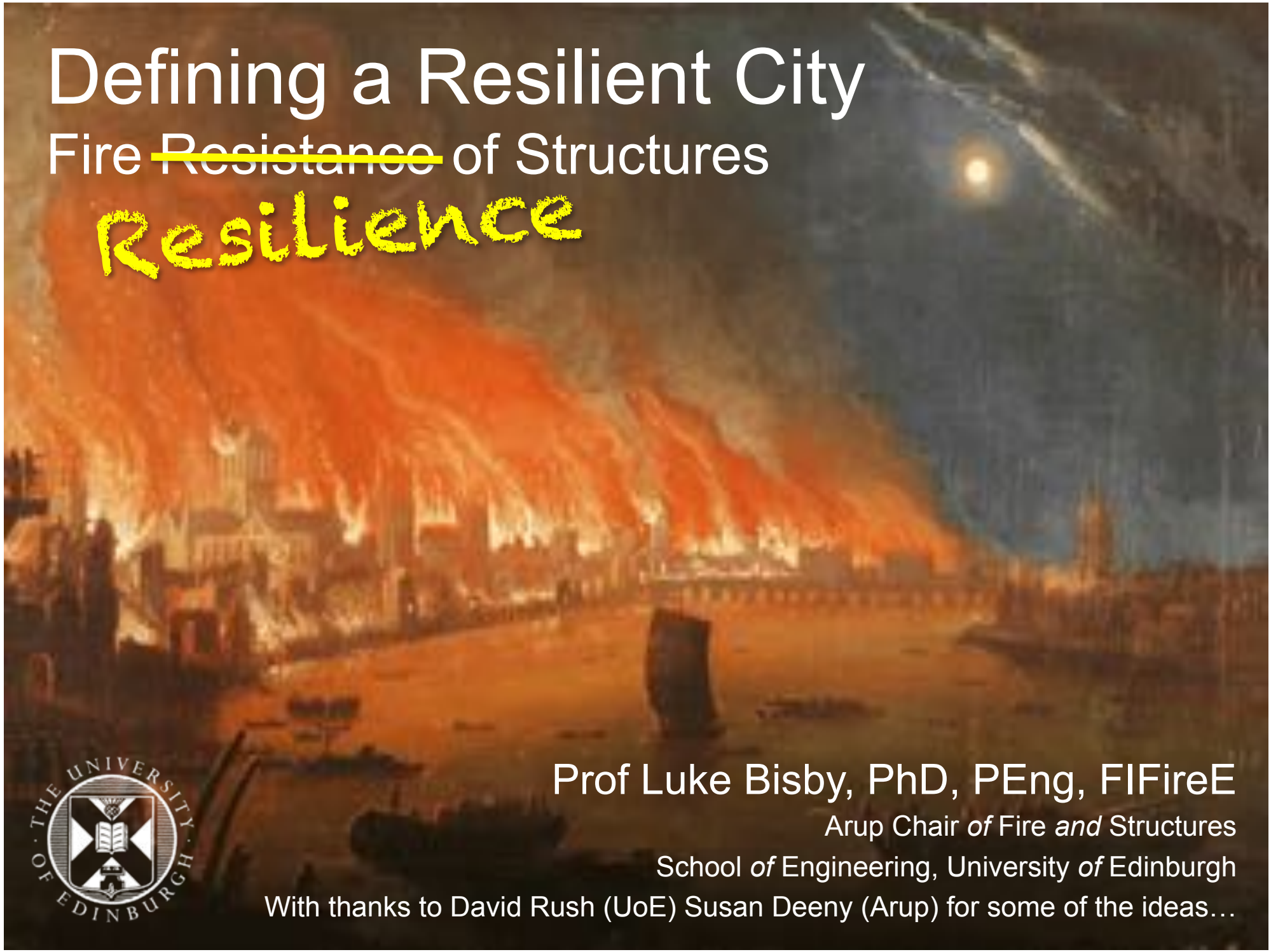
Defining a Resilient City

Fire ~~Resistance~~ of Structures

Resilience



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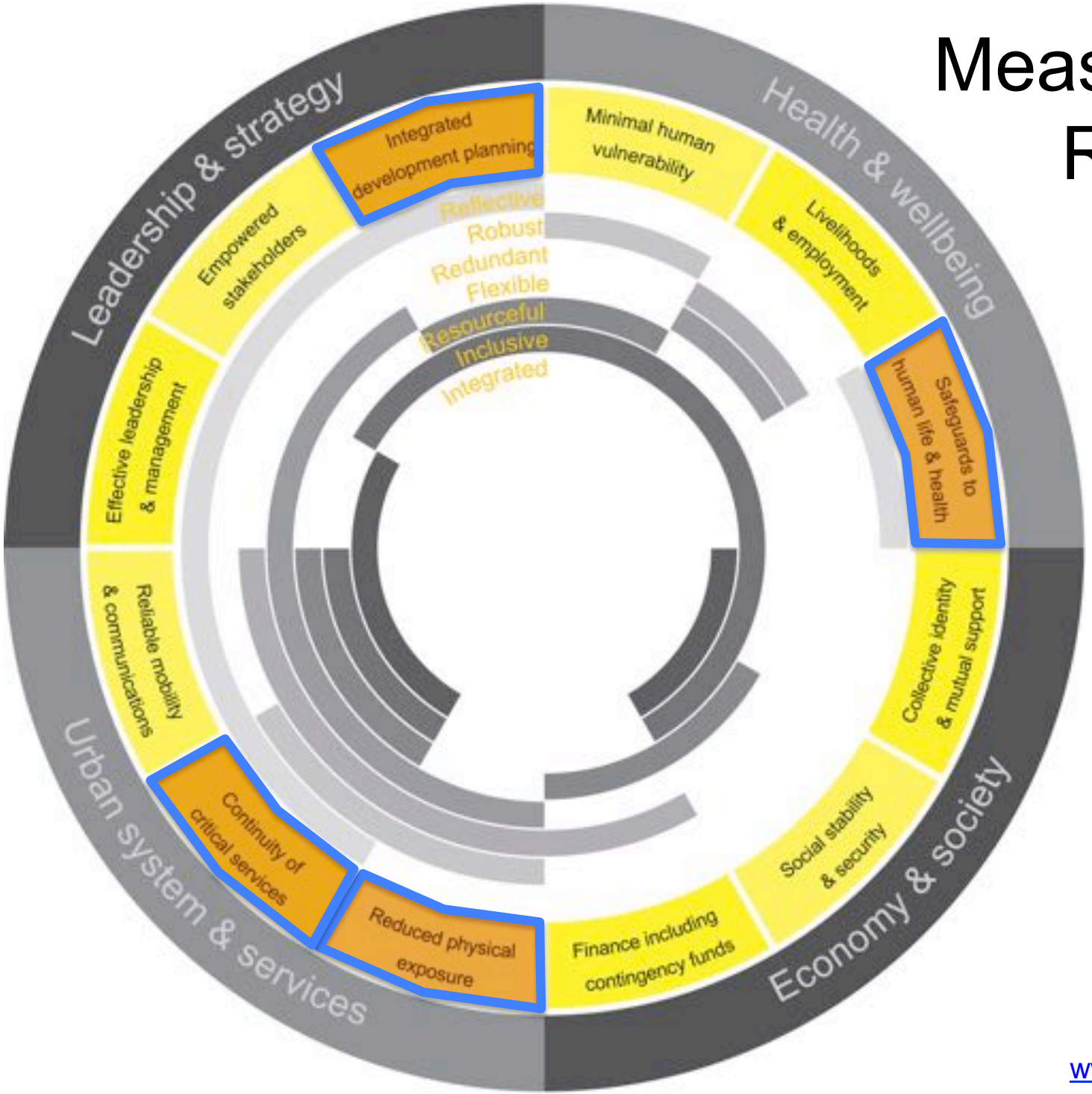
With thanks to David Rush (UoE) Susan Deeny (Arup) for some of the ideas…

The Big Picture: What is City Resilience?

Definition | City resilience describes the capacity of cities to function, so that the people living and working in cities – *particularly the poor and vulnerable* – survive and thrive no matter what stresses or shocks they encounter.

Resilience focuses on enhancing the *performance* of a *system* in the face of *multiple hazards*, rather than preventing or mitigating the loss of assets due to specific events.

Measuring the Resilience of Cities



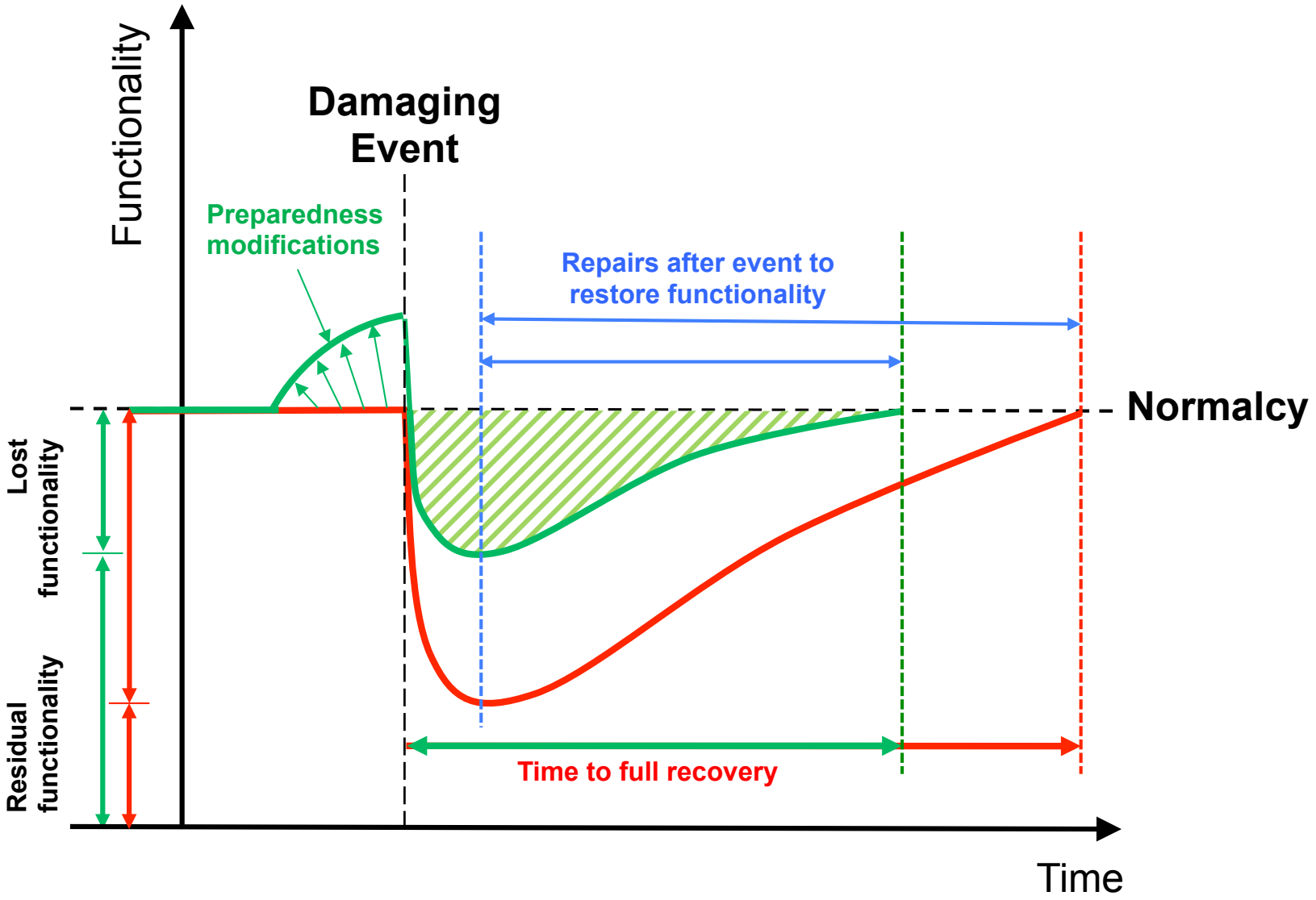
4 Dimensions
12 Goals
7 Qualities
52 indicators

www.cityresilienceindex.org

One key area globally which surely deserves our attention…

The Smaller Picture: Structural Fire Resilience

Resilience (Engineering Concept*)



* Courtesy Dr David Rush, School of Engineering, University of Edinburgh

Hazard #1

Despite the apparent success of the engineering community at mitigating structural collapses in fires, we only very rarely explicitly consider the fire Resilience of designs.

Instead, we tend* to focus on life-safety and on being good neighbours.

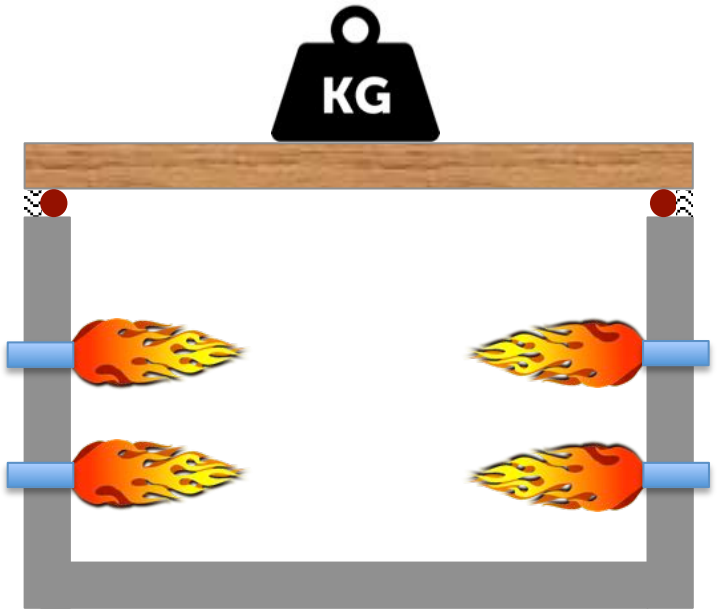
* Notwithstanding some examples of excellent practice by top consultants in the UK

Fire Resistance ‘Design’ of Structures

… the ability of building components and systems to perform their intended **fire separating** and/or **loadbearing** functions for the **required duration** of **standard fire exposure** when tested in a **fire testing furnace.**

Burning Building

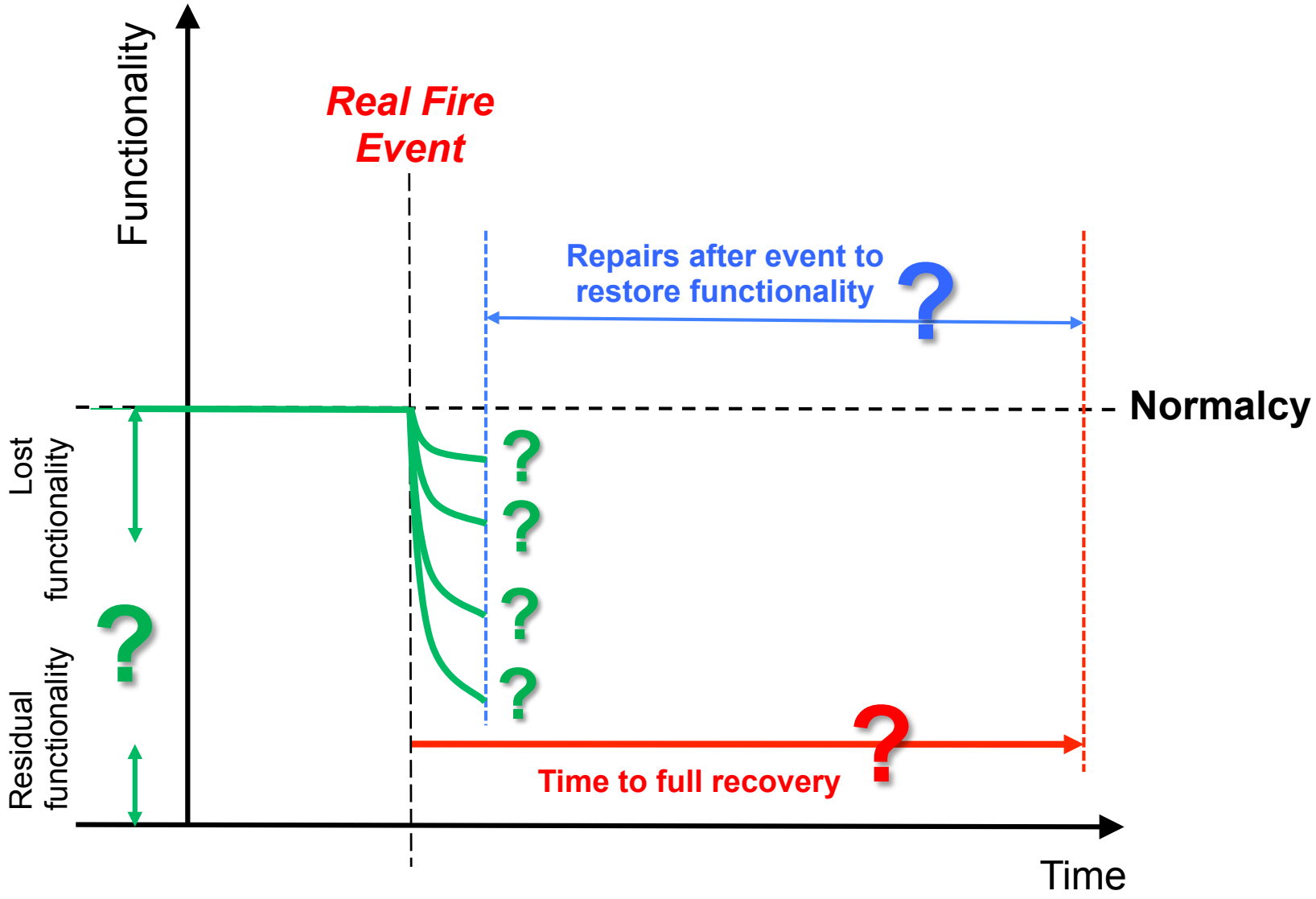
≠



Design Conceptualisation

Design Fire Exposure =
Required Duration of Fire =
Realism of Structural Response =
} ?

The Result? Fire ~~Resilience~~ Resistance



Hazard #1 (reminder)

We rarely consider the fire Resilience of designs. Instead, we focus on ‘fire resistance’.

Hazard #2

Improper or unthinking application of ‘fire resistance’ testing and ‘fire resistance’ ratings represents a threat to the fire Resilience of global cities

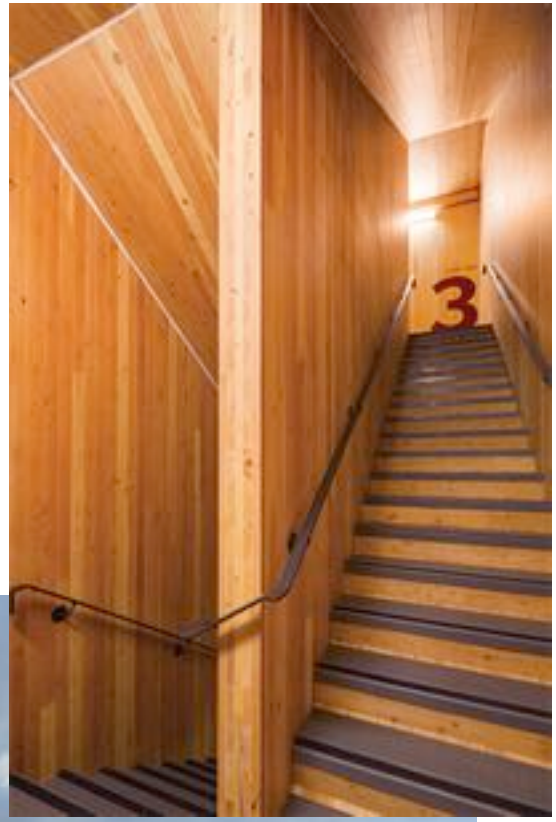
Various areas of ‘concern’

(opinions are my own)

- **Combustible insulation materials**
- **Heat-induced explosive concrete spalling**
- **Tall mass timber buildings** (note: I am ‘pro-timber’)
  - Is the current ‘fire resistance’ framework appropriate for tall buildings with combustible structural frames?

Architectural Vision for Tall Mass Timber Buildings

> … whole urban districts built to increasing heights and density in which engineered timber products are utilised to create truly sustainable communities that are also happy, healthy, and socially engaged.



Tall Mass Timber Buildings in Fire

Appropriate Application of ‘Fire Resistance’?

> “... two hours of **fire resistance** is two hours of **fire resistance**, regardless of whether the building is made from concrete, or steel, or mass timber.”

http://www.treindustrien.no/resources/bilder/41322.jpg

UK Approved Document B

(intended to provide guidance for the more **'common'** building situations)

Table A2 Minimum periods of fire resistance

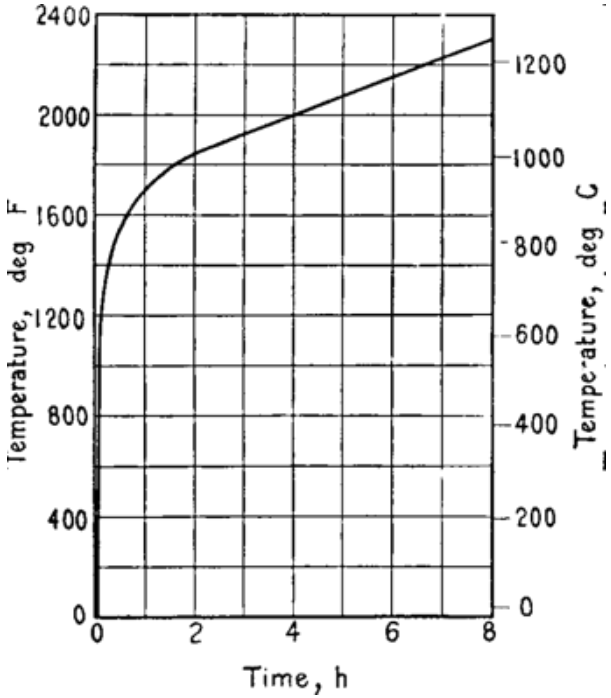
Purpose group of building	Minimum periods of fire resistance (minutes) in a:					
	Basement storey [1] including floor over		Ground or upper storey			
	Depth (m) of a lowest basement		Height (m) of top floor above ground, in a building or separated part of a building			
	More than 10	Not more than 10	Not more than 5	Not more than 18	Not more than 30	More than 30
1. Residential:						
a. Block of flats						
– not sprinklered	90	60	30*	60*†	90*	Not permitted
– sprinklered	90	60	30*	60*†	90*	120*
b. Institutional	90	60	30*	60	90	120#
c. Other residential	90	60	30*	60	90	120#

120 minutes of 'Fire Resistance'

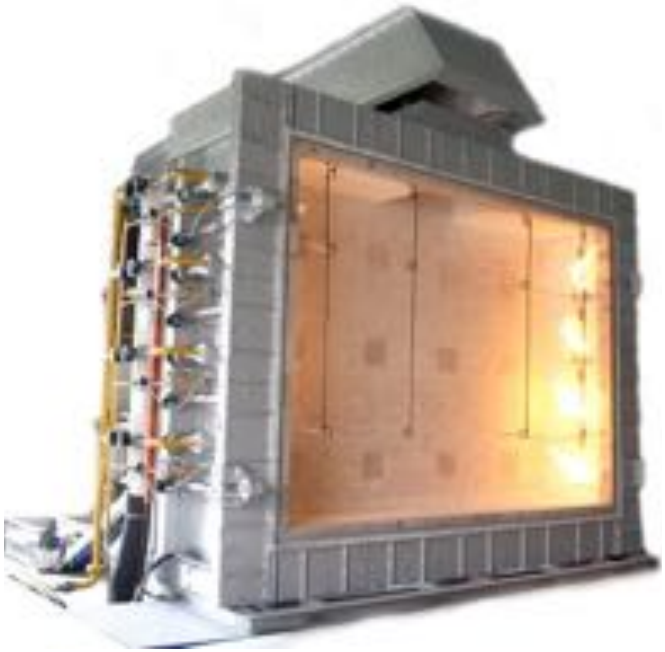
Why?

Fire Resistance: Origins

Stewart & Woolson (1902)



ASTM E119 (1918)



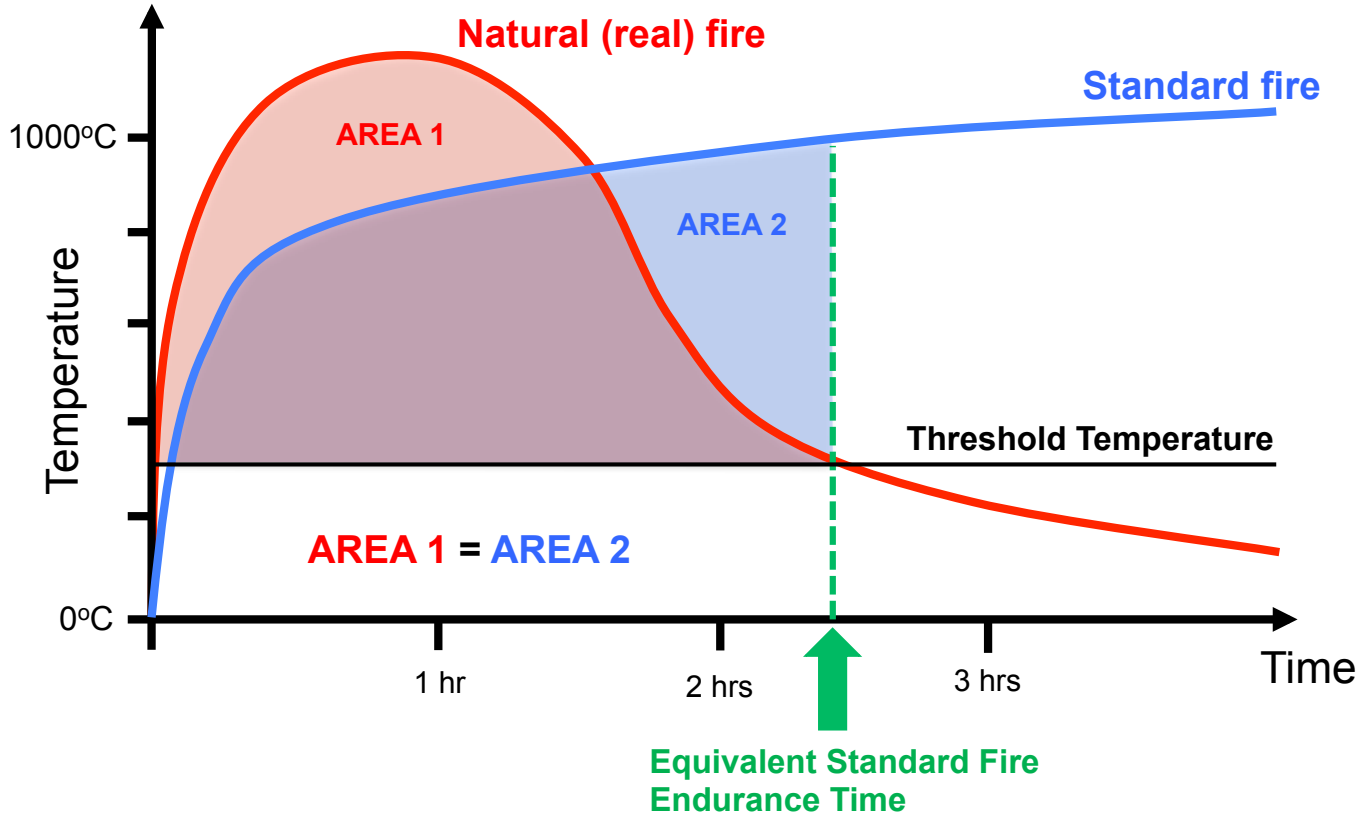
FTT (2016)

Standard fire tests were originally conceived as comparative tests of alleged 'fireproof' building systems in the late 1800s

- Before temperatures in real fires had been properly characterised
- Without the intent to assign fire resistance ratings

Ingberg's 1st Insight: 'Fire Resistance'

(c. 1922-1928)



How to relate real fires to standard fires?

- The **full history (i.e. until burnout)** of a compartment fire can be related to the duration of standard fire that gives the same area under the curve
- This area is what Ingberg called the 'fire severity'

Ingberg's 2nd Insight: 'Fire Severity'

(circa 1928)

Total Combustible Content. (Inclusive of finish floors and trim.)		
Lbs. per sq. ft.	Assumed B.T.U. per sq. ft.	Equivalent Fire Duration Hrs.-Min.
10	80,000	1—00
15	120,000	1—30
20	160,000	2—00
30	240,000	3—00
40	320,000	4—30
50	380,000	6—00
60	432,000	7—30

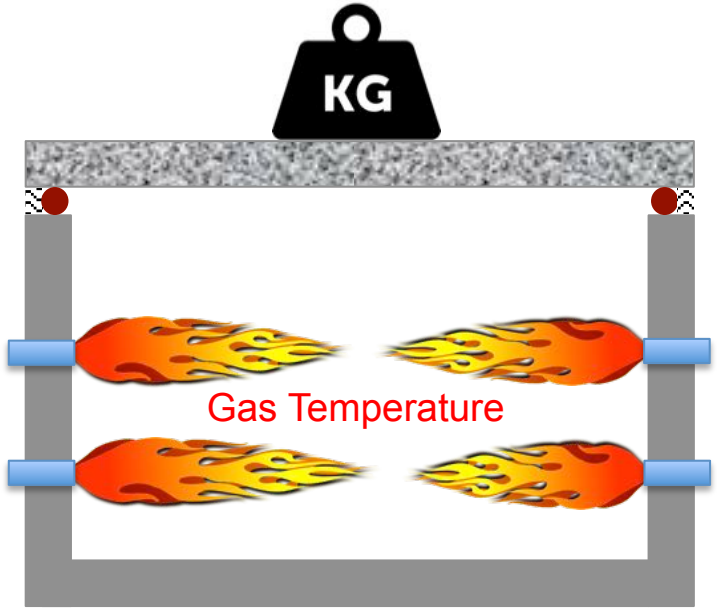
Ingberg (wrongly) said fire severity depends only on fuel load:

- Fire resistance requirements for different occupancies are explicitly linked to fuel loads, which are explicitly linked to burnout fires
- i.e. **Fire resistance originally implied burnout without intervention!**
- Fire resistance has gradually evolved based on other considerations…

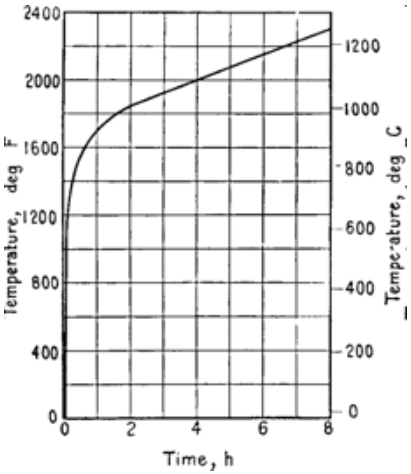
http://www.slideshare.net/novacsi/november-2011-chapter-meet

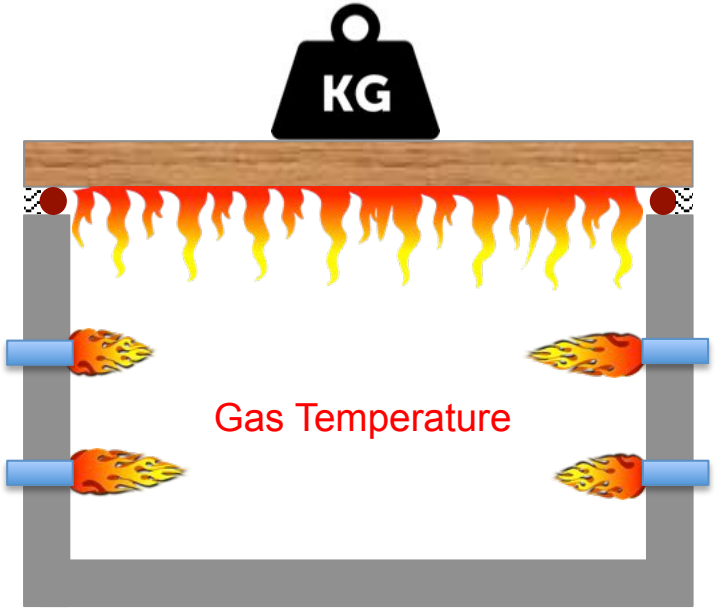
‘Fire Resistance’ applied to Timber

(particularly exposed mass timber)



Concrete Beam





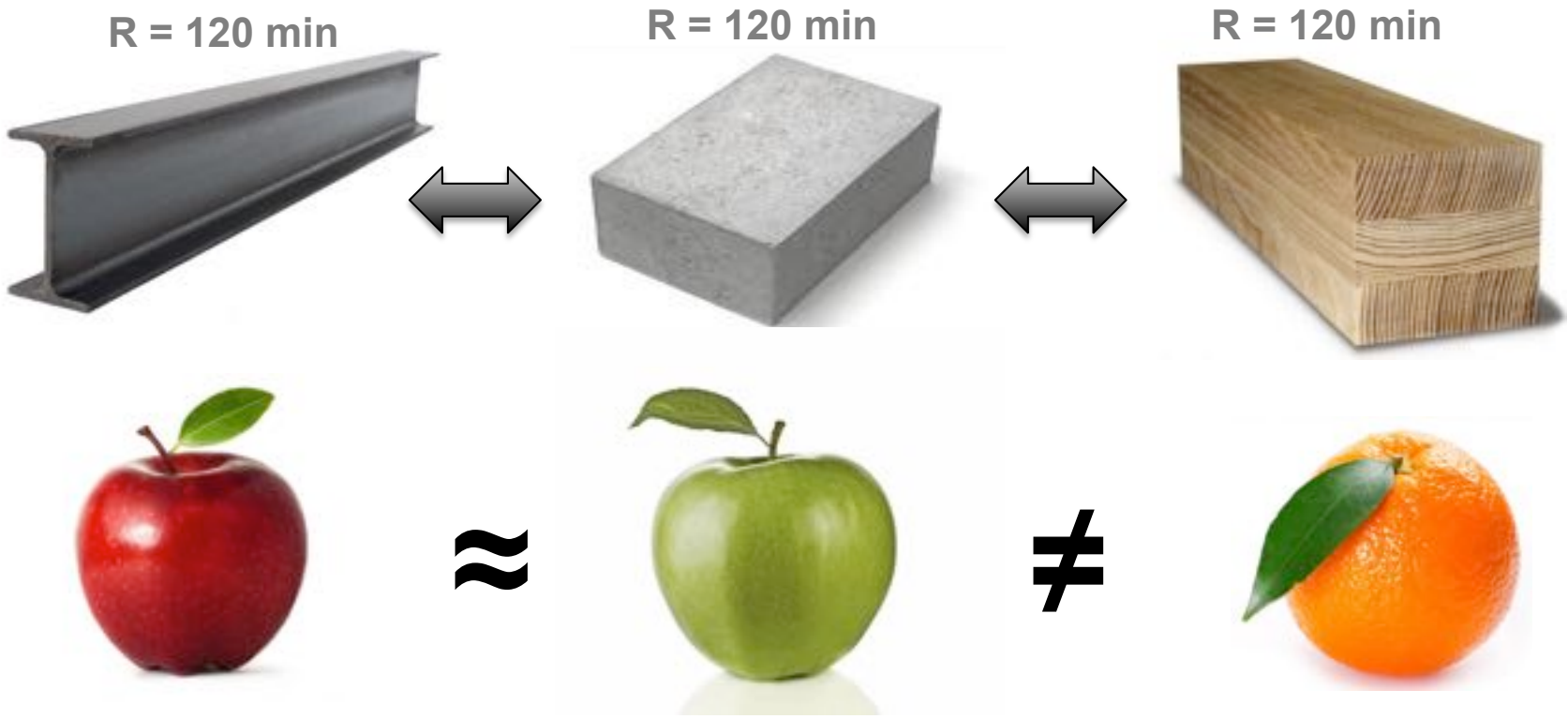
Timber Beam

The test on concrete will use <u>more fuel</u> than tests on exposed timber to yield the same gas temperatures in a furnace:

- Do timber buildings have <u>less fuel</u> in them than concrete buildings?
- Is this a <u>‘fair’ comparison</u> of candidate structural framing systems?

‘Fire Resistance’ is not ‘Apples-to-Apples’

(in particular for buildings with significant amounts of exposed timber)



And research also suggests that in mass timber buildings:

- Fires may grow more rapidly – Suppression? Egress?
- Fires may burn for longer – Time to burnout?
- There is more heat release *outside* the compartment (facades?)
- The structural frame is (potentially) fuel – Does ‘design for burnout’ make sense?

Hazard #2 (reminder)

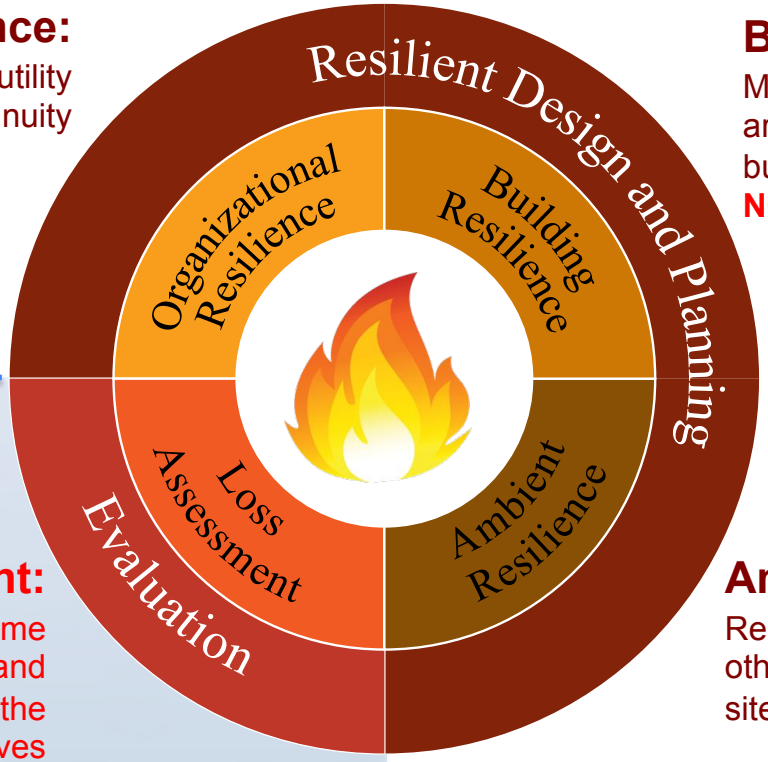
Improper application of ‘fire resistance’ is a threat to the fire Resilience of global cities

Opportunity #1: New Approach

Develop a formal framework for structural fire Resilience*

"… roadmap to resilience that will allow owners to resume business operations and provide livable/functional conditions quickly after a fire."

Organizational Resilience:
Contingency planning for utility disruption and business continuity



Building Resilience:
Minimize expected damage to structural, architectural, and MEP components and building contents through enhanced design.
NOT JUST 'FIRE RESISTANCE'

Loss Assessment:
Evaluate financial losses and downtime to evaluate success of the design and planning measures in meeting the resilience objectives

Ambient Resilience:
Reduce risks that external fire-induced (or other) hazards damage building or restrict site access

* Adapted from Arup's REDi™ Framework for Resilience-Based Earthquake Design Initiative for the Next Generation of Buildings

Opportunity #2: Leadership

Institutional Leadership on Design for Fire Resilience

1. **Integrated and holistic (i.e. 'total') fire engineering design**
   - Required for all 'uncommon' building situations?
2. **Regulation**
   - Are the current regulatory / oversight / review processes suitably robust?
3. **Education / Accreditation**
   - Who is suitably qualified / competent?
4. **Research**
   - Which knowledge gaps are most critical to address?


We’ve learned (but also forgotten) a lot in 350 years.
The challenge is to apply our knowledge in support of fire resilience, rather than just resistance.
Thank you
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