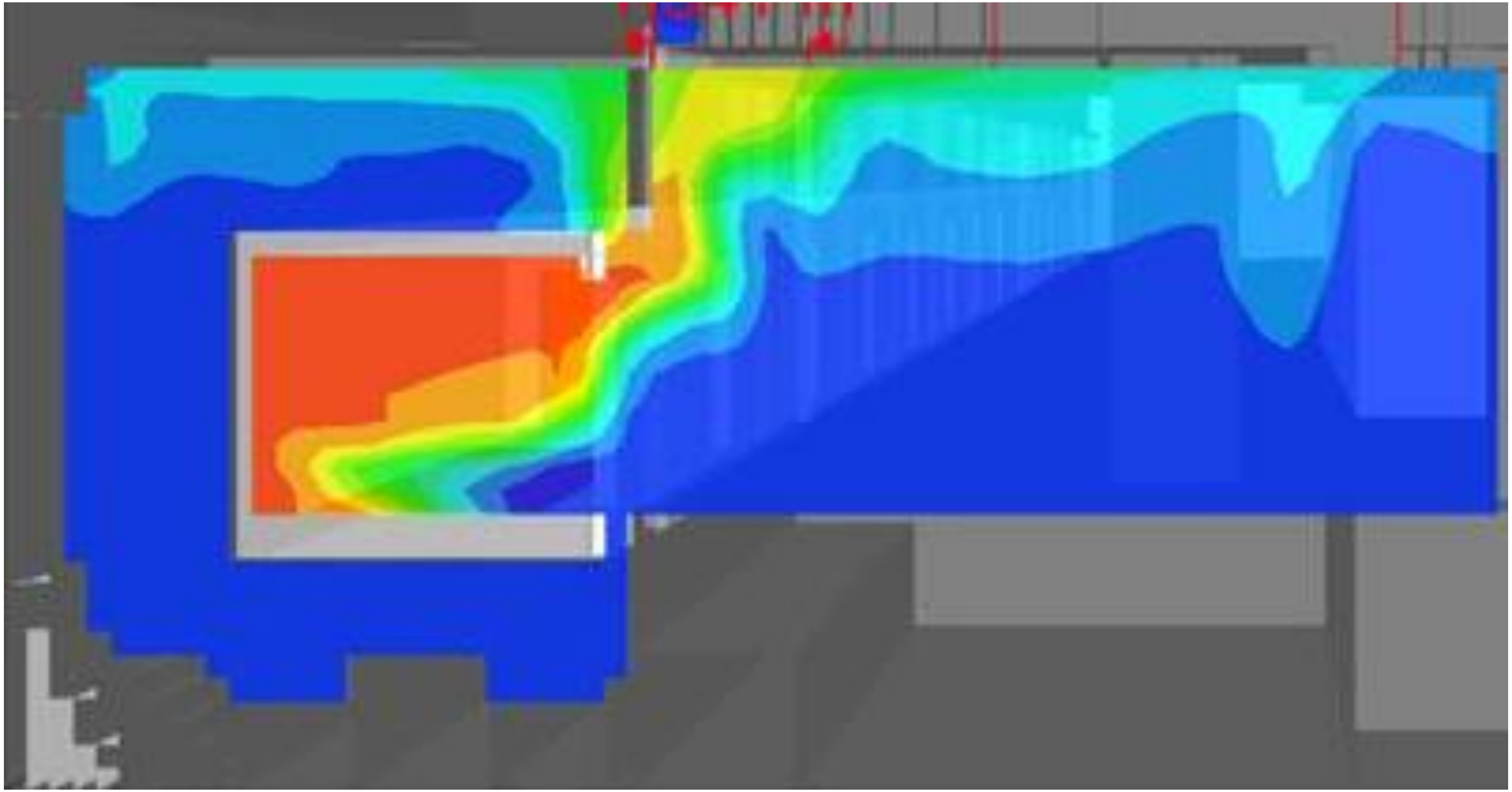
Risk for peak and crush occupant load

Station Trackway Fires

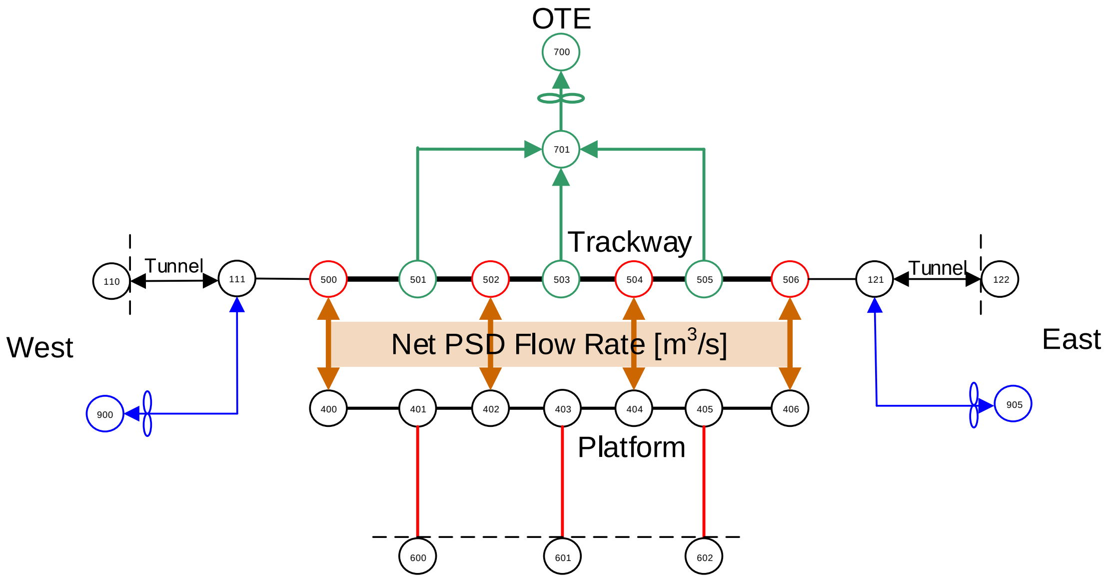
Different results

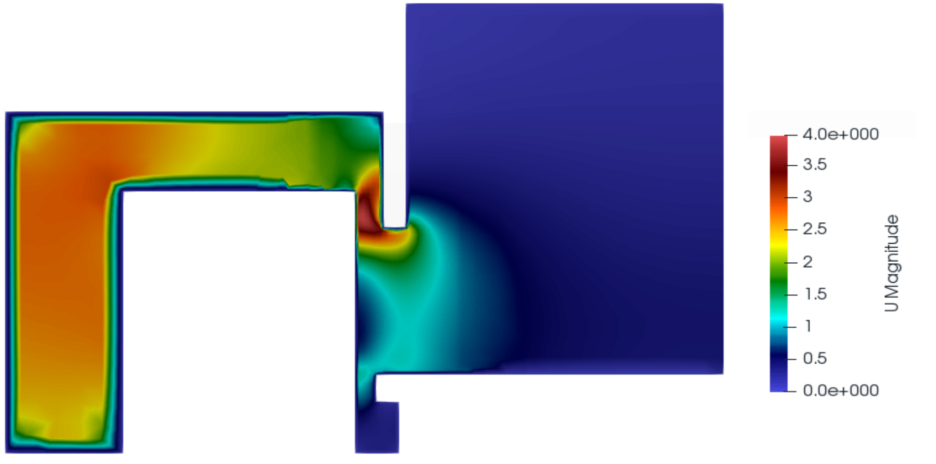
[Major difference in FDS results due to use of different boundary conditions – pressure v velocity boundary]

Impact Platform Screen Doors

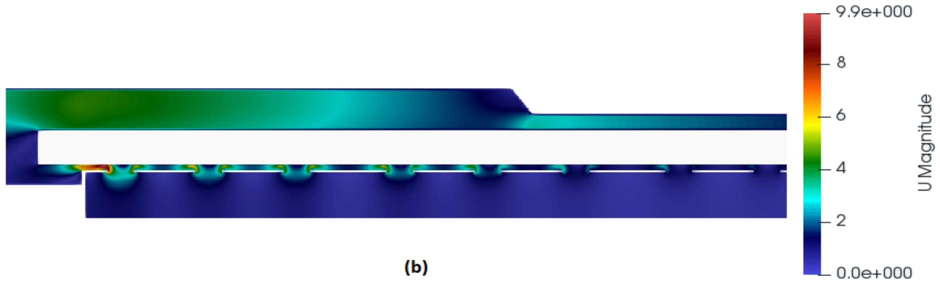


Integrate with Tunnel Ventilation Modelling



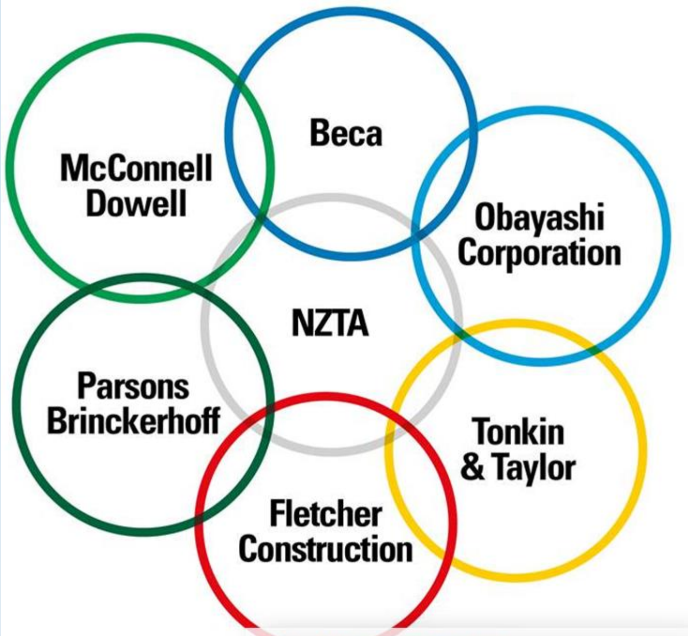


(a) Velocity contour - Trackway cross section

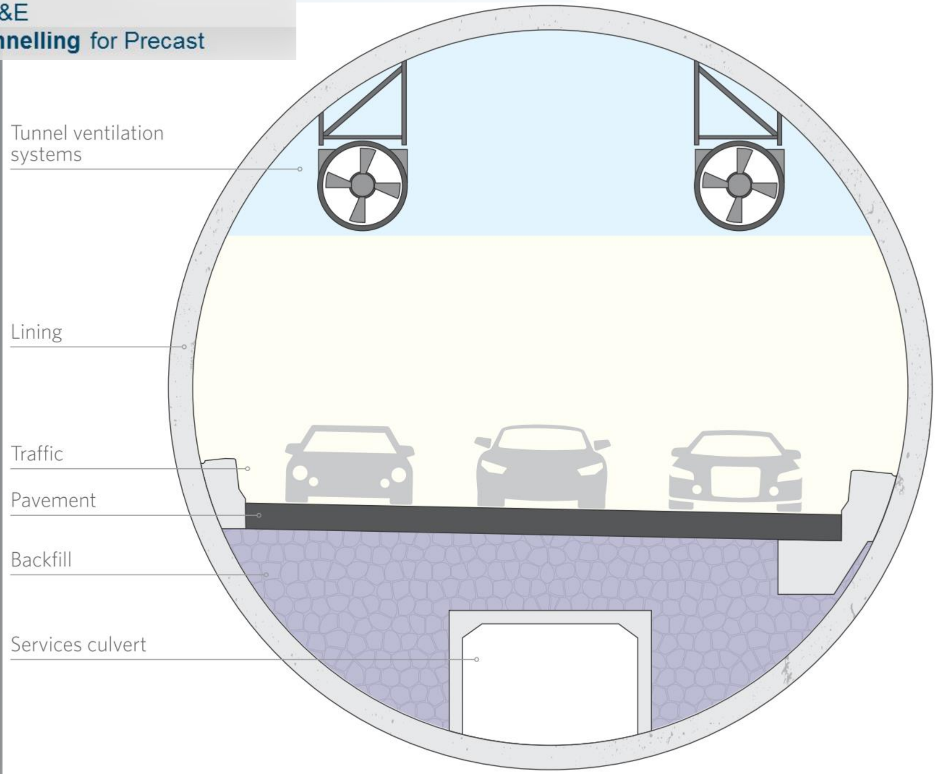


(b) Velocity contour - Trackway top view

Waterview
Auckland
New Zealand



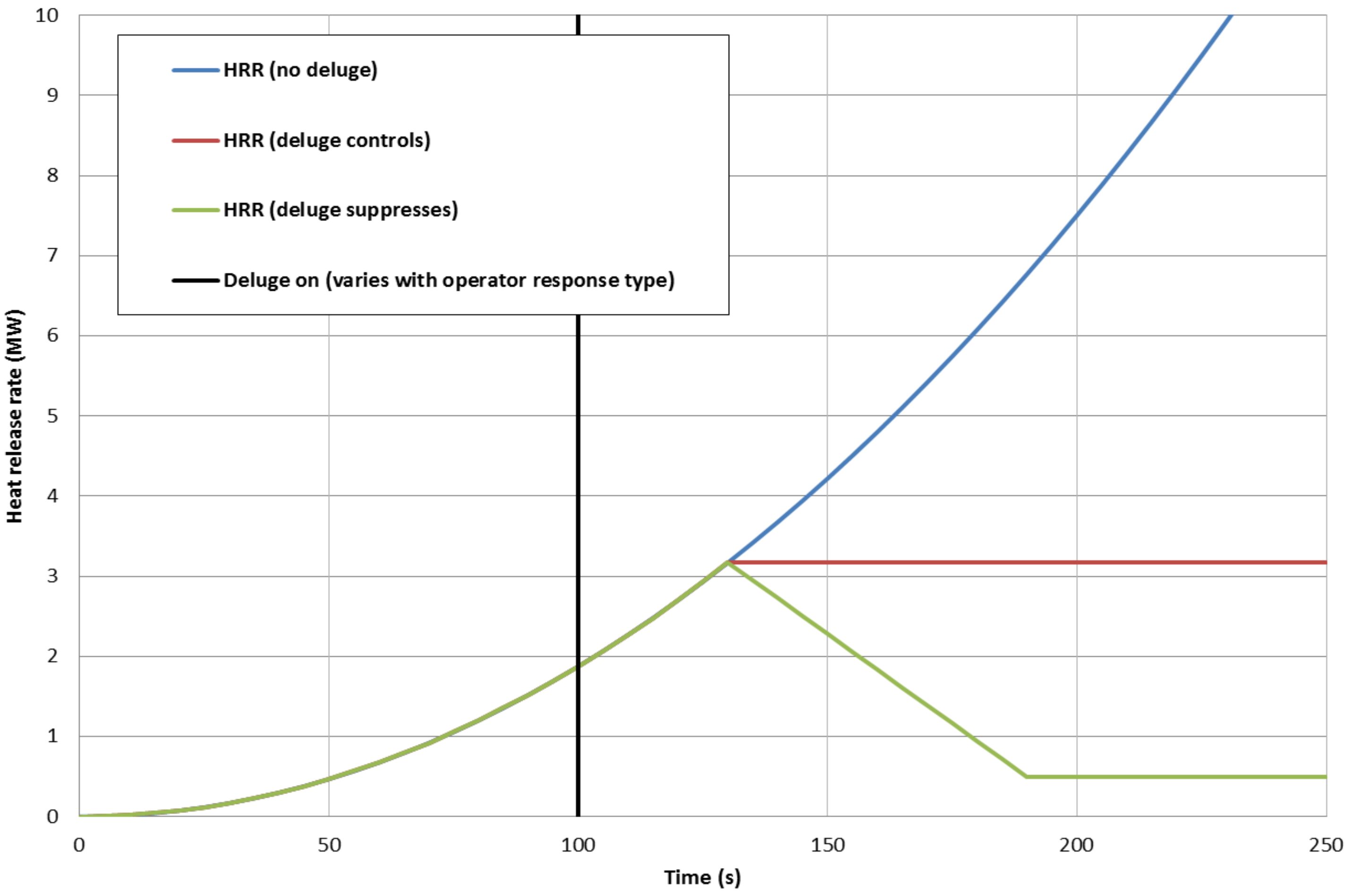
Sub-Alliance Partners:
- **SICE** for M&E
- **Wilson Tunnelling** for Precast



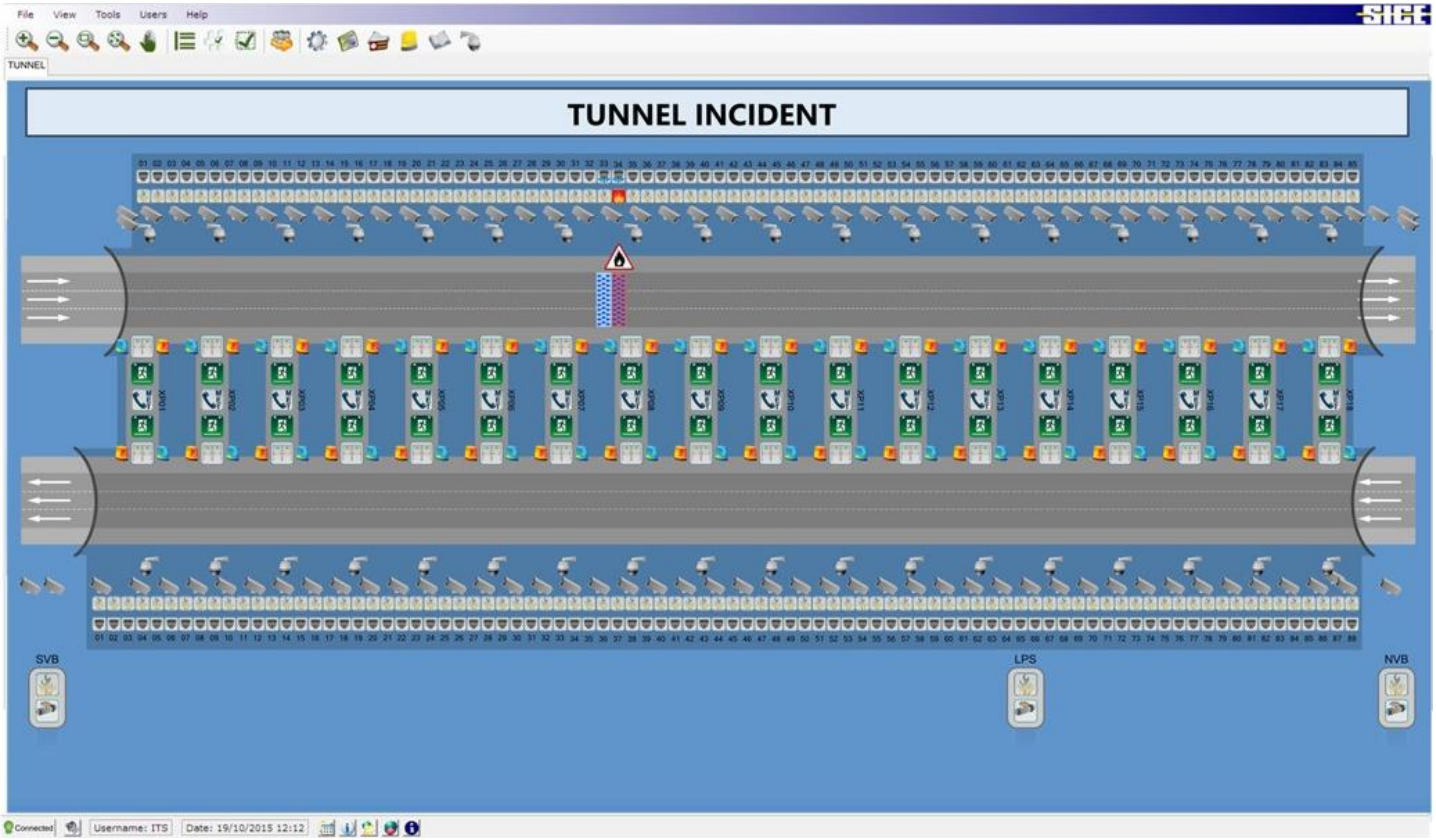
Fire Engineering – Detailed Design Role

- **Tunnel Systems services:**
- Integrated design team all disciplines
- Services included tunnel ventilation, fire systems and fire engineering
- **Key services issues:**
- Fire engineering analysis including QRA to assess fire safety options
- Full detailed systems design
  - Integrated tunnel ventilation and fire engineering
- Fire service intervention planning
- Systems commission planning
- Fire strategy input into design of graphical interface design in control room.

Systems Performance and Fire Safety Performance



Flow chart for Tunnel Indent Response



File
View
Tools
Users
Help
SICE
TUNNEL
TUNNEL INCIDENT
SVB
LPS
NVB
Connected
Username: ITS
Date: 19/10/2015 12:12

Tunnel Procurement

Procurement Staged

Staged design:

- Business case & feasibility
- Reference design
- Scheme Design
- Detailed design

- Change in fire safety engineer:
  - Methods
  - Opinions
  - different knowledge and experience
  - Commercial pressures.
- Who is responsible?