July 2017

Workshop on Fire Safety Engineering

Towards establishing a Centre of Excellence in Turkey

Organizers:

Prof. Yong WANG, University of Manchester

Assist. Prof. Serdar SELAMET, Boğaziçi University

Newton Research Collaboration Programme
Royal Academy of Engineering

FIRE IS A HIGH RISK ON STRUCTURES


Caracas


Taipei


Los Angeles


Philadephia


Beijing


Dubai


Istanbul


Jakarta

EARTHQUAKE AND FIRE

- Fire is more probable after an earthquake (no sprinklers, natural gas lines, no immediate fire brigade intervention.)
- In high-rise buildings, fires are more difficult to contain and rescue missions are more complicated.


Kobe, Japan 1995

FIRE REGULATIONS IN TURKEY

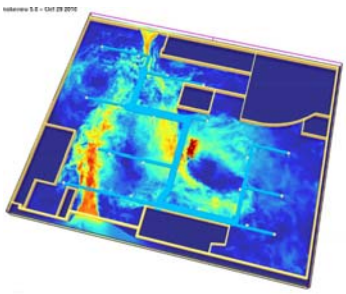
Prescriptive Approach

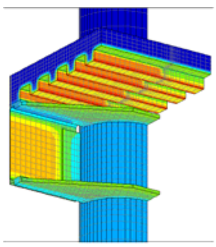
BYKHK: Binaların yangından korunması hakkında yönetmelik

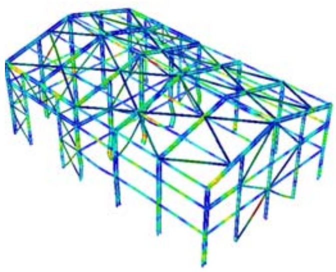
Fire Safety Engineering
(Performance-based Approach)

structural response (REI)
non-structural response (EI)
fire protection
fire compartmentation
fire detection / supression
egress
fire growth
smoke

FIRE SAFETY ENGINEERING







- Turkish regulation is not equipped for complex infrastructure and development in Turkey.
- Turkish fire regulation needs to allow «fire strategy reports» using performance-based fire engineering principles
- Therefore, there is a need of a Center of Excellence in Fire Safety Engineering !
- We need state-of-the-art knowledge transfer on fire safety engineering from UK fire experts. * NEWTON PROGRAMME

WORKSHOP OBJECTIVES

- ✓ Create awareness of **fire safety engineering** in Turkey. Current Regulation is not sufficient to answer special construction projects
- ✓ Initiate **knowledge transfer** from UK on performance based fire engineering approach
- ✓ Pave the way to establish a **national research center of excellence** in fire safety engineering

Glenfell Tower
London 2017

Performance Based Fire Engineering
- introduction to workshop

Yong Wang

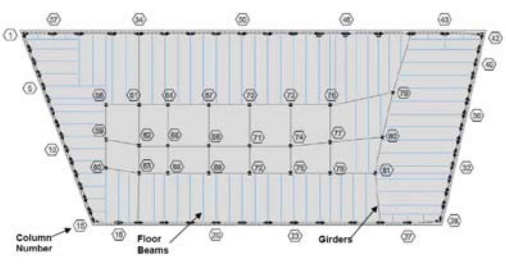
Professor of Structural and Fire Engineering

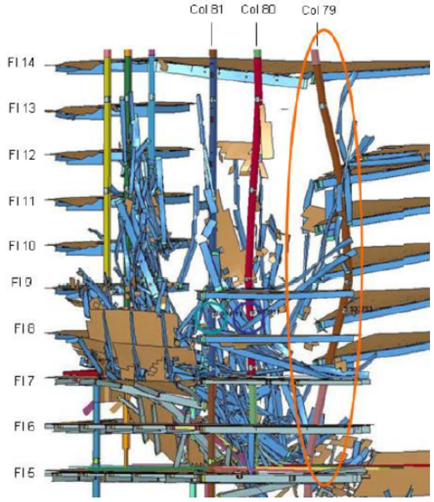
School of Mechanical, Aerospace and Civil Engineering,
University of Manchester, UK

Performance based fire engineering

- application of science and engineering to design fire protection and life safety systems to meet the unique fire safety requirements of different buildings
- opposite prescriptive generic checklist requirements

Unquantifiable safety of prescriptive solution – WTC7





Example of PB vs. prescriptive solutions – means of escape

B1 DESIGN FOR HORIZONTAL ESCAPE

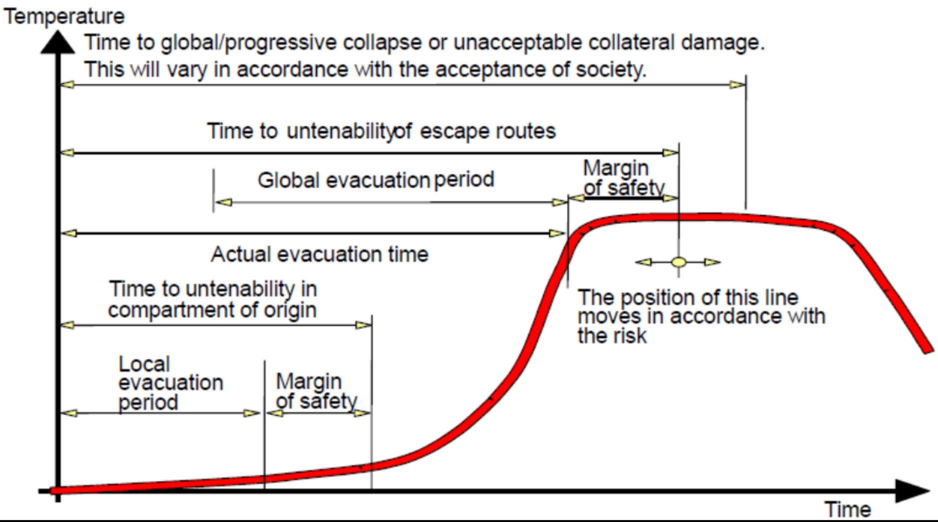
Table 2 Limitations on travel distance

Purpose group	Use of the premises or part of the premises		Maximum travel distance [1] where travel is possible in: One direction only (m)	More than one direction (m)
2(a)	Institutional		9	18
2(b)	Other residential:			
	a. in bedrooms [2]		9	18
	b. in bedroom corridors		9	35
	c. elsewhere		18	35
3	Office		18	45
4	Shop and commercial [3]		18 [4]	45
5	Assembly and recreation:			
	a. buildings primarily for disabled people		9	18
	b. areas with seating in rows		15	32
	c. elsewhere		18	45
6	Industrial [5]	Normal Hazard	25	45
		Higher Hazard	12	25
7	Storage and other non-residential [5]	Normal Hazard	25	45
		Higher Hazard	12	25
2–7	Place of special fire hazard [6]		9 [7]	18 [7]
2–7	Plant room or rooftop plant:			
	a. distance within the room		9	35
	b. escape route not in open air (overall travel distance)		18	45
	c. escape route in open air (overall travel distance)		60	100

Notes:

1. The dimensions in the Table are travel distances. If the internal layout of partitions, fittings, etc is not known when plans are deposited, direct distances may be used for assessment. The direct distance is taken as 2/3rds of the travel distance.

Fire engineering solution – time based



Demands of PB fire engineering

0.34 It is possible to use quantitative techniques to evaluate risk and hazard. Some factors in the measures listed above can be given numerical values in some circumstances. The assumptions made when quantitative methods are used need careful assessment.

0.32 Factors that should be taken into account include:

a. the anticipated probability of a fire occurring;

b. the anticipated fire severity;

c. the ability of a structure to resist the spread of fire and smoke; and

d. the consequential danger to people in and around the building.

0.33 A wide variety of measures could be considered and incorporated to a greater or lesser extent, as appropriate in the circumstances. These include:

a. the adequacy of means to prevent fire;

b. early fire warning by an automatic detection and warning system;

c. the standard of means of escape;

d. provision of smoke control;

e. control of the rate of growth of a fire;

f. structural robustness and the adequacy of the structure to resist the effects of a fire;

g. the degree of fire containment;

h. fire separation between buildings or parts of buildings;

i. the standard of active measures for fire extinguishment or control;

j. facilities to assist the fire and rescue service;

k. availability of powers to require staff training in fire safety and fire routines;

l. consideration of the availability of any continuing control under other legislation that could ensure continued maintenance of such systems; and

m. management.

Benefits of PB Fire Engineering

- Greater freedom of design
- Achieve “impossible” solution
- Optimising resources
- Enhanced safety

Introduction to workshop

- To share knowledge
- To encourage PB fire engineering in Turkey
- To promote fire engineering research and development
- Themes: means of escape, smoke control, fire resistance
- Workshop instructors:
- Iris Chang: Design Fire Consultants
- Panos Kotsovinos: Arup Fire
- Yong Wang: University of Manchester
- Serdar Selamet: Bogazici University

Iris Chang

Iris CHANG, MEng AIFireE, Fire Engineer - Design Fire Consultants, UK
Iris joined Design Fire Consultants in 2016. She has an MEng degree in Structural and Fire Safety Engineering and 4 years of experience working as a Fire Engineer. Iris has worked on projects across many sectors, in particular Commercial and Residential. She has been involved in schemes that are at their design, construction or operational phase, using the fundamentals of fire engineering principles to develop alternative solutions where prescriptive assumptions are inappropriate. Recent examples include using radiative heat transfer calculation to help realise a highly glazed façade design to a new office building in Manchester; and maximising the occupant load potential in an existing office building by the use of internal fire compartmentation. Iris is currently based in the Manchester office working on local projects as well as those around the UK.

Panos Kotsovinos

Panos KOTSOVINOS, Fire Engineer, Arup Manchester, UK
Panos is a fire engineering consultant with Arup in the UK. He has involved on a variety of building and infrastructure projects in the UK and internationally primarily as a designer and at times as peer-reviewer. Panos has a PhD in structural fire engineering. He has published a number of journal and conference papers in the field of fire engineering and has contributed to the development of best-practice guidance documents. Panos is currently a guest lecturer at Imperial College London and Arup Industrial Supervisor for a number of PhD and Master projects at Imperial College. Panos is also involved in various BSI, ISO, IFE and SFPE technical committees.

DESIGN FIRE CONSULTANTS

Fire Safety Engineering Workshop, Istanbul

26 July 2017

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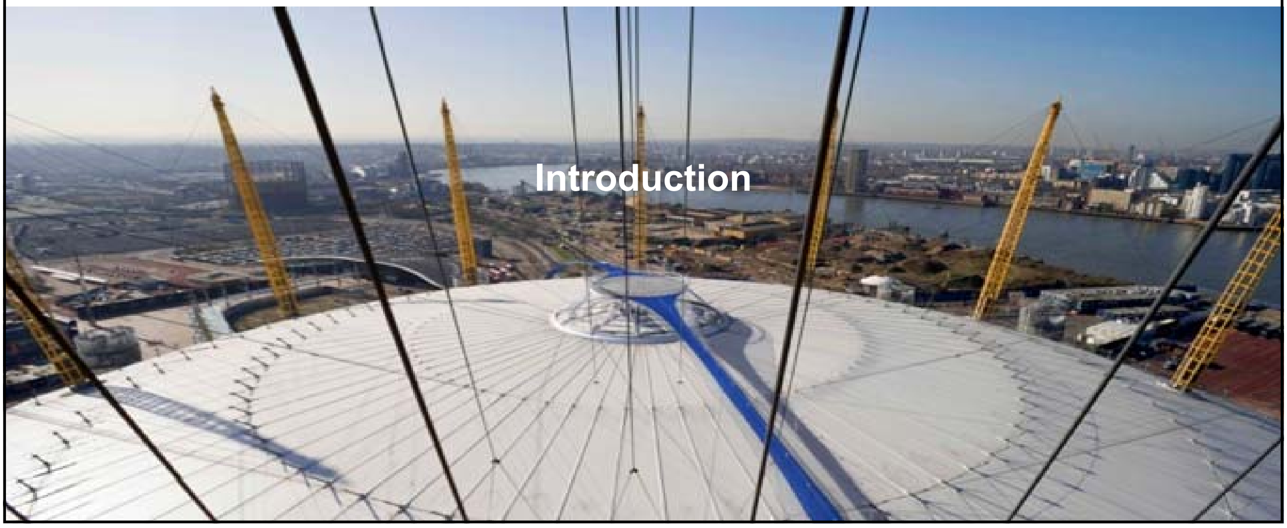
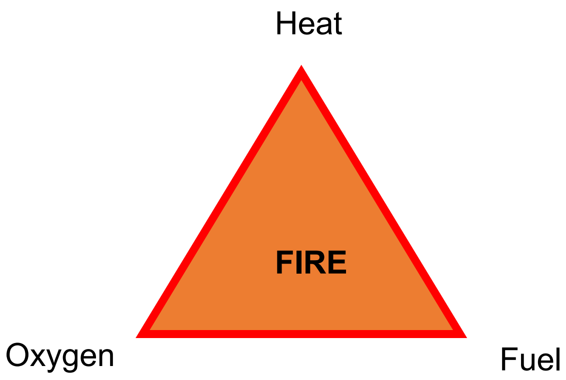
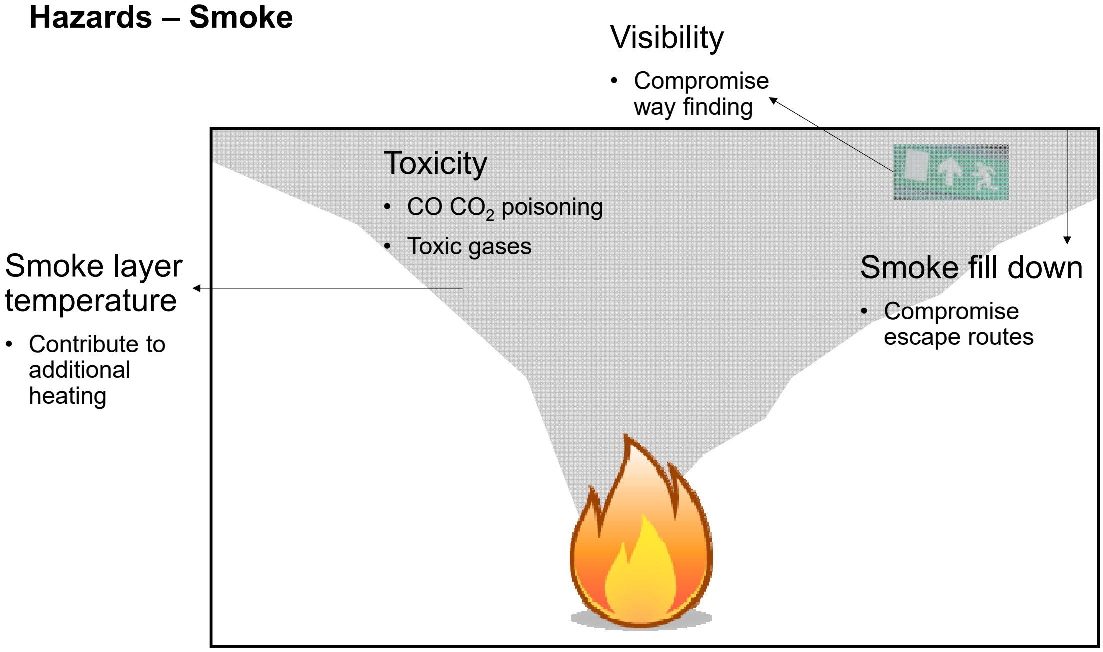


The Fire Triangle

- Characterising the fire



Hazards – Smoke



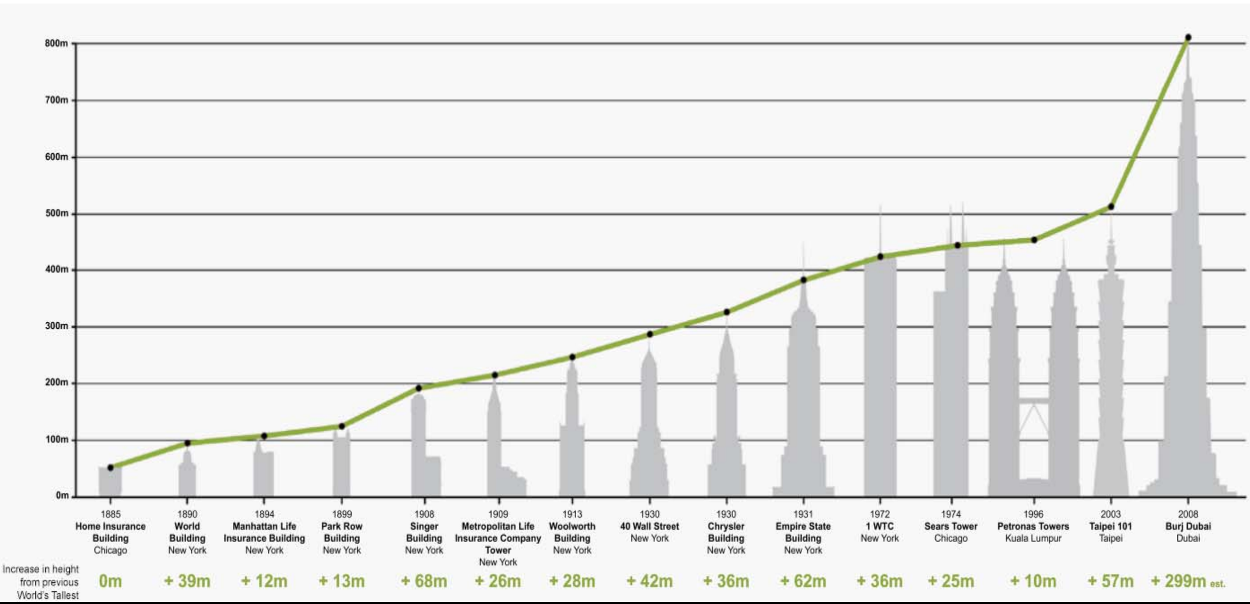
What is "more common building situations.."?

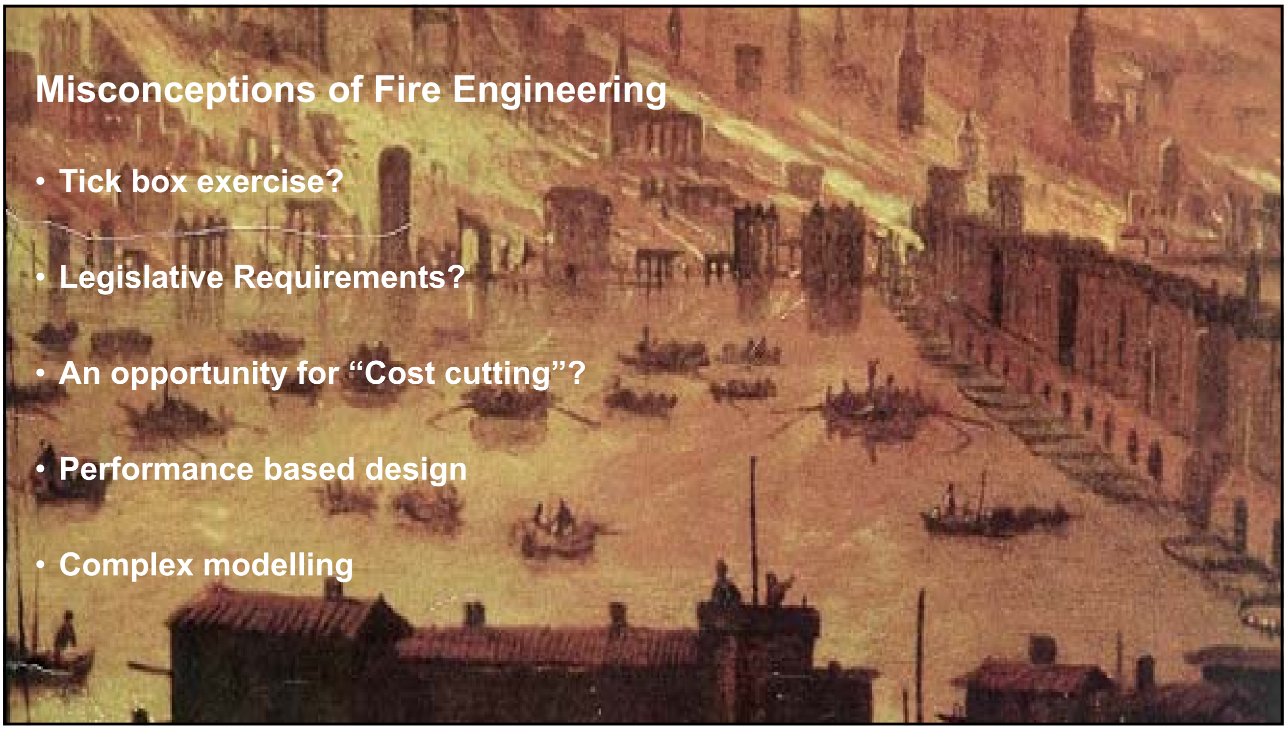
…Approved Documents are intended to provide guidance for some of the more common building situations...

Is prescriptive guidance still appropriate?

Modern Buildings

- Rate of Change - Height





Misconceptions of Fire Engineering

- Tick box exercise?
- Legislative Requirements?
- An opportunity for "Cost cutting"?
- Performance based design
- Complex modelling

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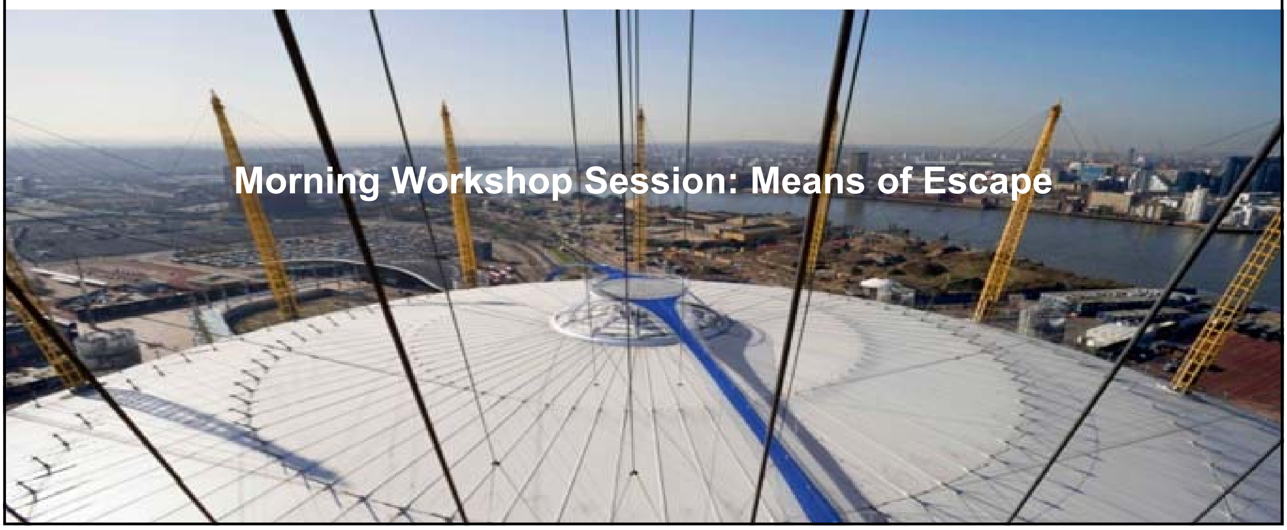


Morning Workshop Session: Means of Escape

Means of Escape

How do we get people out of the building safely?

Imagine a new office

- A 2,000m^2 open plan office / floor
- 10 storeys

A 2,000m^2 open plan office / floor
10 storeys

Client aspiration = Maximise Value

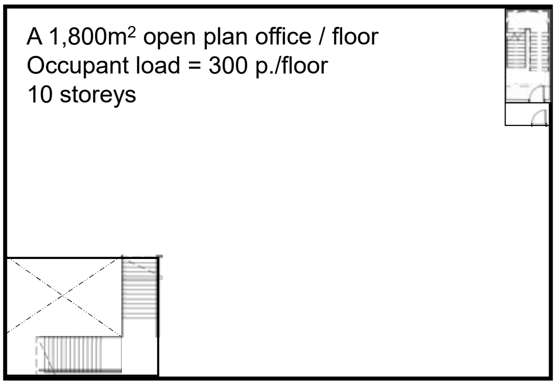
Client Brief:

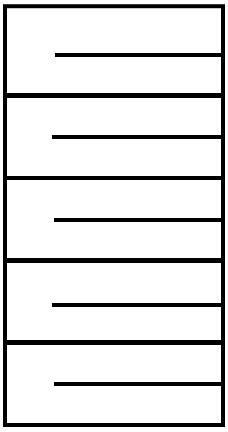
- Maximise Useable Floor Area
- Office Floor to be Light and Open
- Achieve £100/m^2/month in Value by Design

Imagine a new office

- What did the Architect imagine?

A 1,800m² open plan office / floor
Occupant load = 300 p./floor
10 storeys

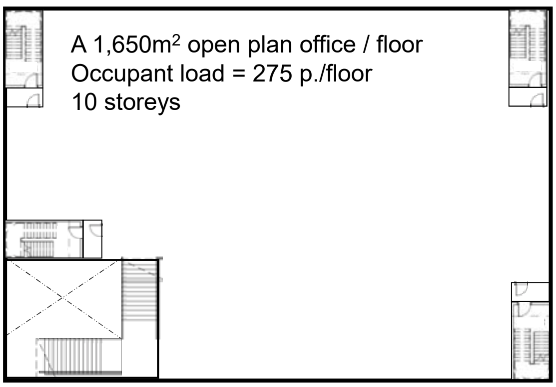


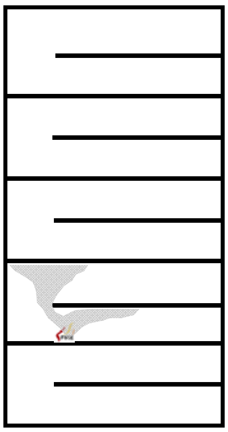


Imagine a new office

- Using Prescriptive Design: Option 1
  - Lost 200m² useable floor area / floor to protected stairs
  - Total Loss in Value = £200,000 / month
  - Use of additional resources whilst aspired capacity is compromised

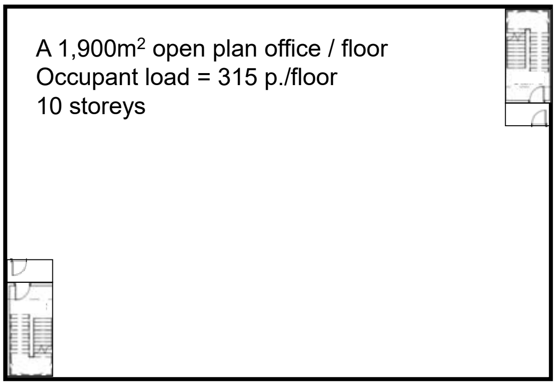
A 1,650m² open plan office / floor
Occupant load = 275 p./floor
10 storeys

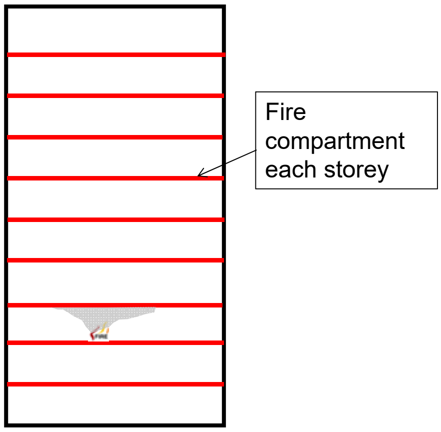




Imagine a new office

- Using Prescriptive Design: Option 2
  - Lost in lettable value
  - Total Loss in value = £ 80 / m^2 /month
  - Gained in floor area but compromised on the social aspect



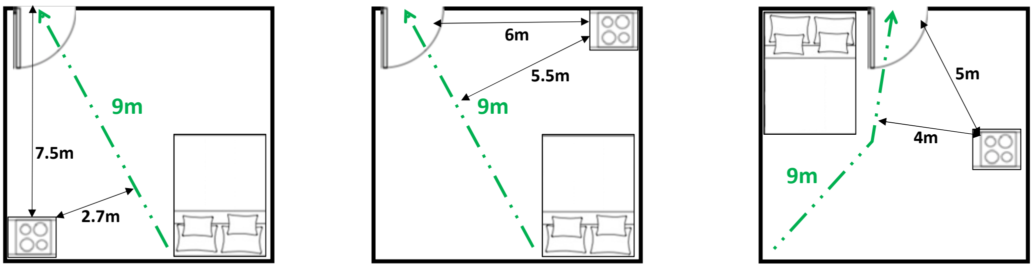


Are They the Same?

- Prescriptive guidance

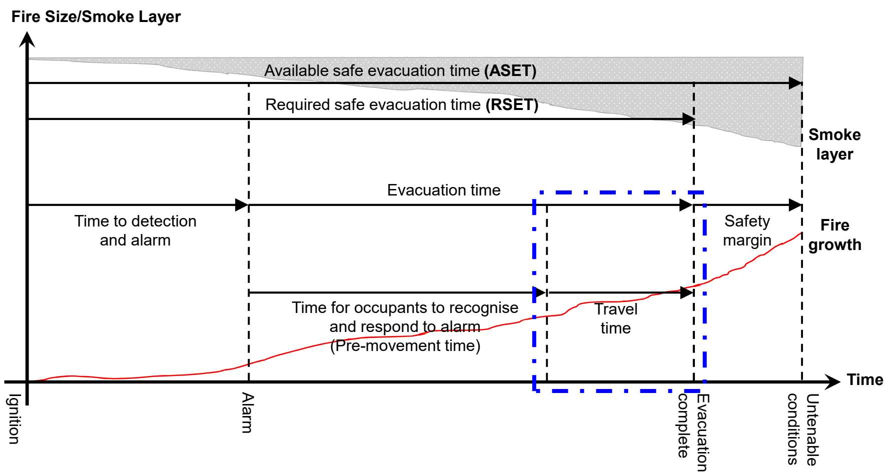
  Travel distance in a studio is limited to 9m…

  Cooking facilities to be sited are 'remote' from the entrance door and do not prejudice escape…



Is this the safest???

What is Travel Time?

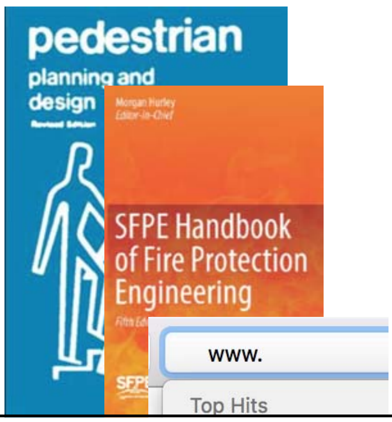


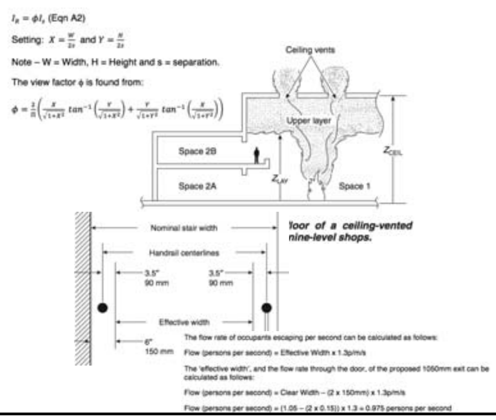
But How Do We Quantify it All?

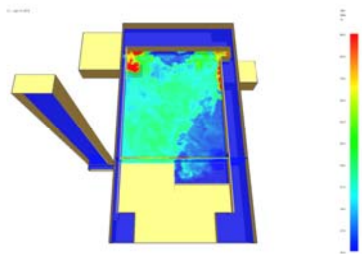
Literature and research

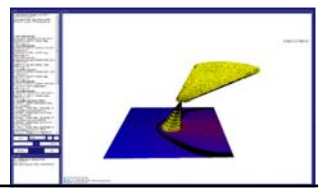
Simple calculations and comparative study

Computational Modelling



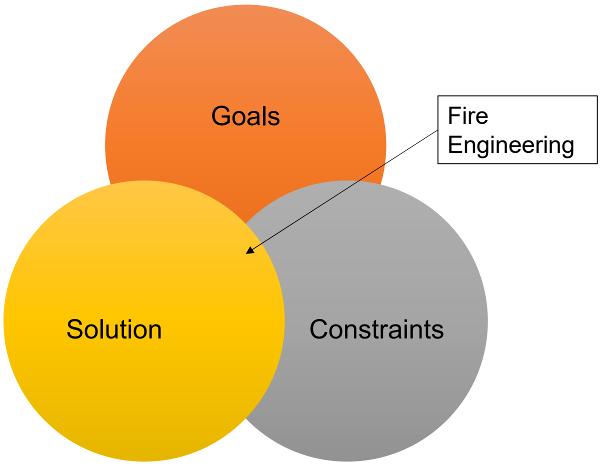




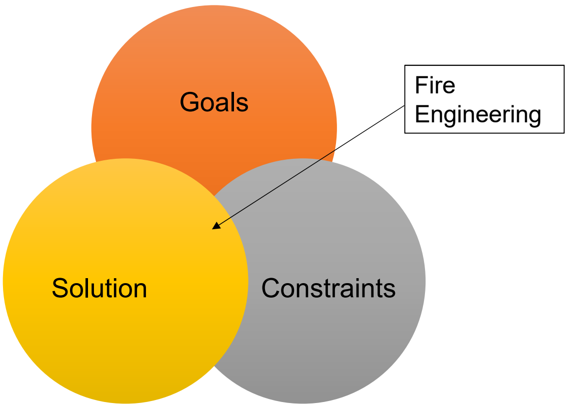


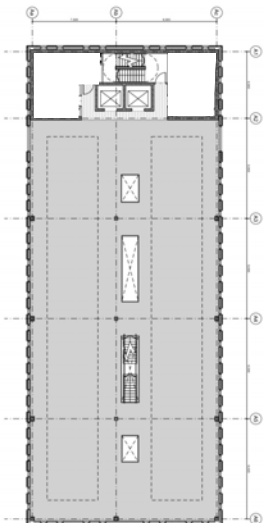
What about reality?

- Buildability? Cost? Aspirations?
- Being confident in the solution
  - What are the risks in not complying?
  - How are they addressed?
  - Level of risk v.s. complexity in analysis



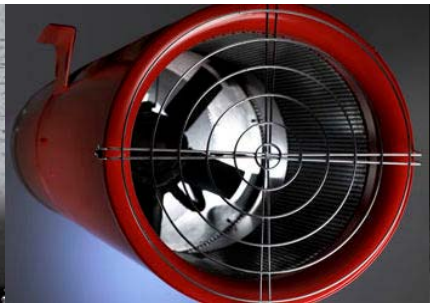
It is about the bigger picture!





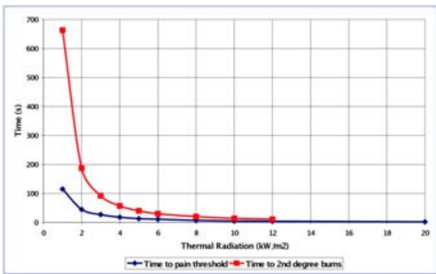
Conclusion

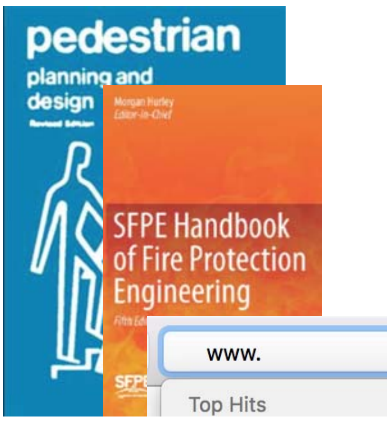
- What might help and how? Identify options that can be explored



Conclusion

- But is it safe? Seek out knowledge
- Risk v.s Complexity in Analysis





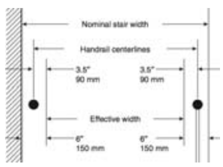
$I_R = \phi I_s$ (Eqn A2)

Setting: $X = \frac{W}{2s}$ and $Y = \frac{H}{2s}$

Note – W = Width, H = Height and s = separation.

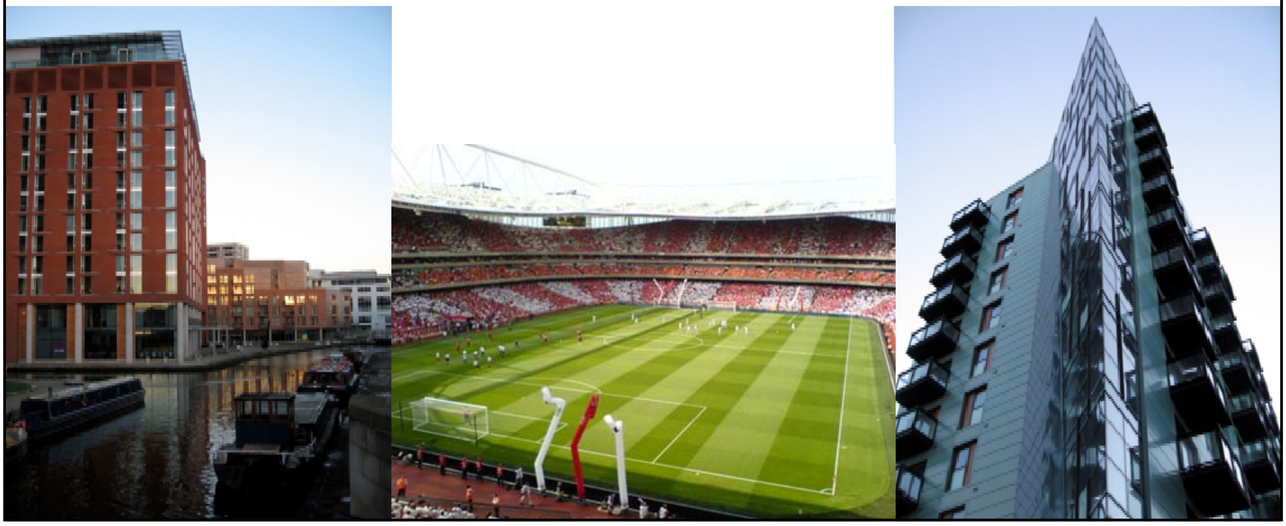
The view factor ϕ is found from:

$$\phi = \frac{2}{\pi}\left(\frac{X}{\sqrt{1+X^2}}\tan^{-1}\left(\frac{Y}{\sqrt{1+X^2}}\right) + \frac{Y}{\sqrt{1+Y^2}}\tan^{-1}\left(\frac{X}{\sqrt{1+Y^2}}\right)\right)$$



Conclusion

- Know the costs, the limitations and the values.
- Find a balance.



To Conclude the Day

- Let's revisit our introduction…
- What is fire safety engineering?

OR

To Conclude the Day

- What is fire safety engineering?

- Simple
- Conservative (safe)
- Quick (low risk)
- Easy to manage

OR

- Complex
- Reducing safety
- Design & Approvals Risk
- Special management

By Definition…

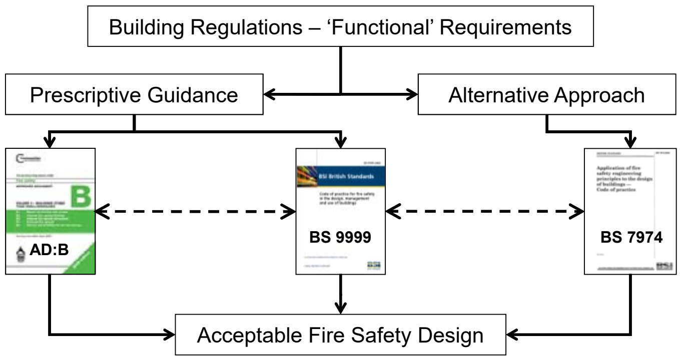
- engineering n. The application of scientific and mathematical principles to practical ends
- fire engineering n. The application of fire scientific and mathematical principles to practical ends
- IFE - the science and practice of Fire Extinction, Fire Prevention and Fire Engineering and all operations and expedients connected therewith

"What is a Fire Engineer" , 1990, Margaret Law MBE

- *"…Any rules need to have an engineering basis and be goal related: the purpose of which needs to be understood by both researchers and regulators…"*
- *"The magic numbers embodied in regulations are accepted without any questions whilst any engineering solutions is subject to a disporportionately high standard of proof"*

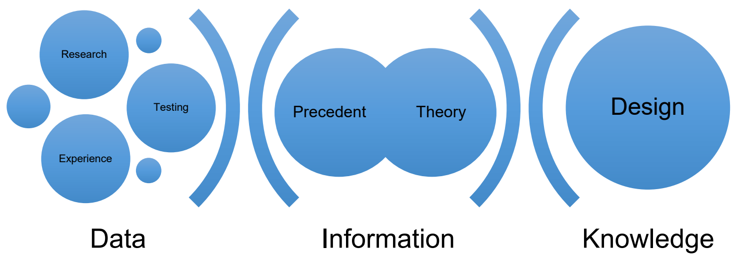
To Conclude the Day

- What is fire safety engineering?
  - Knowing when prescriptive design is not appropriate
  - Identify the hazards, remove the unknowns
  - Fire Engineering is not just complicated analysis



Conclusions

- Make engineering the norm, not the exception



Competent people developing a coordinated design that complies with the brief, mitigates fire risks and is put into practice through construction and operation.

1. Competent Team
2. Fire Engineering Brief
3. Fire Safety Design
4. Adequacy
5. Coordination
6. In Practice

Conclusions

- It is about the bigger picture!

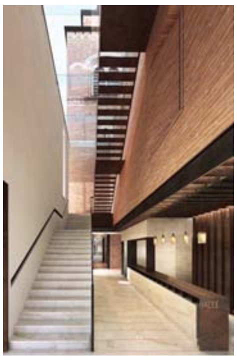
- Minimise total cost, where:

Cost = Cost of Prevention + Cost of Protection + Cost of Occurence

Social	Environmental	Economic
		

Conclude the Day

- By staring to…
  - Question the assumptions
  - Identify the goals
  - Identify the hazards
  - Identify the constraints
  - Assess the risks
  - Find opportunities outside the guidance and be part of the ‘team’ in realising modern and innovative design without compromising safety



Thank you for listening!

- Questions? Questions? Questions?
- Feedback?

The speakers:

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Fire Engineering Design – Smoke Control

Dr Panos Kotsovinos

Life Safety Goals to comply with the regulations

As a minimum, the fire strategy must comply with the legal requirements:

- Part B of the Building Regulations 2013
- Construction Design and Management Regulations 2007 (CDM)
- Regulatory Reform (Fire Safety) Order 2005 (RRO)

ARUP

Goals beyond life safety

Goal	Social	Economic	Environmental
People	Life safety		
Quality of Asset	Quality of space	Cost and value of asset	Construction impact
Quality of Operation	Functionality of space	Operational costs	Operational impact
Protection of Asset	Environmental continuity of asset	Property Protection	Prevention of fire damage to the environment
Protection of Operation	Continuity of function	Business Continuity	

Total Cost = Cost of Prevention + Cost of Protection + Cost of Occurrence

Goal based engineering does consider resilience

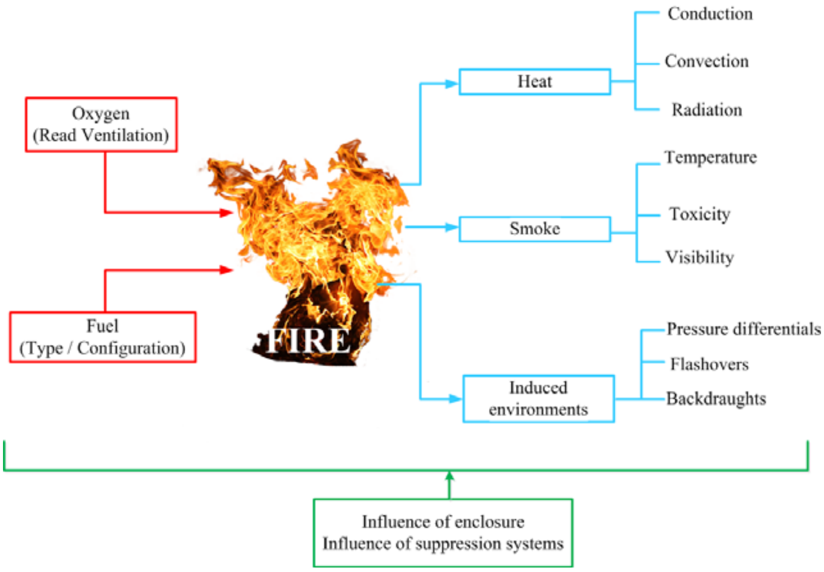
Designers have to know about it though

ARUP

What is Fire Dynamics?

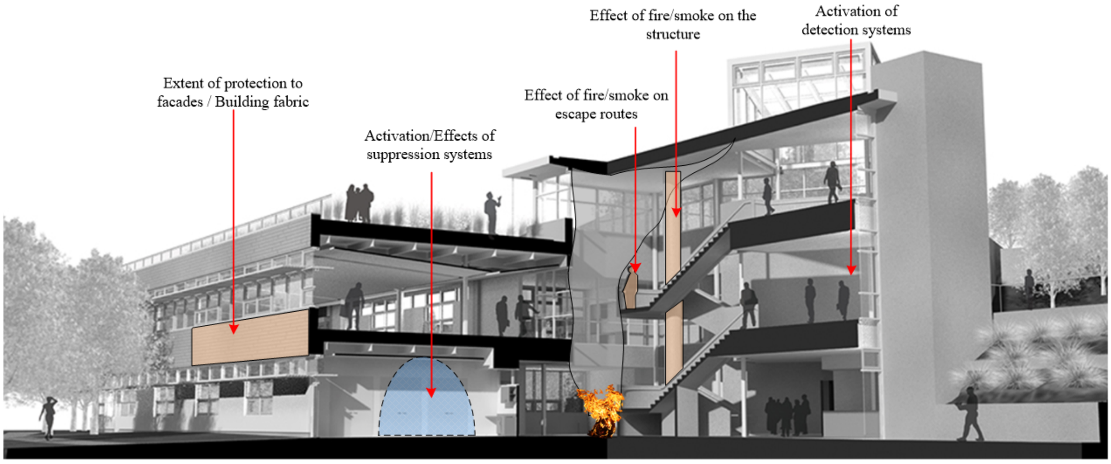
Fire is a complex phenomenon and understanding its behaviour requires input from a variety of disciplines.

Factors influencing fire dynamics



Applying Fire Dynamics

The list is not exhaustive…..



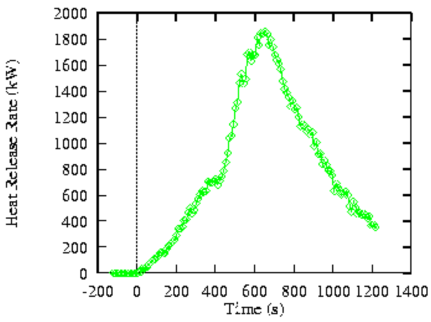
The Benefits of Fire Engineering

- Delivers an appropriate and safe design solution
- Benefits interaction of space
- Tailors fire protection to building use and client requirements
- Achieves best value solution without compromising design or life safety
- Reduces regulatory risk
- Reduces cost risk

Applying Fire Dynamics – The design fire

The design fire :

- Fuel – what type of building is it and what are it's contents.
- Fire Size (HRR) – will the fire size be limited e.g. by suppression, isolation, ventilation or will it continue to grow.
- Fire Growth Rate – how fast will the fire grow.



Applying Fire Dynamics – The design fire

Fire Growth Rate

It has been found that after an initial incubation period, the heat release rate grows approximately as the square of time, i.e.:

$$Q = a\,t^2$$

Fire class	Characteristic growth time, t_g / s	Constant a / kW.s^{-2}
Ultra-fast	75	0.1876
Fast	150	0.0469
Medium	300	0.0117
Slow	600	0.0029

Where:

- Q = Heat release of the fire (kW)
- a = A constant depending on the accommodation (kW/m^2)
- t = time (s)

Smoke Hazard

courtesy Dr W Poh
Noel Arnold & Associates

Applying Fire Dynamics – Smoke Behaviour

When considering fire safety systems to protect against the spread of smoke and / or build up of heat the first step is to define the design fire.

Smoke Produced Depends on:

- Fuel – what type of building is it and what are it's contents.
- Fire Size (HRR) – will the fire size be limited e.g. by suppression, isolation, ventilation or will it continue to grow.
- Ventilation Conditions – will there be sufficient oxygen for the fire to grow.
- Entrainment – how will the smoke plume interact with the surroundings.

Smoke Movement

- Potential paths for smoke spread include:
  - shafts
    - stairs
    - lifts
    - services
  - air handling equipment (supply and exhaust)
  - penetrations
  - construction joints

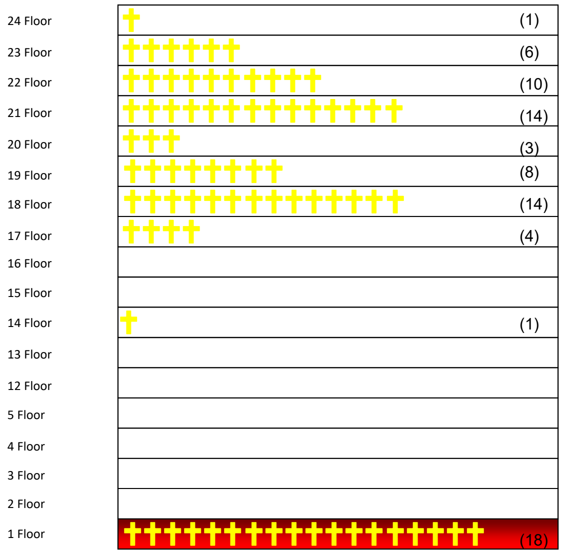
Smoke Hazard

- Why should we be so concerned with smoke?
  - Often the first indication of fire
    - usually present before flames appear - sometimes days
  - Approximately 50% of fire fatalities are reported as "overcome by smoke and toxic fumes" [Purser, 1995]
  - Smoke can spread quickly and silently, well beyond the compartment of fire origin
  - Graphic examples of fatalities due to smoke spread include:
    - MGM Grand Hotel - Las Vegas, Nevada, USA (1980)
    - Johnson City Retirement Centre - Tennessee, USA (1989)
    - Roosevelt Hotel - Jacksonville Florida (1963)

Smoke Hazard

MGM Grand

21 November 1980



Smoke Control – Basic Principles

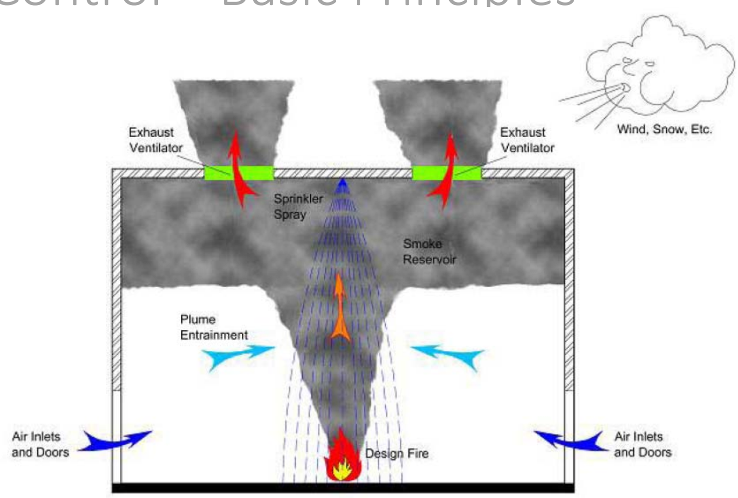


Figure 1.5: **Principle of a SHEVS [courtesy of NV IFSET SA]**

Basic Principles – Spill Plumes

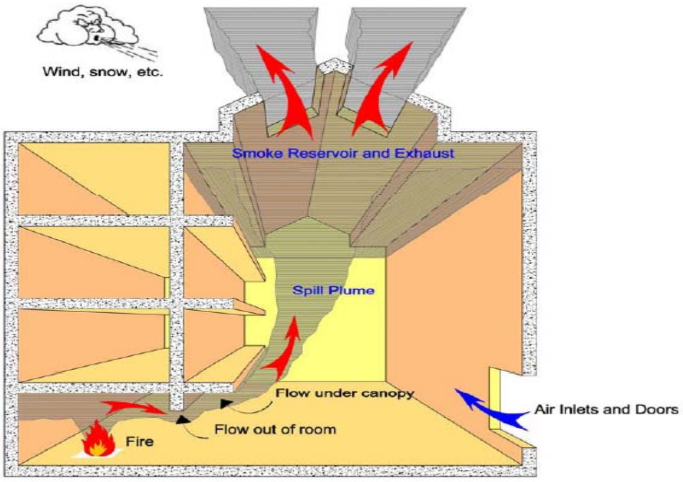


Figure 1.7: A SHEVS with a spill plume [courtesy of NV IFSET SA]

Natural vents or mechanical extract?

Natural vents

Extract rate increases as fire grows

Typically simple system

Limited maintenance

Cheaper than mechanical systems

Smoke vents can be combined with normal vents e.g. atria

Does not perform well with low smoke temp/high external temp

Hard to control smoke in complex volumes e.g. two storey smoke zones

Sensitive to wind conditions

Can be used in non-sprinklered buildings

Mechanical Extract

Works independent of smoke temp

Can be used for more complex situations

Not sensitive to wind

Can be combined with normal comfort ventilation systems

Not ‘self regulating’ with fire size

Maintenance

Higher cost than natural venting

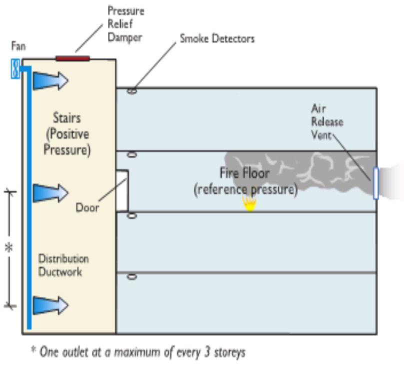
Complex system design (dampers, duct work, duplicate power, duty+standby fans, etc)

Requires sequential fan start-up

Often requires sprinklers to be installed

Smoke control systems – Pressurisation

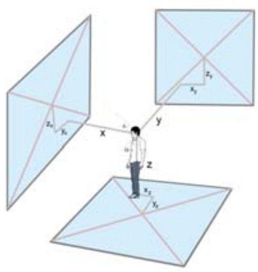
- Complicated to design
- Often problems with commissioning
- Difficult to achieve air flow rate through open doors if lobbies are small
- May fail to achieve the minimum pressure rating across closed doors if lobbies are small
- Difficult to balance 30 air changes per hour with a maximum door opening force of 100N if lobbies are large
- Large lobbies can result in very high airflows through the open door
- May depend on maintenance of relief paths in private accommodation
- Record of poor reliability
- Not widely used in UK outside of major cities. UK /Fire Service often not familiar, reluctant to accept



Tools for Design

- Algebraic models
  - Equations to calculate flame height, heat release rate, plume and ceiling jet velocities, gas layer temperatures and depth, radiation etc.
  - e.g. PD 7974, CIBSE Guide E, TM 19, SFPE Handbook etc.

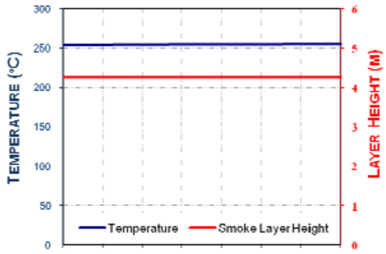
maximum radiation at a point

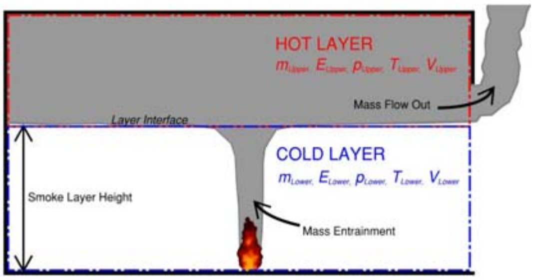


$$dQ = \sigma T^4 \cos\alpha \frac{\cos\beta}{\pi r^2} \frac{dF1}{dF2}$$

Tools for Design

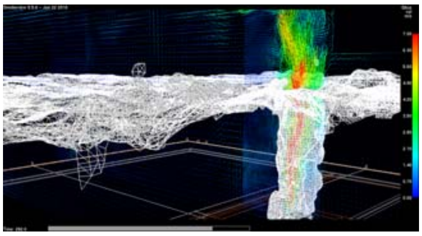
- Zone models
  - 2 or 3 zones: temperatures, velocities and other properties are assumed to be uniform within these zones
  - Simple (rectangular) geometries
  - e.g. FlashOva, CFAST etc.

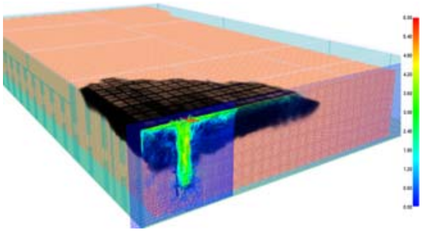




Tools for Design

- Field models (CFD models)
  - Numerical methods to solve and analyse problems that involve fluid flows
  - E.g. Fire Dynamics Simulator (FDS):
    - Fire-driven fluid flow
    - Numerically solves the Navier-Stokes equations
    - Appropriate for low-speed, thermally-driven flow, with an emphasis on smoke and heat transport from fires
    - Large verification & validation library





Residential fire engineering

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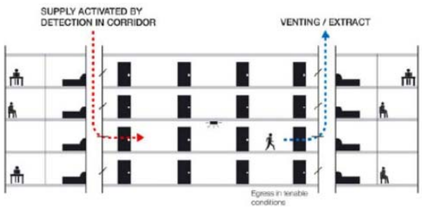
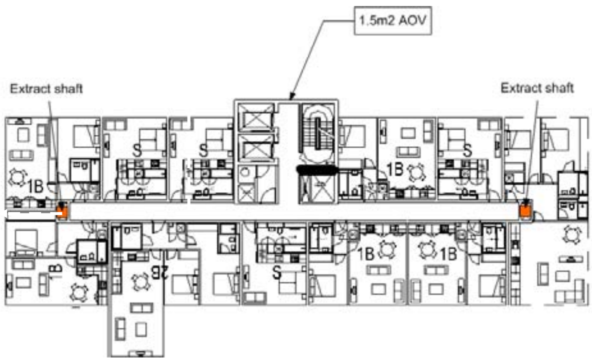
Use of smoke shafts

FSE Mechanical assisted shafts

3 primary systems:

- **Mechanical supply and extract**
- **Mechanical supply with natural venting**
- **Natural supply with mechanical extract**





Thank you for listening

Any questions?

Dr Panos Kotsovinos

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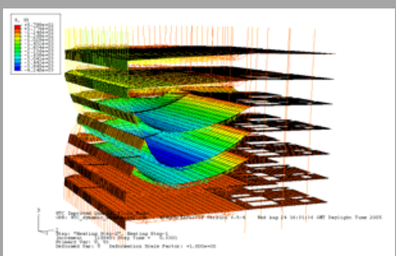
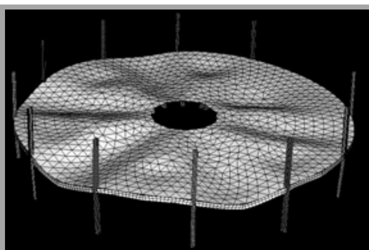
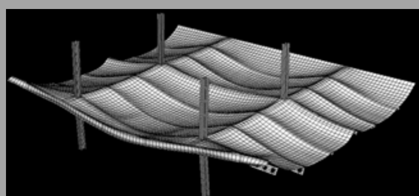
Fire Engineering Design – Fire resistance

Dr Panos Kotsovinos







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Building Regulations Requirement (UK)

- Part B3 – Functional Requirement

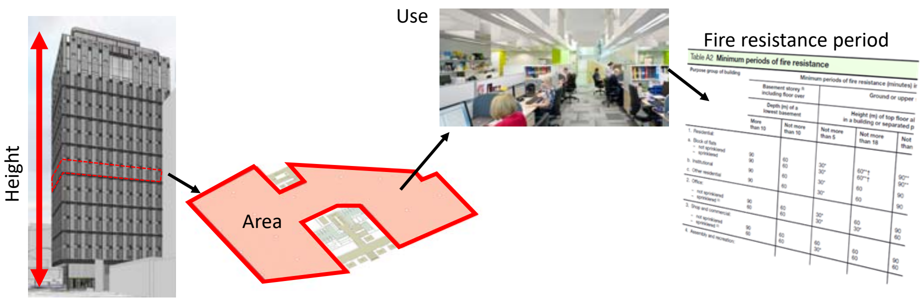
"In a fire a structure should remain standing for a reasonable period of time."

Deemed-to-satisfy approaches available in ADB, i.e. Blanket fire protection

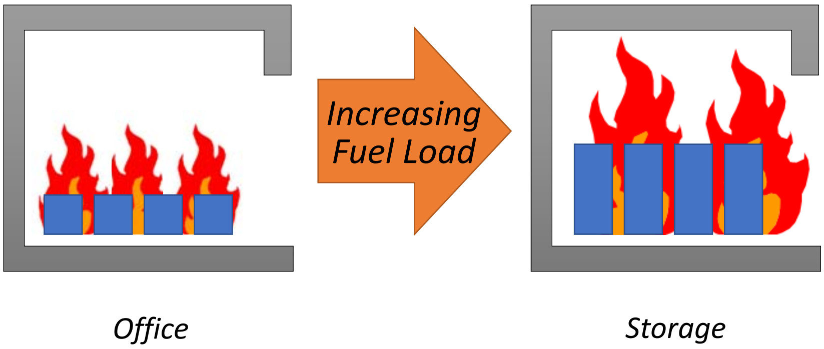
Assess problem from first principles through Structural Fire Engineering

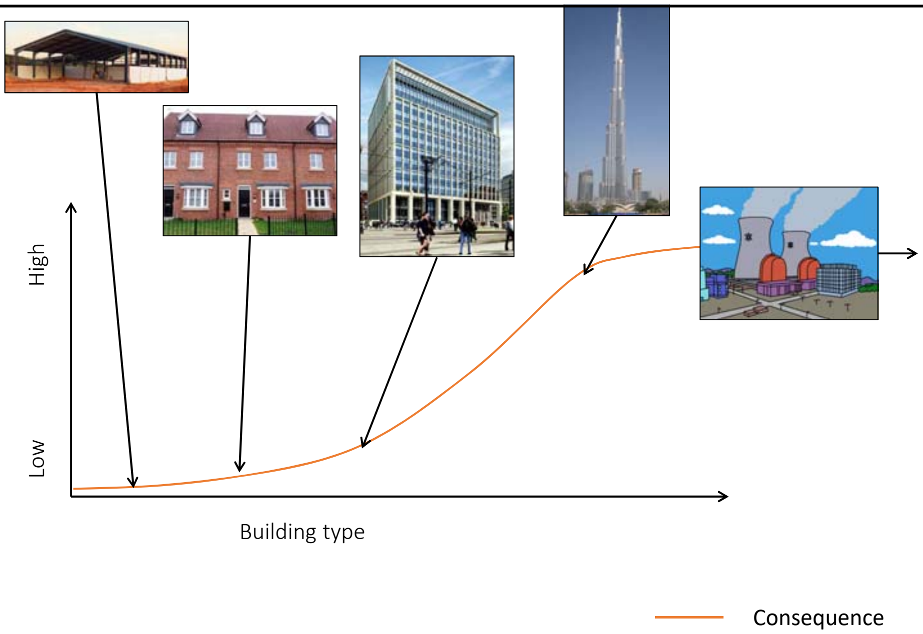
Prescriptive design process

- How?

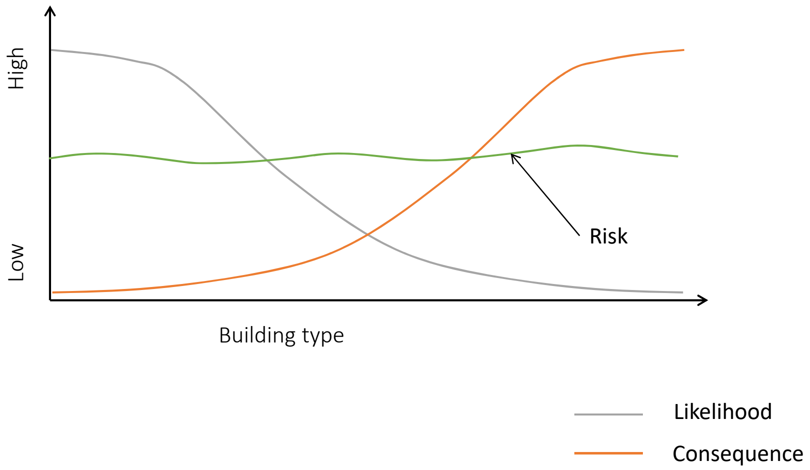


Fire severity is proportional to building fuel load

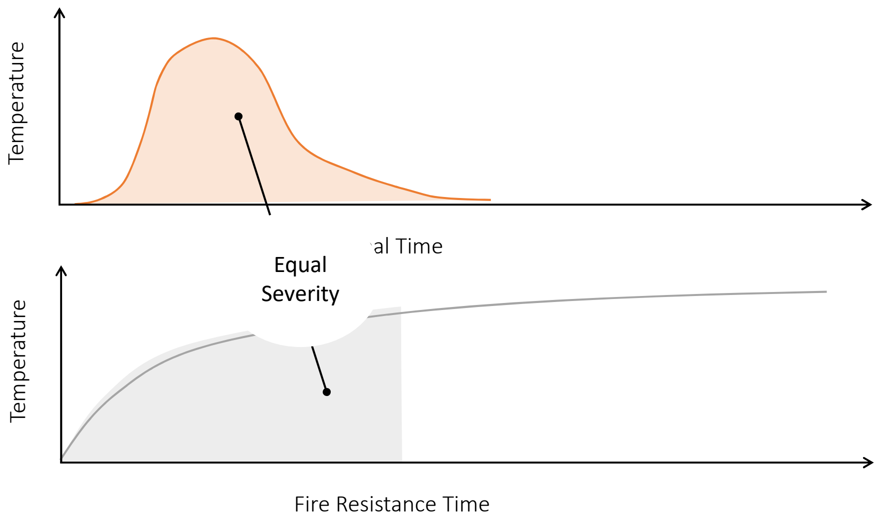




likelihood × consequence = Risk

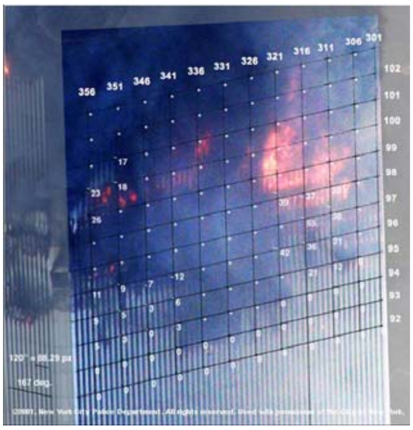


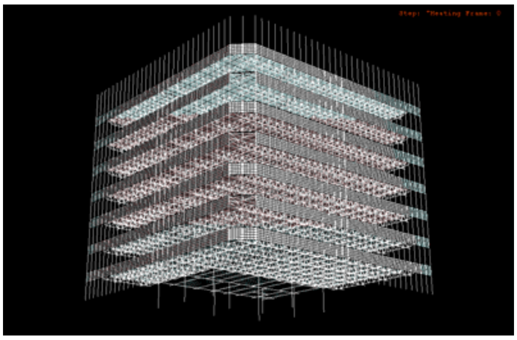
Delivering fire performance: fire resistance

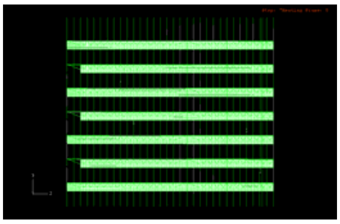


WTC studies

- Similar collapse mechanism as seen in the WTC





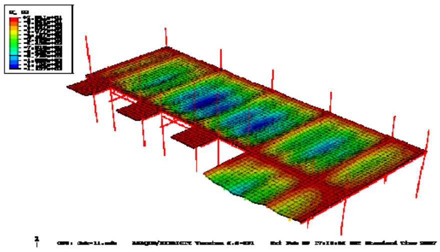


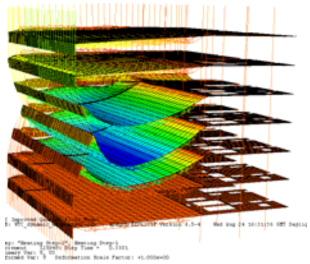
Lessons learned from WTC and other failures

- Innovative structural systems and materials
- Prescriptive rules are not always conservative
- Performance based engineering is required
- Fire is considered a load like winds/earthquakes
- Determine strengths and weaknesses
- Cost effective and robust design

How can you use structural fire engineering?

Response of the structure

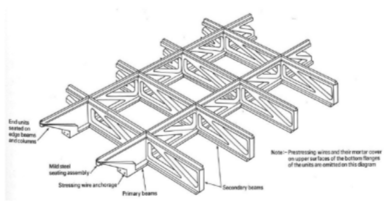


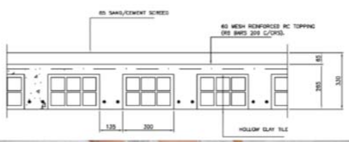


How can you use structural fire engineering?

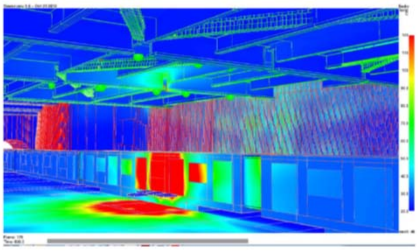
(1)Existing Buildings
(2)Infrastructure

Existing buildings…



Beyond Buildings…



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