Fire Engineering in High Rise

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www.arup.com
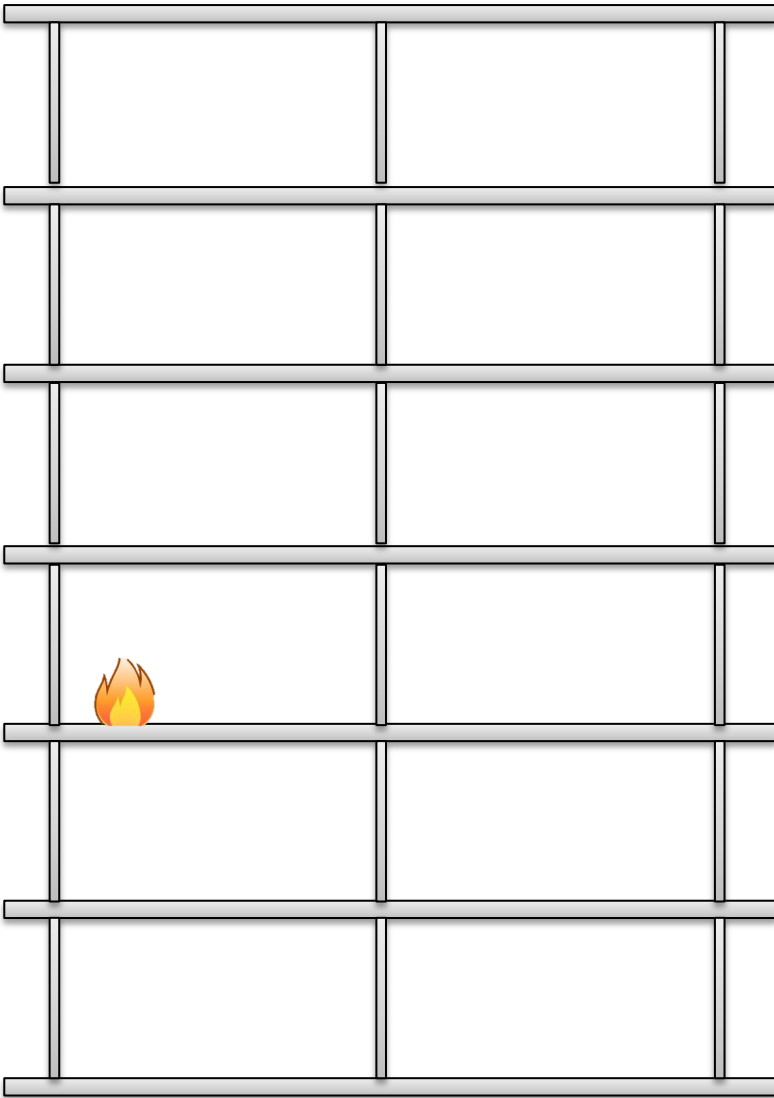
Neal.Butterworth@arup.com

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Contents

- How do we protect against fire?

- How do we know this works?

- Why evacuate?

- What assumptions are made?

- How are buildings procured?

- What are the alternatives?

- Total Fire Engineering – an integrated approach.
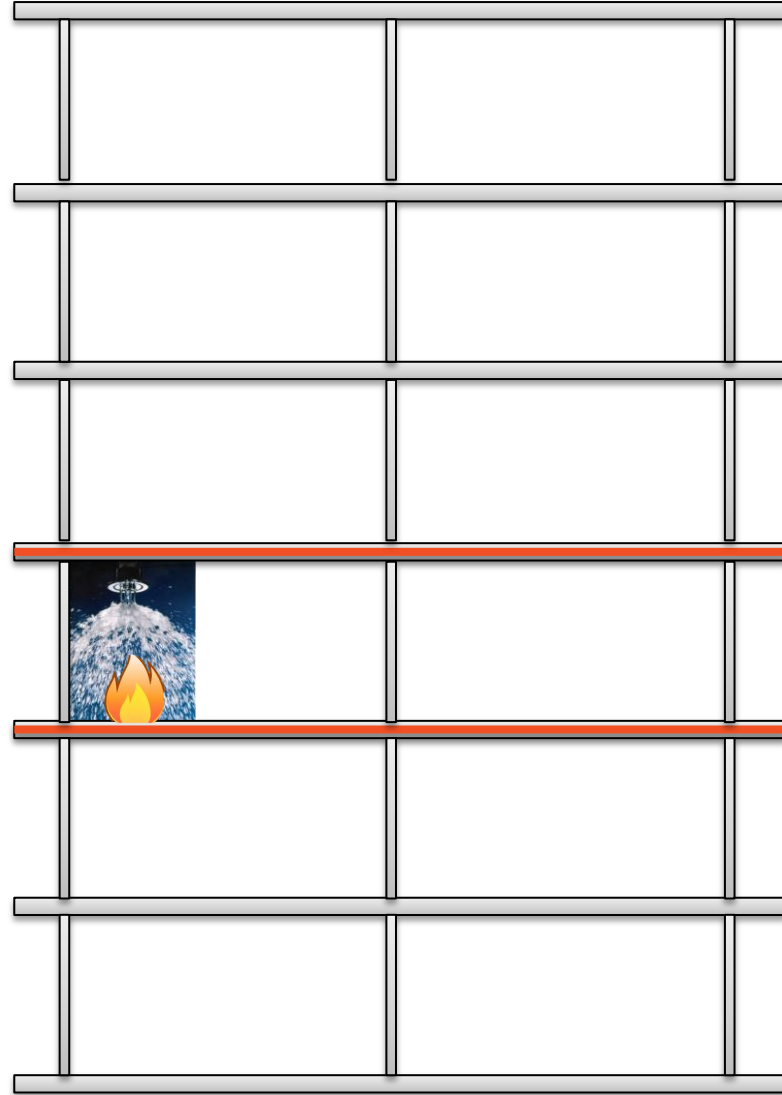
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Caveat

- Talking in very generic terms!

Typical Fire Strategy Concepts

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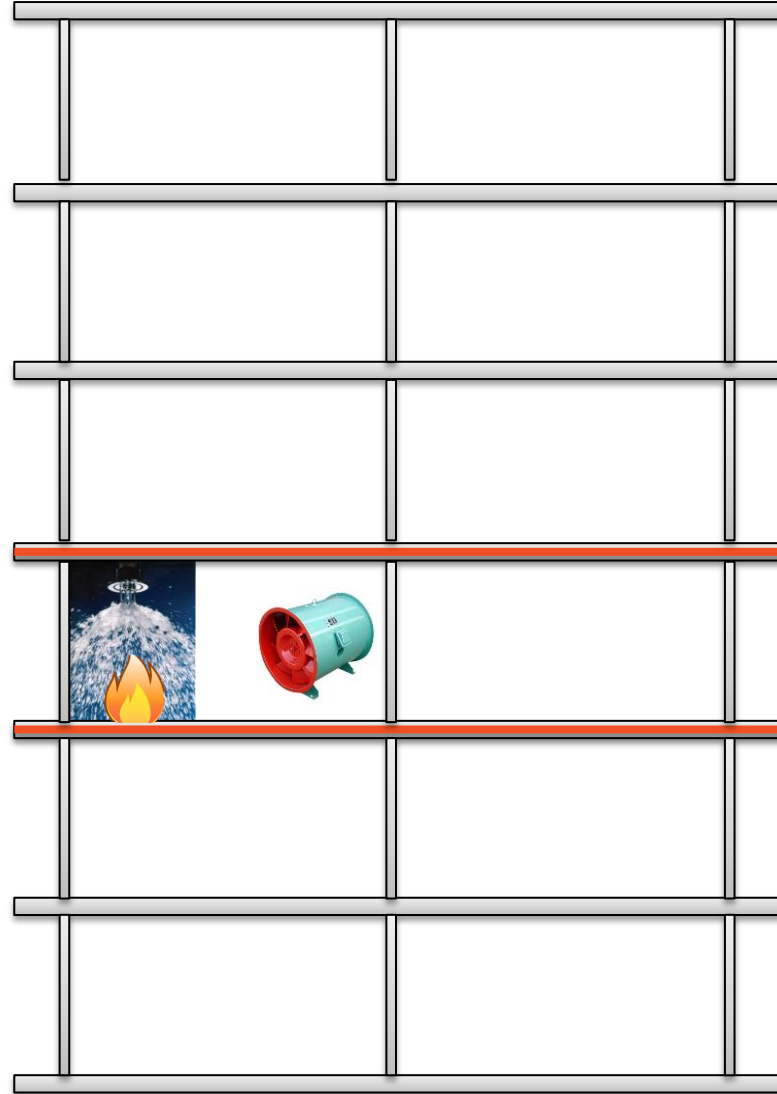# Typical High Rise Strategy Components

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Typical High Rise Strategy Components

- Contain fire:
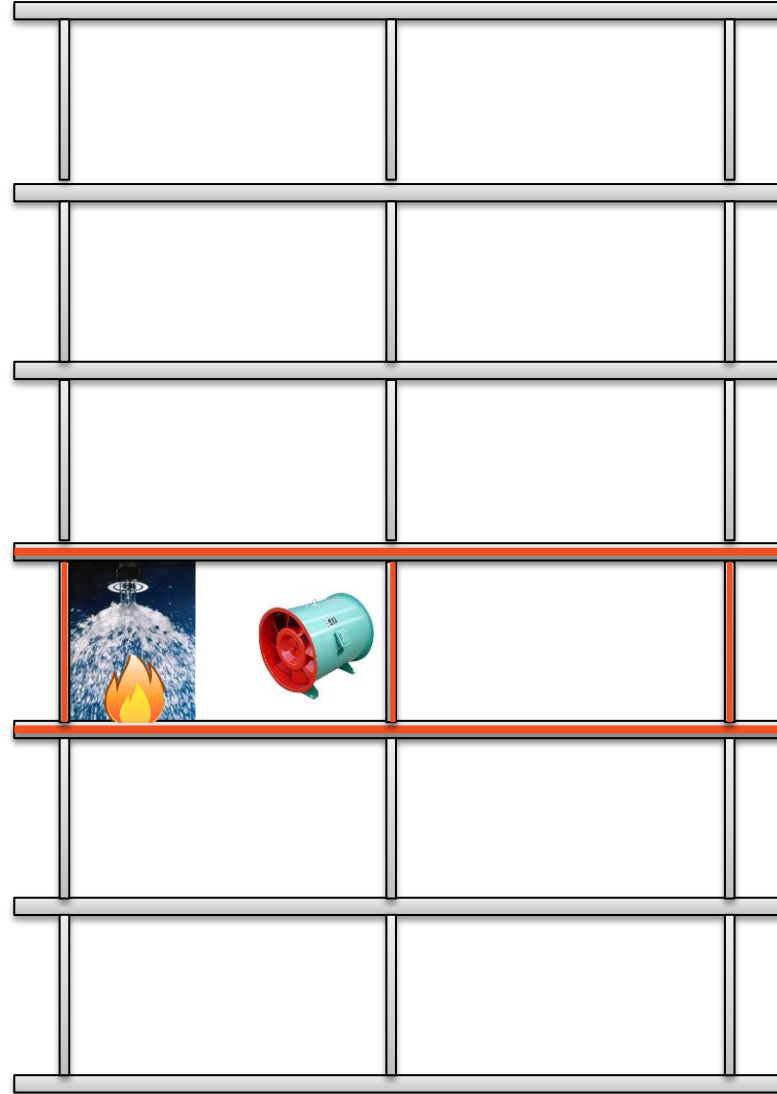 - Sprinklers
  - Compartments

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Typical High Rise Strategy Components

- Contain fire:
  - Sprinklers
  - Compartments

- Contain smoke
  - Compartments
  - Smoke Control

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Typical High Rise Strategy Components

- Contain fire:
  - Sprinklers
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- Contain smoke
  - Compartments
  - Smoke Control

- Prevent collapse
  - Fire resistance

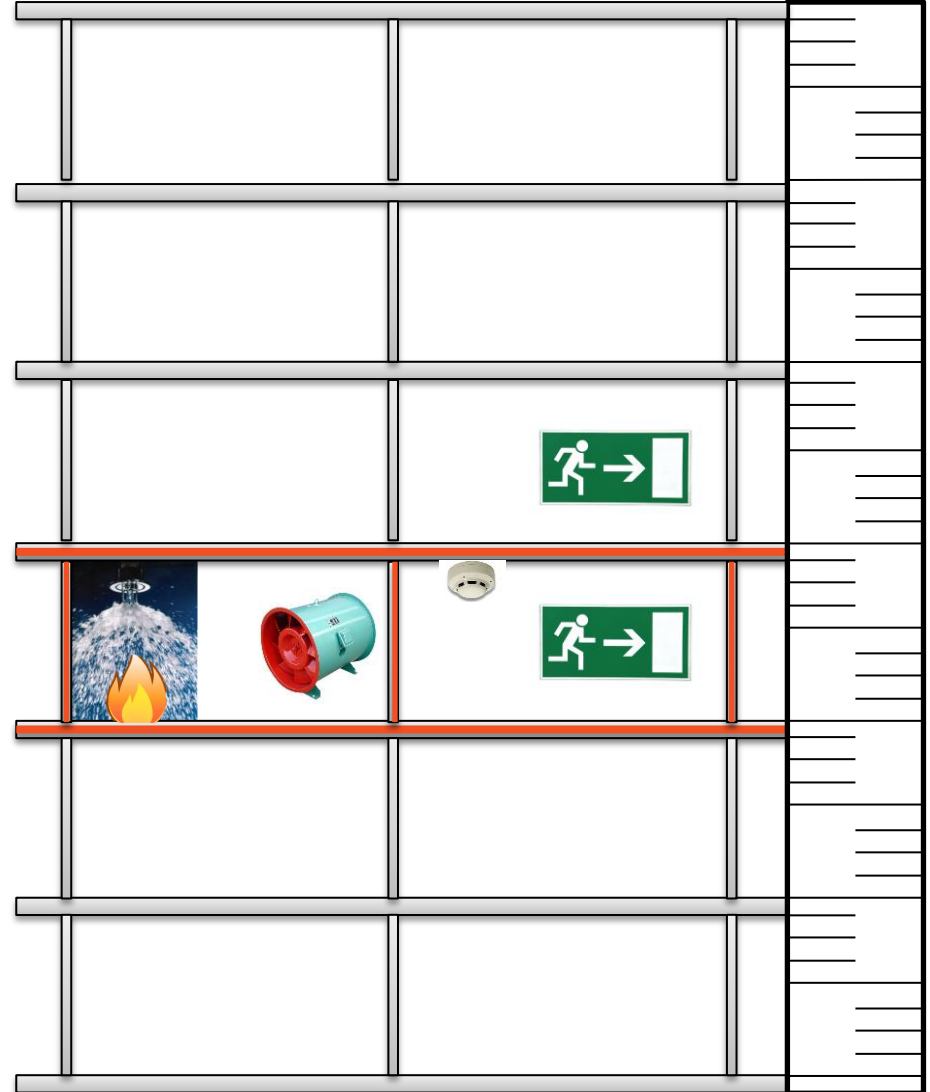**ARUP**

Typical High Rise Strategy Components

- Contain fire:
  - Sprinklers
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- Contain smoke
  - Compartments
  - Smoke Control

- Prevent collapse
  - Fire resistance

- Evacuation
  - Detect and alarm
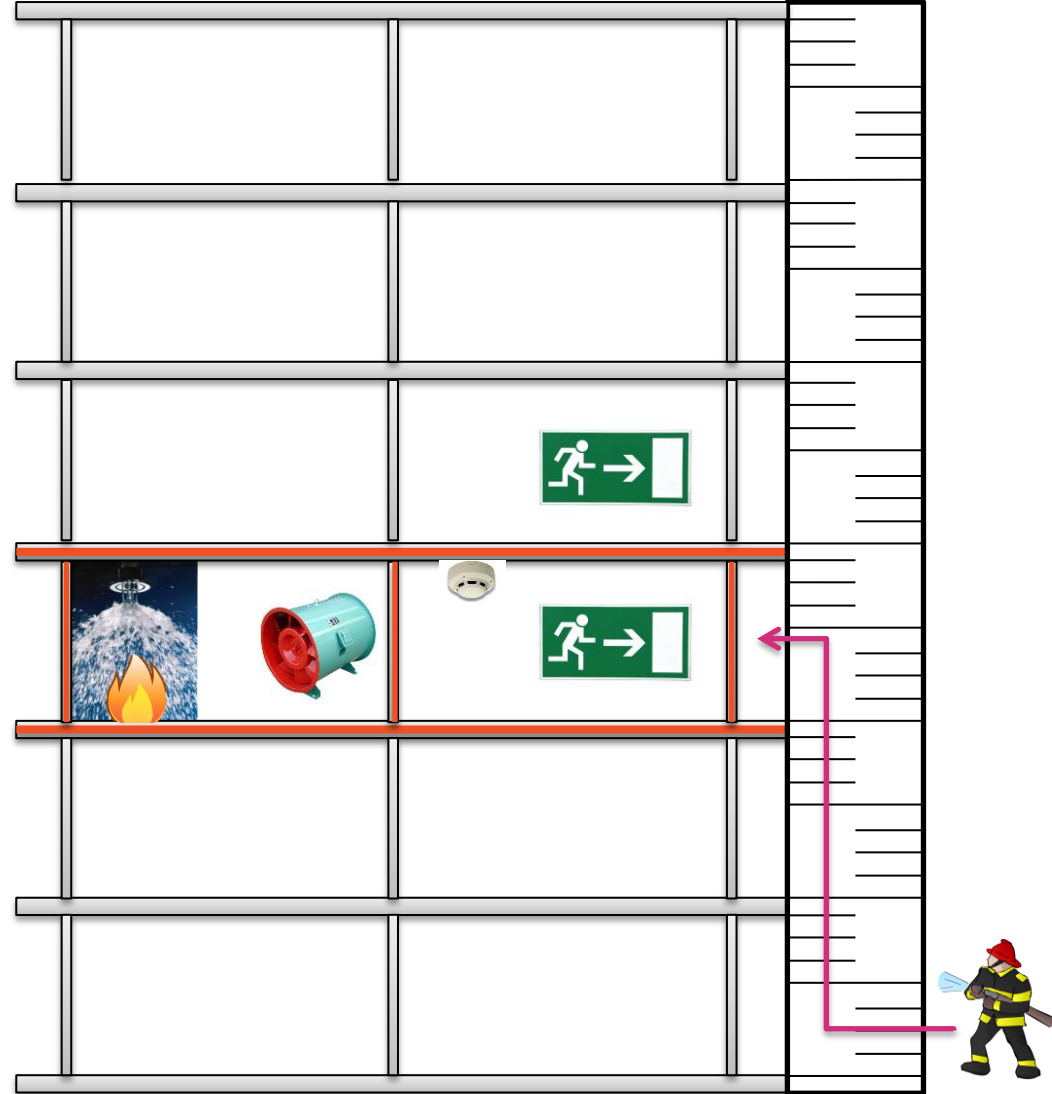 - Stairs
  - Evacuate pairs of floors

Typical High Rise Strategy Components

- Contain fire:
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- Contain smoke
  - Compartments
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  - Evacuate pairs of floors

- Fire fighting
  - Provide access

Acceptability through Precedent

Fire Strategy Development

- Build what we want

- Learn from fire incidents and disasters

- Amend legislation and guidance when risk is unacceptable.

- This has led to established fire strategy concepts for:
  - Low rise,
  - Medium rise, and
  - High rise.

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Low Rise – 1 to 2 Storeys

- Evacuation possible directly to outside

- Rescue possible from outside

- Collapse not a significant risk

- Fire spread not a significant life risk

- Fire fighting possible from outside

- Limited protection to evacuation routes

- Single stairs permissible

- Limited fire resistance requirements

- Limited compartmentation

- No specific fire fighting provisions

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Medium Rise – 3 to 8 storeys

- Evacuation reliance on stairs

- Rescue not possible from outside

- Stability required for a short period

- Fire spread starts to impact on risk

- Fire fighting difficult from outside

- At least two protected stairs

- Medium fire resistance requirements

- Some compartmentation required

- Fire fighting shafts introduced

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High Rise – 8+ Storeys

- Prolonged evacuation

- Rescue not possible from outside

- Stability required for a long period

- Risk associated with vertical

- Fire fighting difficult from inside

- Phased evacuation strategy

- High fire resistance requirements

- Compartment floors

- Sprinklers

Precedent

Height	Buildings	Time (years)	Building Years
Low	Many millions	Thousands	1,000,000,000
Medium	Many hundred thousands	Hundreds	10,000,000
High	Many thousands	Tens	10,000
Super-high	Hundreds?	Tens	1,000

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Theme (guidance vs. risk)

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Super-high rise Strategy?

- Prolonged evacuation

- Rescue not possible from outside

- Stability required for a long period

- Risk associated with vertical

- Fire fighting difficult from inside

- **Evacuation very long / impossible**

- Rescue not possible from outside

- **Collapse unacceptable**

- **High risk** associated with vertical

- Fire fighting difficult from inside

Super-high rise risks are different from high rise – **shouldn't the strategies be different**?
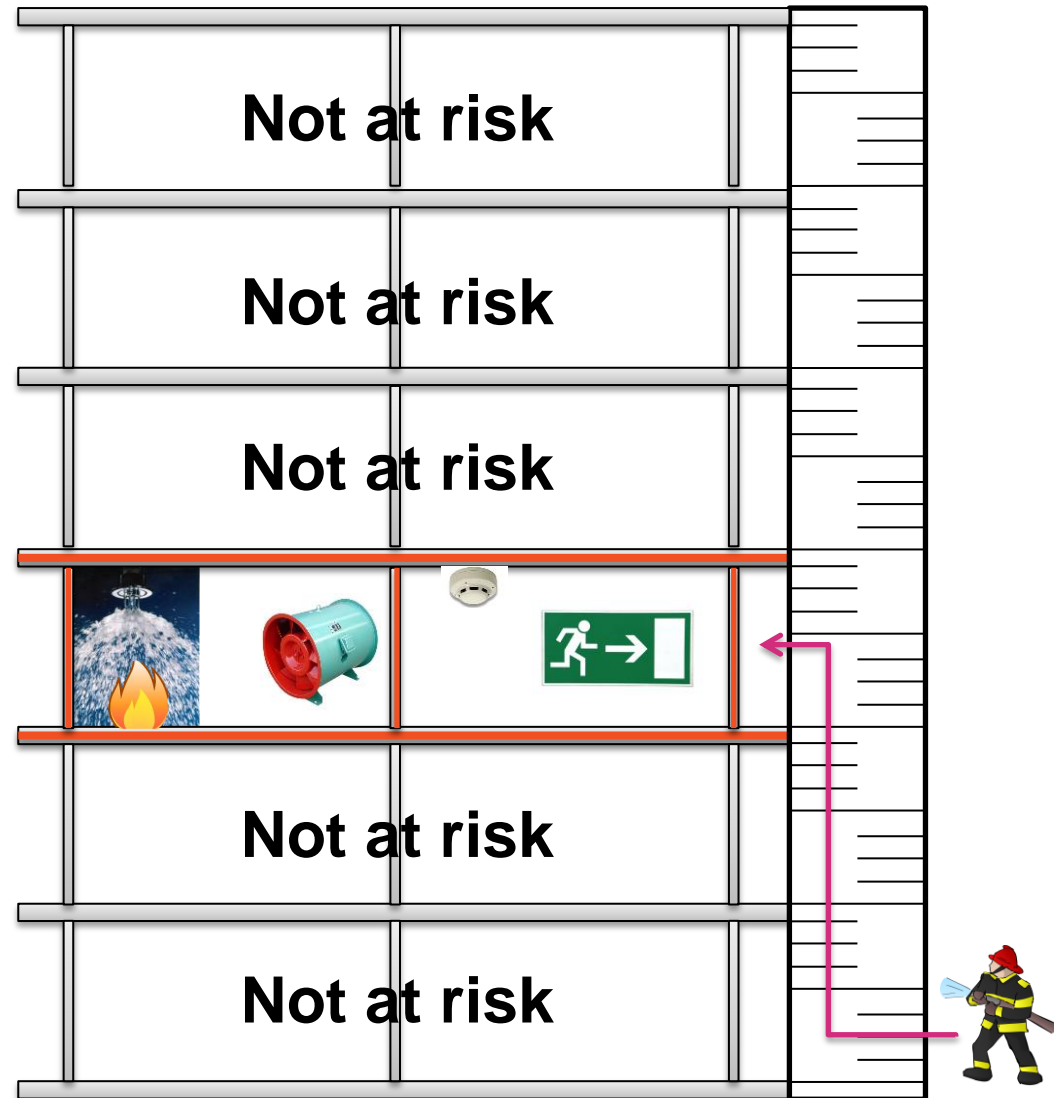
Why evacuate?

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If fire and smoke protection works…

- **Contain fire:**
  - Sprinklers
  - Compartments

- **Contain smoke**
  - Compartments
  - Smoke Control

- **Prevent collapse**
  - Fire resistance

- Evacuation
  - Detect and alarm
  - Stairs
  - Evacuate pairs of floors

- Fire fighting
  - Provide access

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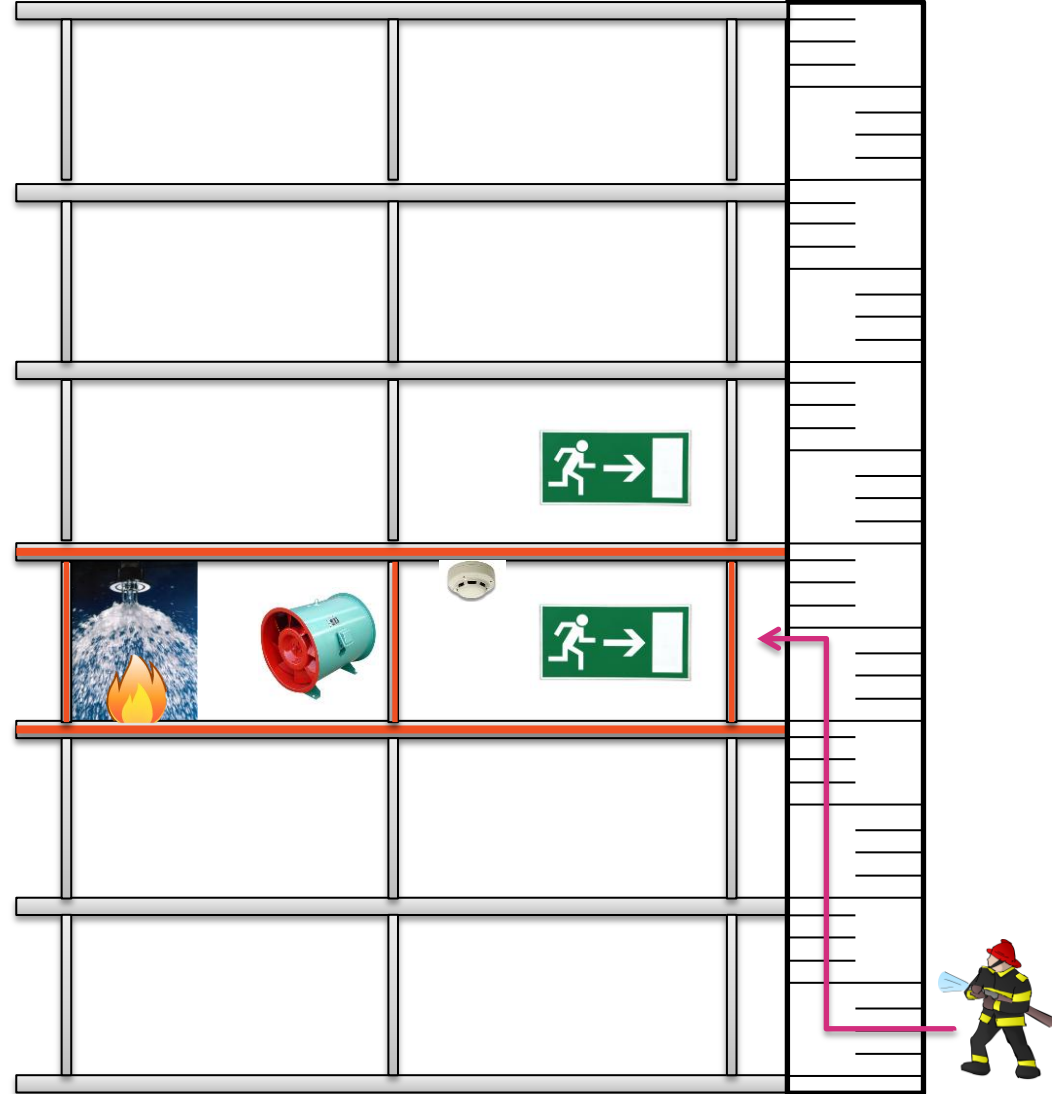
Why Evacuate?

- Fire and smoke are contained

- Structural stability will be maintained

- Only those in immediate vicinity at risk

- Fire service can extinguish any fire that is not already extinguished

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Many Reasons not to Evacuate

- Space requirements (evacuation points)

- Mobility impairments

- Fatigue

- Trips and falls

- Business disruption

- Paperwork

- Security breeches

- Complaints

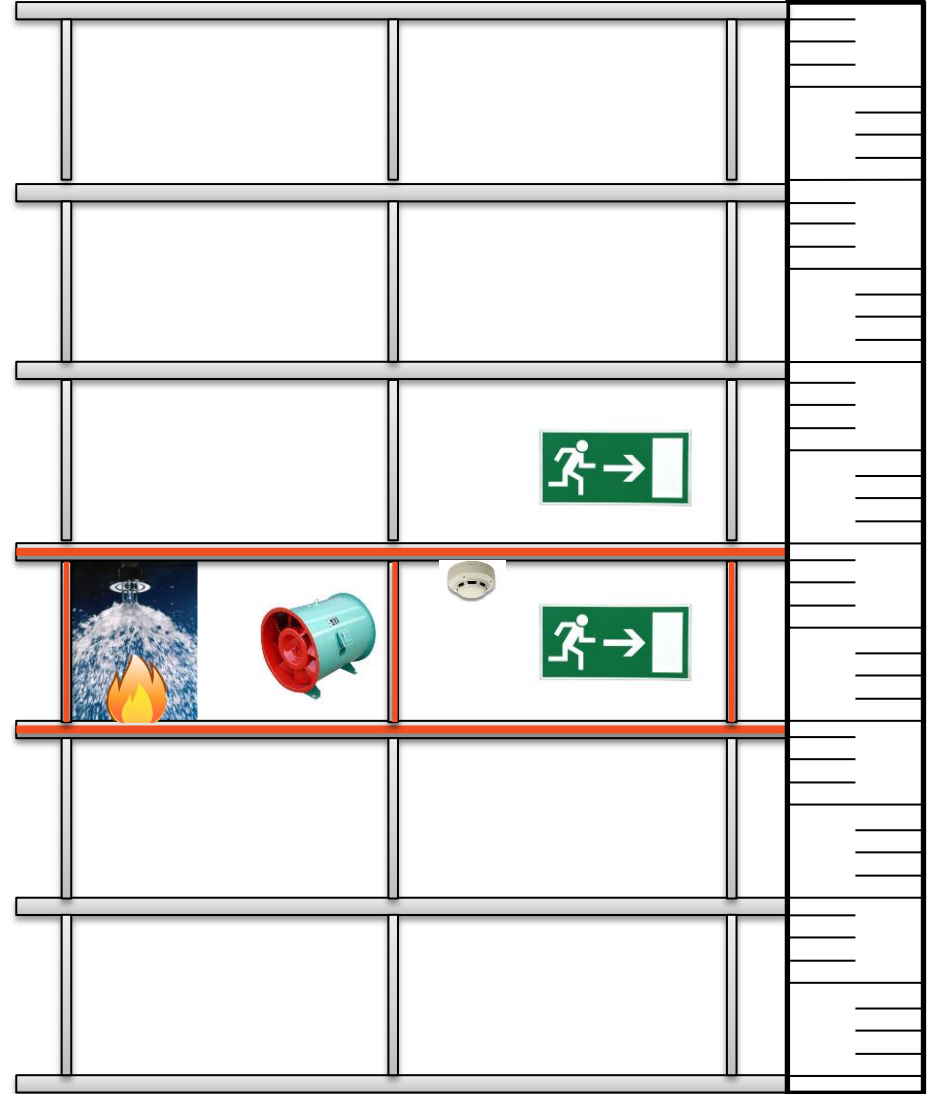**ARUP**

High Rise – 8+ Storeys

- **Prolonged** evacuation

- Rescue not possible from outside

- Stability required for a **long** period

- Risk associated with vertical

- Fire fighting difficult from inside

- **Inhibit** fire and smoke spread

- **Reasonable** stability

- **Phased** evacuation strategy

- **Evacuation period is relatively short!**

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Super-high Rise – 100+ Storeys

- Prolonged evacuation

- Rescue not possible from outside

- Stability required for a long period

- Risk associated with vertical

- Fire fighting difficult from inside

- **Evacuation very long / impossible**

- Rescue not possible from outside

- **Collapse unacceptable**

- **High risk** associated with vertical

- Fire fighting difficult from inside
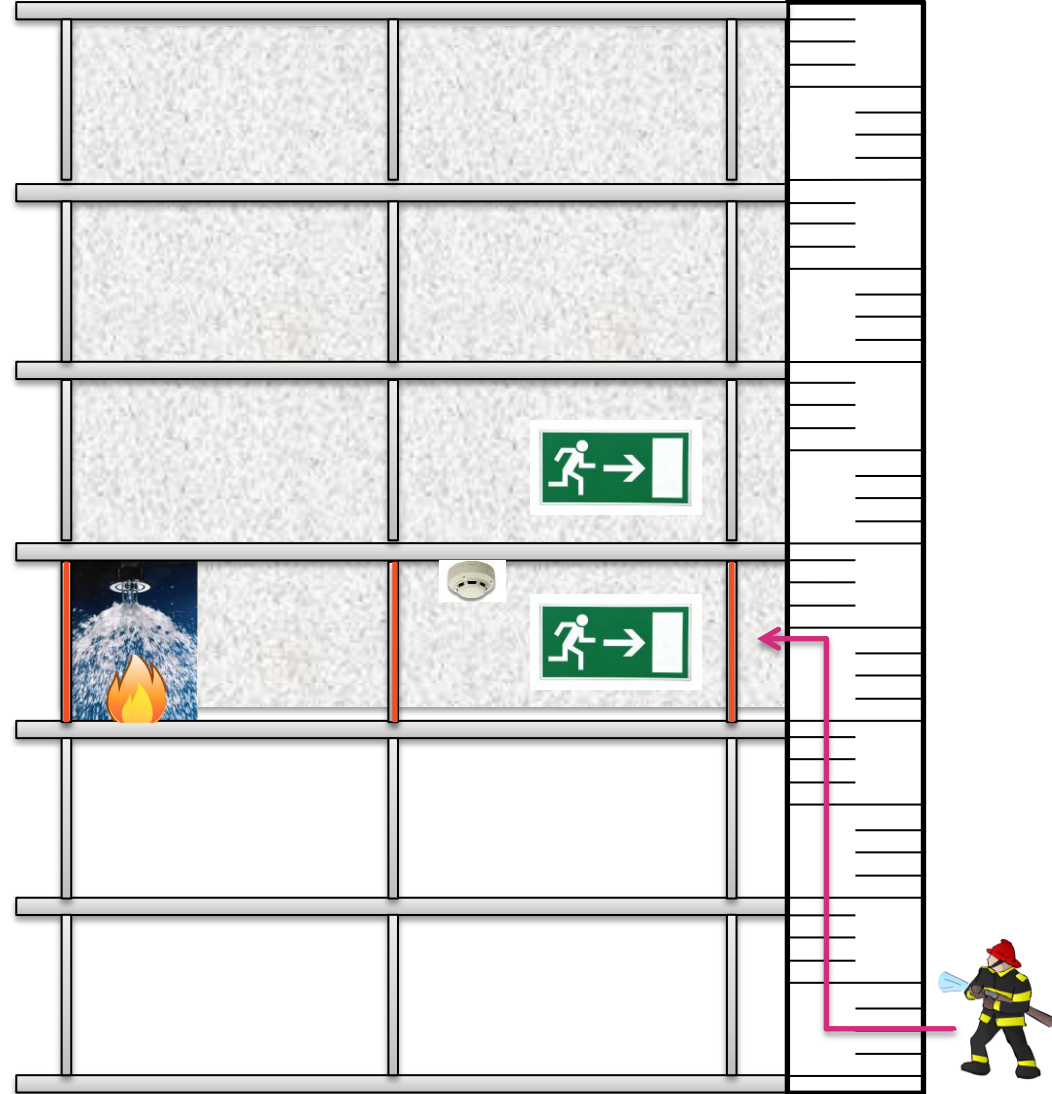
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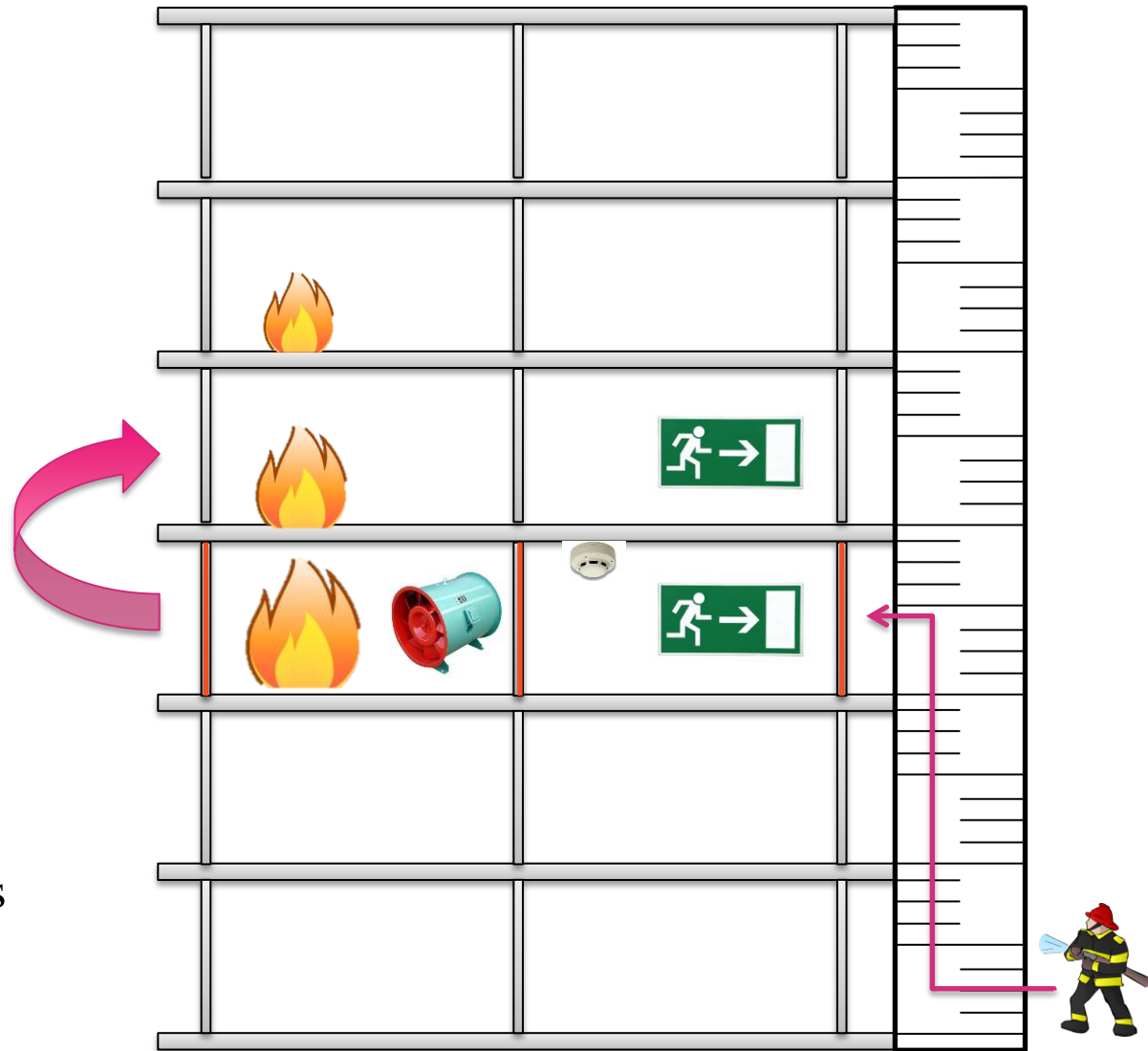# What assumptions are made?

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Typical High Rise Strategy Components

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  - Smoke Control

- Prevent collapse
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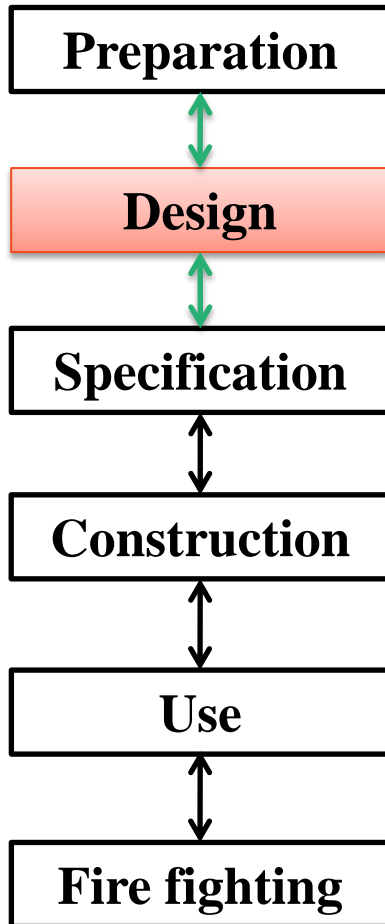
- Fire fighting
  - Provide access

Causes of Failure

- Accidental failure
  - Poor design, specification, construction or use
  - System failure
  - Cause and effect failure
  - Combined accidental loads

- Deliberate failure
  - Larger fire or multiple fires
  - Sabotage of systems
  - Combined events

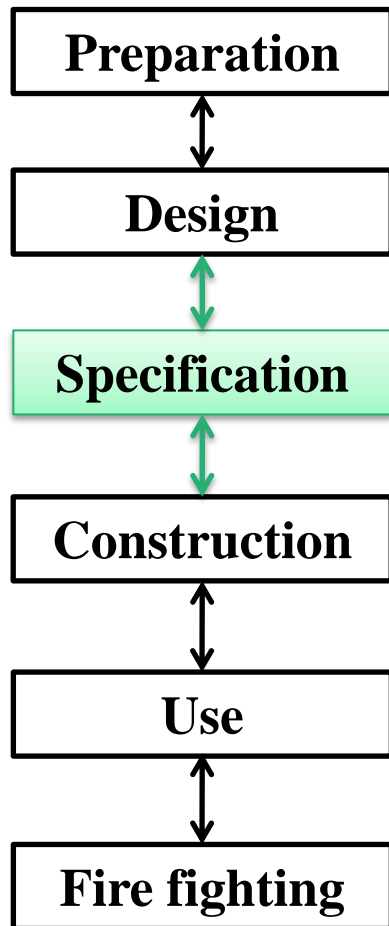- Low Probability but Extreme Consequence = **High Risk?**
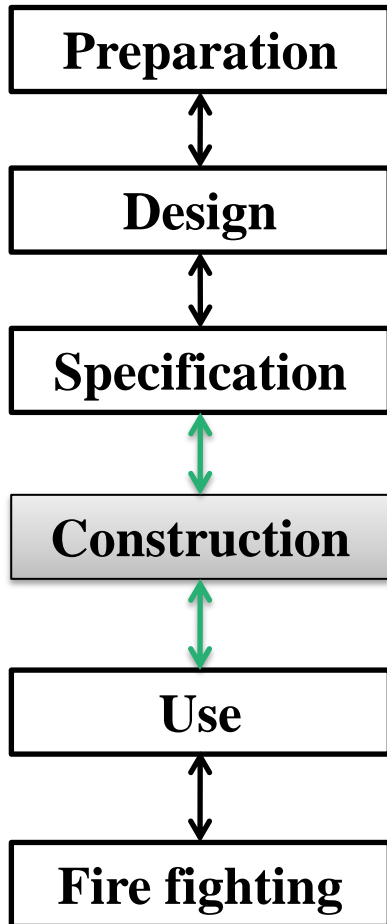
Building Procurement

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Building Procurement

```
┌─────────────────────┐
│    Preparation      │
└─────────────────────┘
         ↕
┌─────────────────────┐
│      Design         │
└─────────────────────┘
         ↕
┌─────────────────────┐
│   Specification     │
└─────────────────────┘
         ↕
┌─────────────────────┐
│   Construction      │
└─────────────────────┘
         ↕
┌─────────────────────┐
│       Use           │
└─────────────────────┘
         ↕
┌─────────────────────┐
│   Fire fighting     │
└─────────────────────┘
```

- Means of escape
  - Can people really walk down?

- Smoke control
  - Stack and wind effect, building systems, cause and effect

- Fire control
  - Changing fire load

- Fire Resistance
  - Assume single storey fire
  - Don't assess overall stability

- Fire Fighting
  - Assume single storey fire

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Fire Engineering

```
┌─────────────────┐
│   Preparation   │
└─────────────────┘
         ↕
┌─────────────────┐
│     Design      │
└─────────────────┘
         ↕
┌─────────────────┐
│  Specification  │
└─────────────────┘
         ↕
┌─────────────────┐
│  Construction   │
└─────────────────┘
         ↕
┌─────────────────┐
│      Use        │
└─────────────────┘
         ↕
┌─────────────────┐
│  Fire fighting  │
└─────────────────┘
```

- Disconnect between design and specification

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Fire Engineering

Preparation

↕

Design

↕

Specification

↕ (green arrow)

Construction

↕ (green arrow)

Use

↕

Fire fighting

- Construction quality
  - Fire stopping

- Commissioning
  - Systems commissioned separately

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Fire Engineering

Preparation

↕

Design

↕

Specification

↕

Construction

↕

Use

↕

Fire fighting
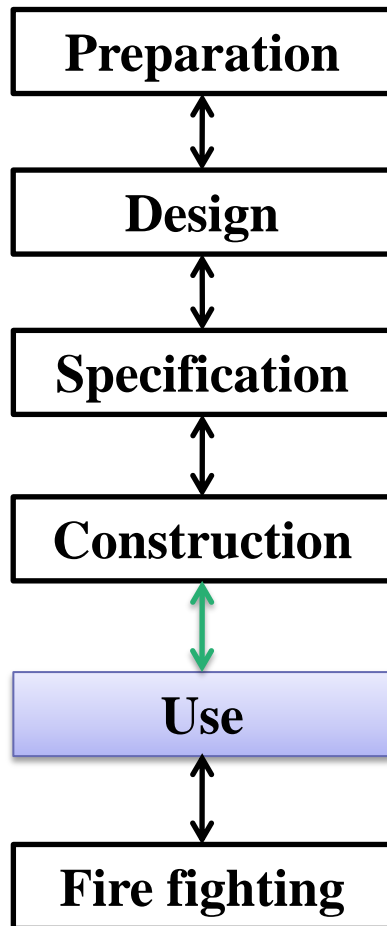
- Quality of Handover
  - Do users know what has been built?

- Building Management
  - Quality of house-keeping
  - Quality of maintenance
  - Quality of training and staff

- Apparent Simplicity masks Actual Complexity

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Fire Engineering

```
┌─────────────────┐
│   Preparation   │
└─────────────────┘
         ↕
┌─────────────────┐
│     Design      │
└─────────────────┘
         ↕
┌─────────────────┐
│  Specification  │
└─────────────────┘
         ↕
┌─────────────────┐
│  Construction   │
└─────────────────┘
         ↕
┌─────────────────┐
│      Use        │
└─────────────────┘
         ↕
┌─────────────────┐
│  Fire fighting  │
└─────────────────┘
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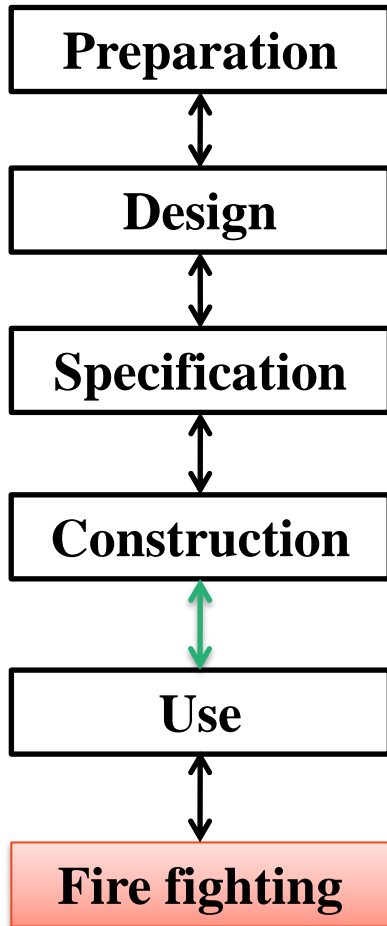
- What information about the assumptions in the original design are available.

Alternatives

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Capability

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Fire Scientists

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Fire and smoke modelling

Computational Evacuation Simulation

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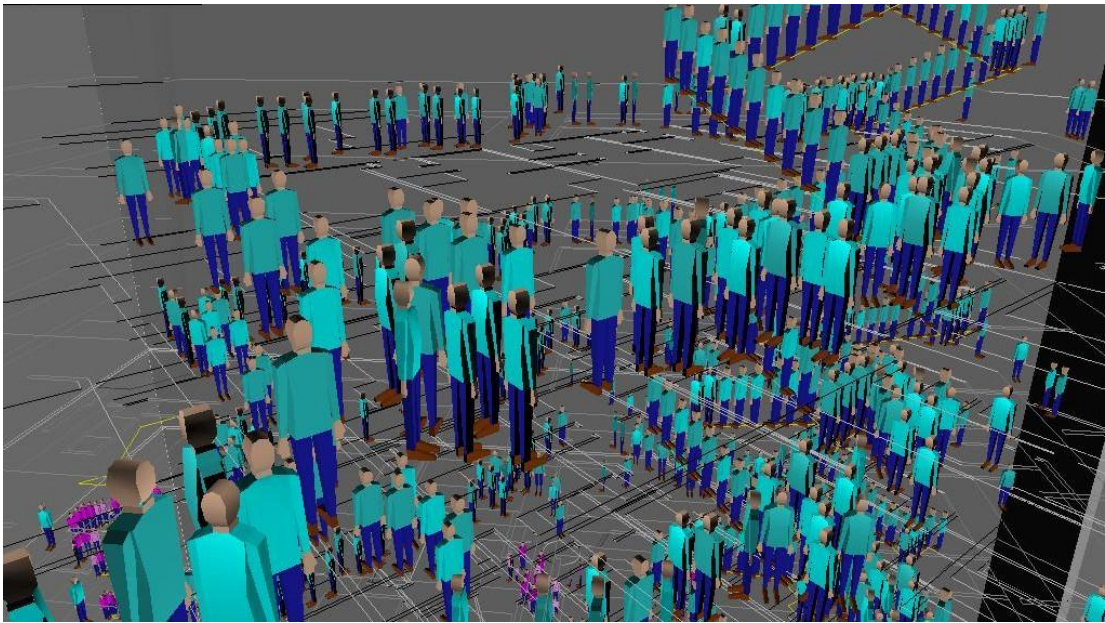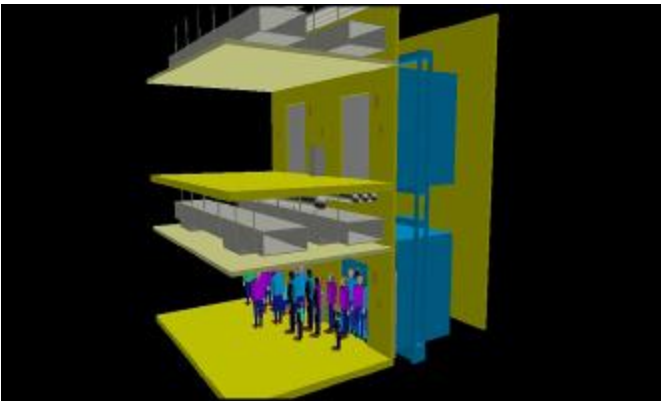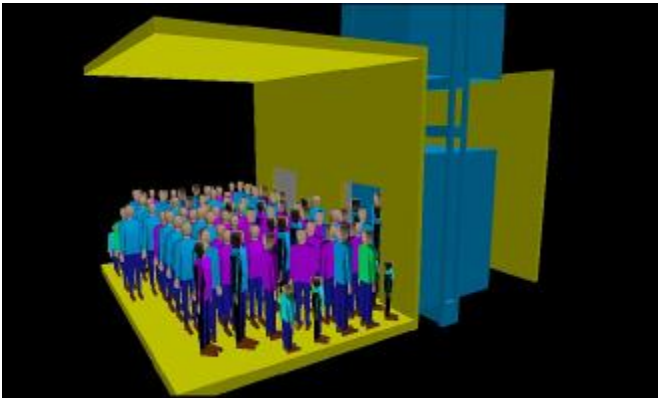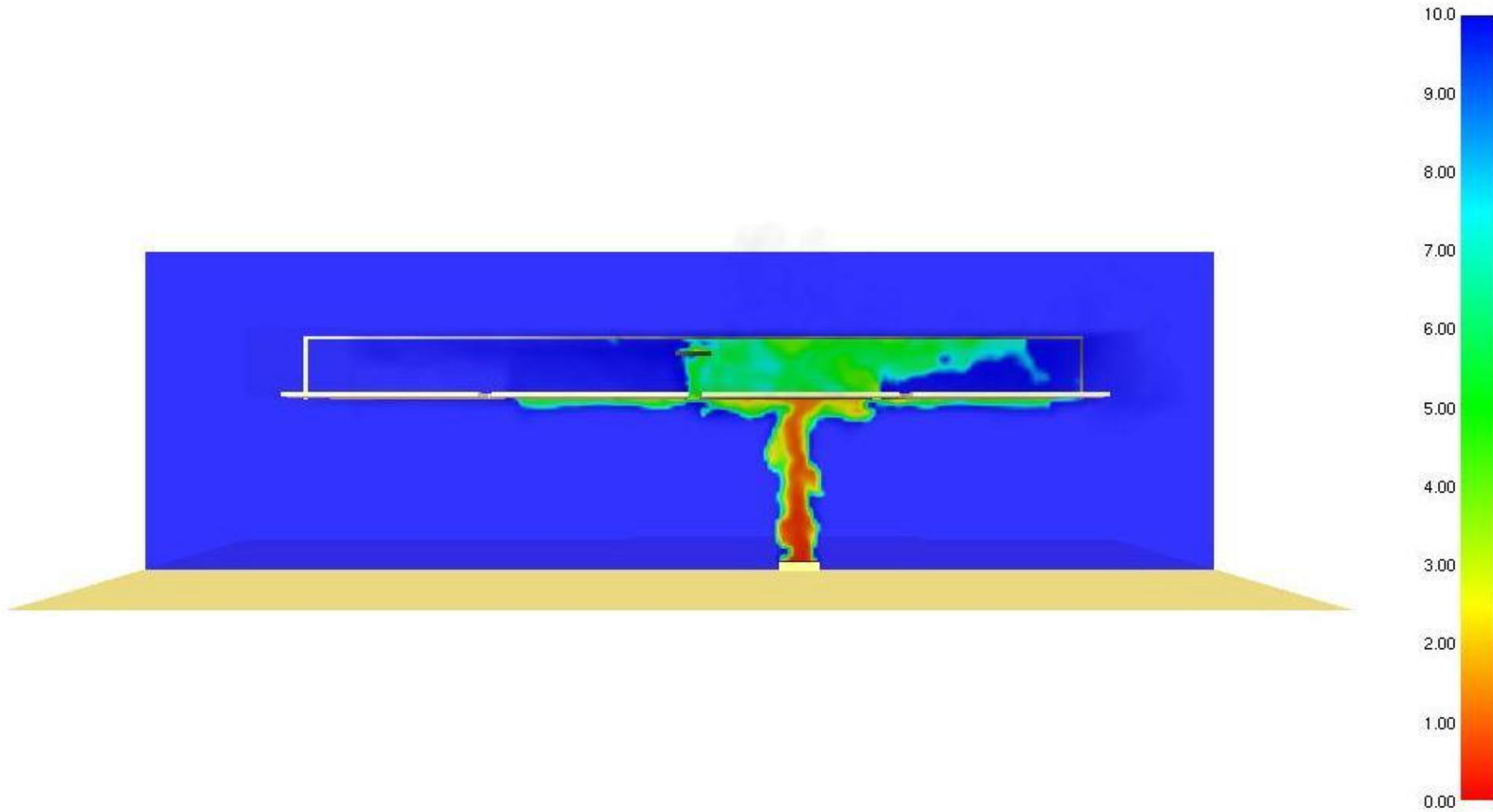
Computational Fluid Dynamics

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U, U3
+8.526e+01
+1.103e+01
-6.320e+01
-1.374e+02
-2.117e+02
-2.859e+02
-3.601e+02
-4.344e+02
-5.086e+02
-5.828e+02
-6.570e+02
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-8.055e+02
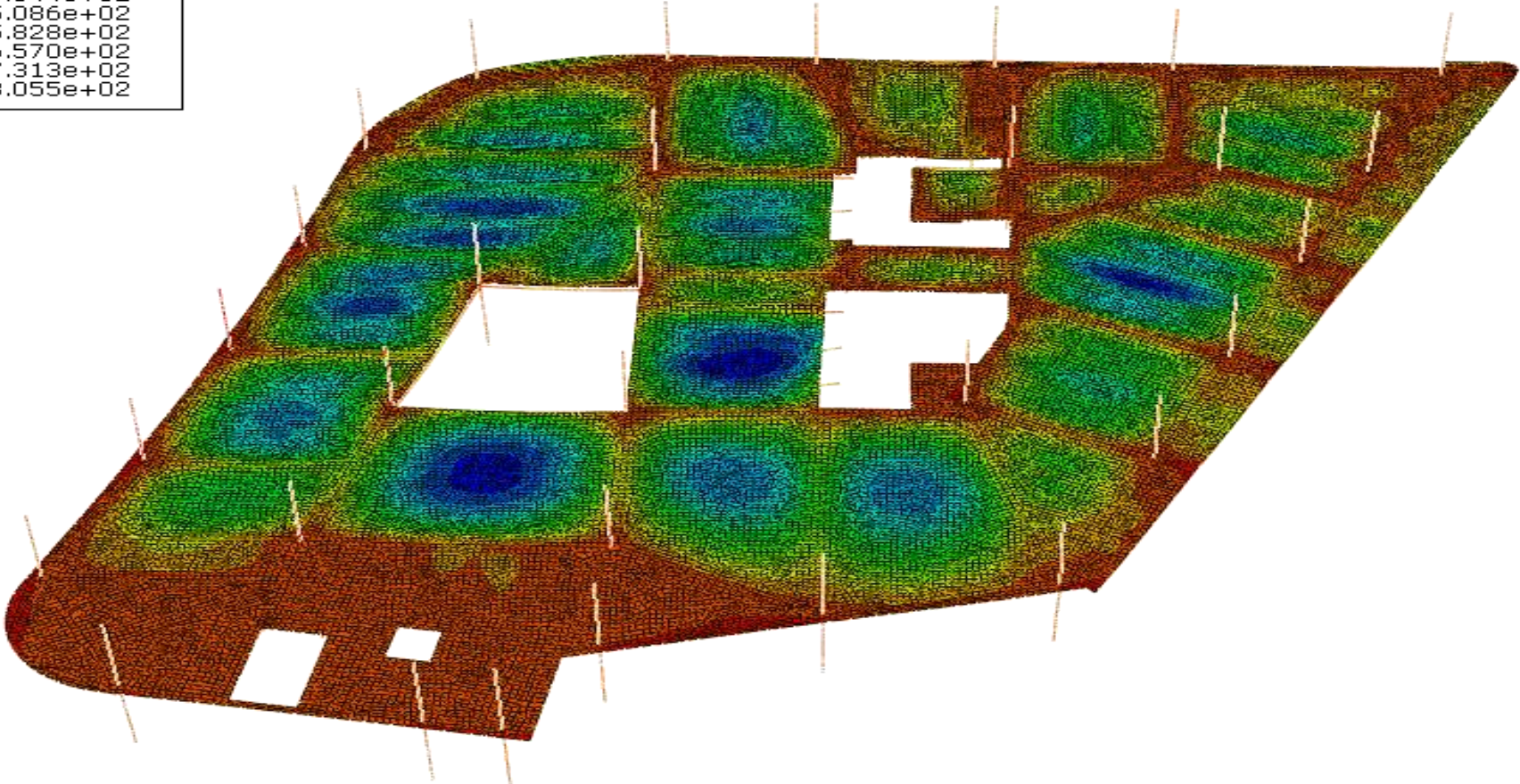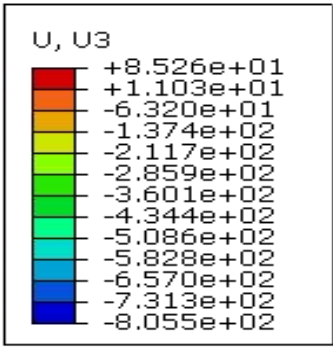
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Structural Fire Modelling

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Fire systems specialists

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Total Fire Engineering

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All Design Decisions

Evacuation

Suppression

All credible scenarios

Containment

Resistance

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Integrate Design

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Organised Team

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Conclusions

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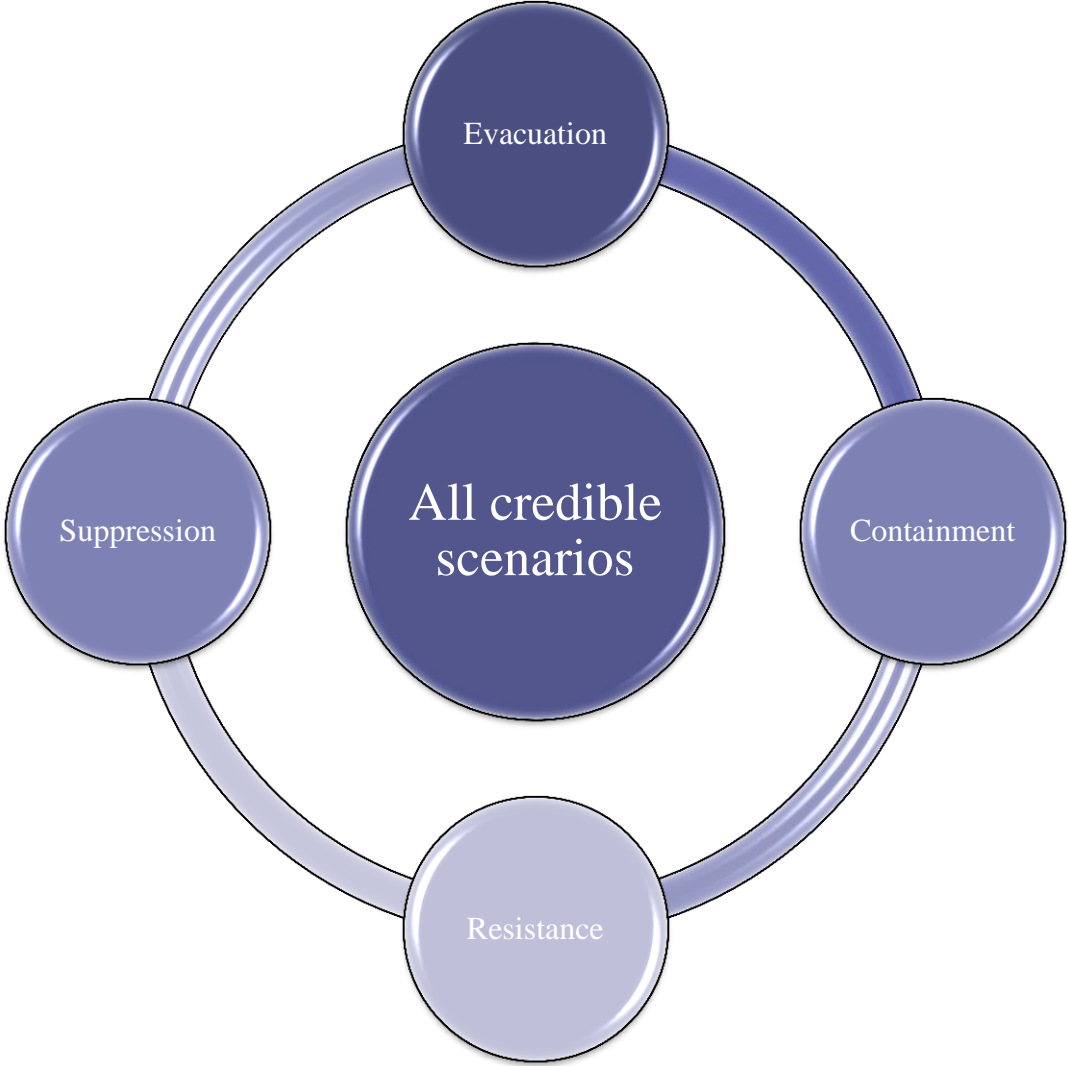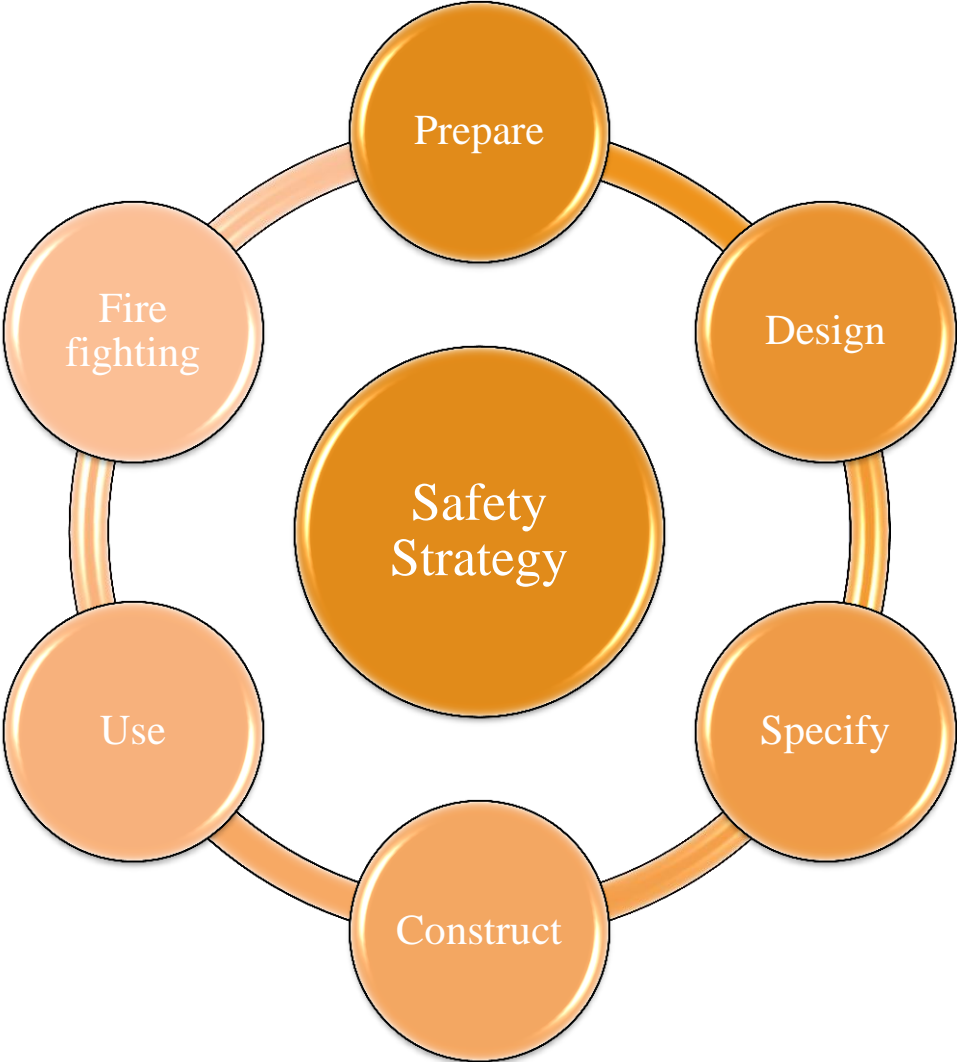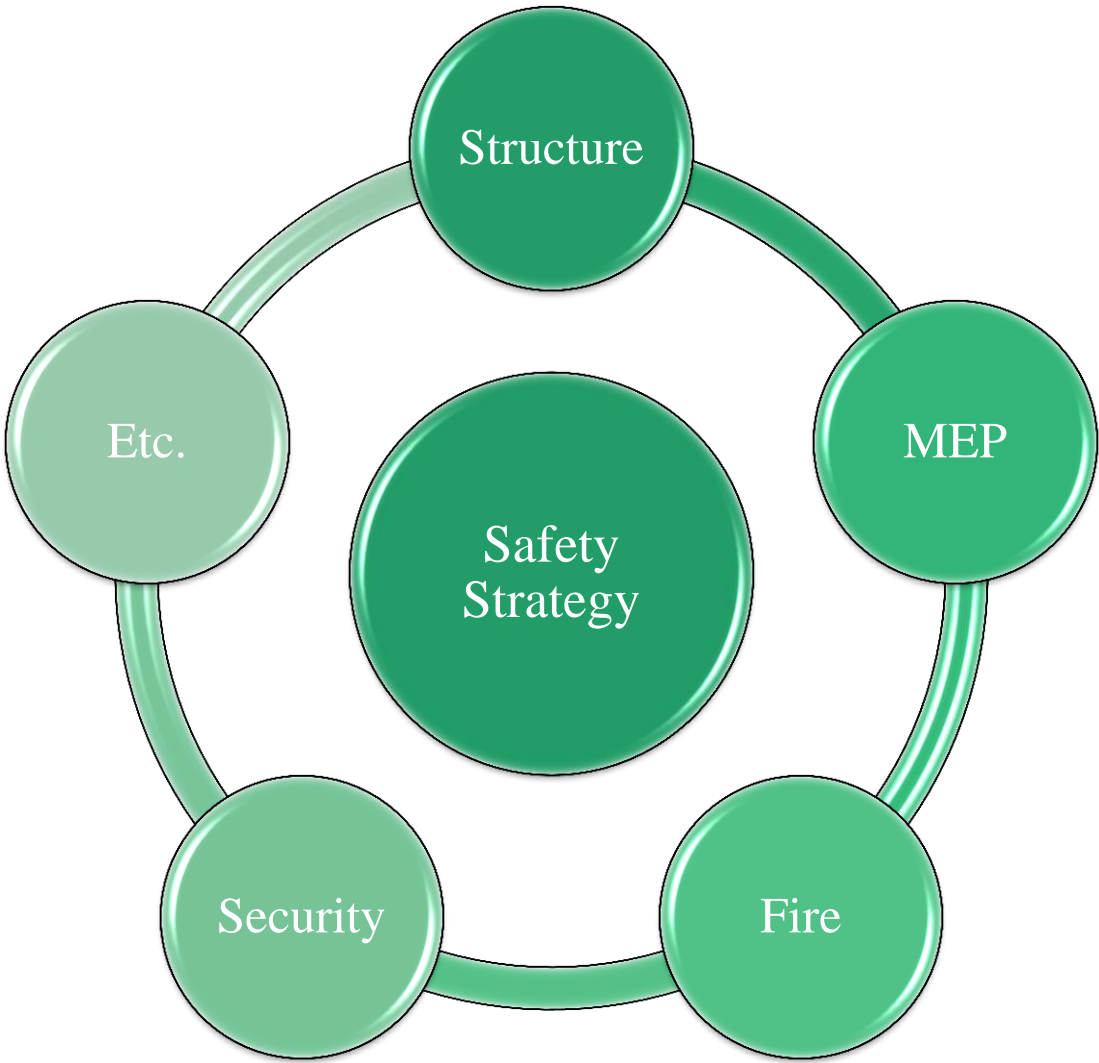
Conclusions

- Rapid advanced in building design mean that acceptability by precedent is no longer possible.

- Consequence of fire spread in super-tall buildings are very high

- **We must proactively identify acceptable levels of risk and design accordingly.**

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Conclusions

- Great reliance is placed on the efficacy of the fire protection features and systems that we incorporate into our strategies.

- There is limited margin of safety for failure.

- **We must design, specify, install, operate and maintain our systems correctly.**
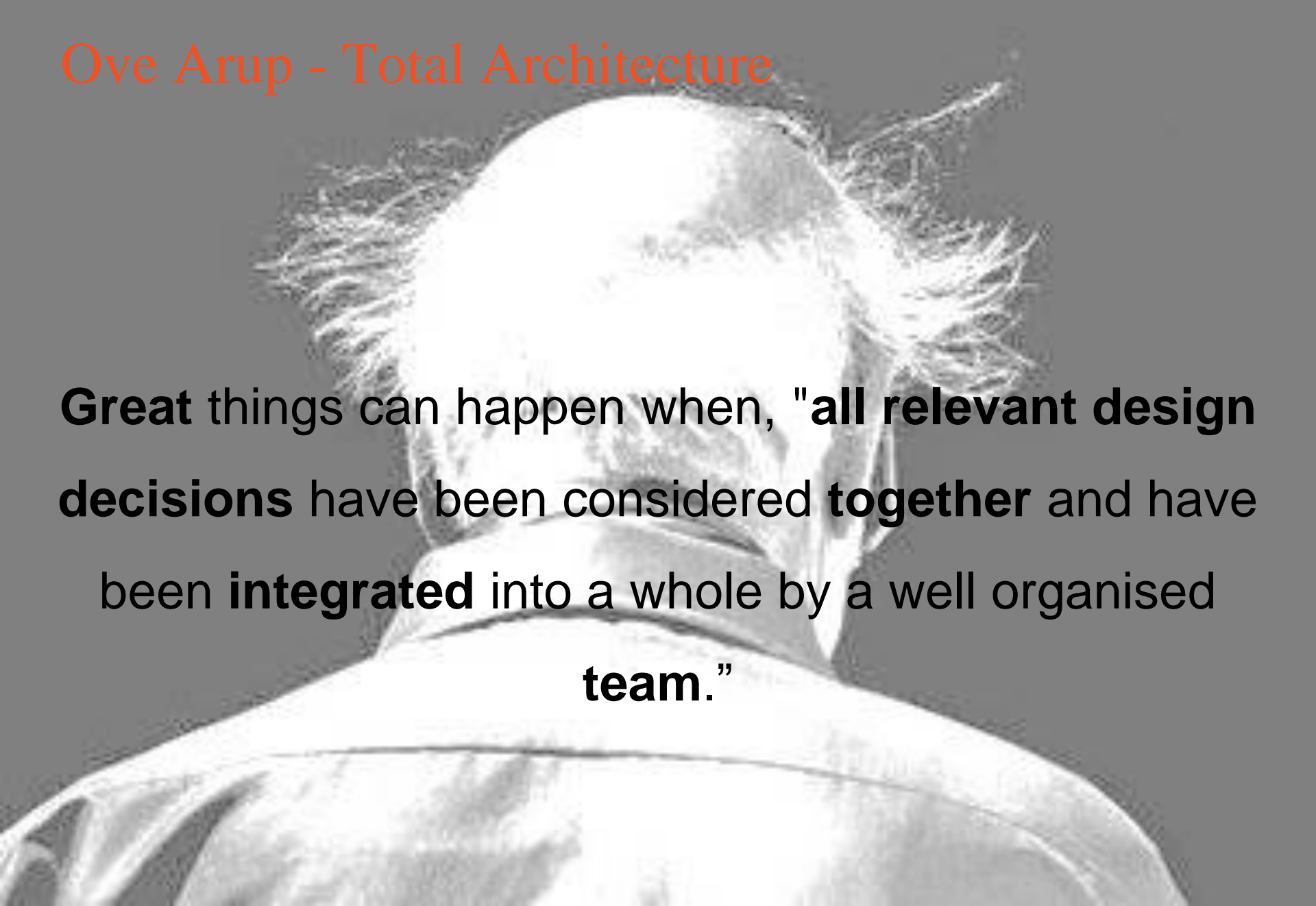
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Conclusions

- Design assumptions that are valid for high rise design are not necessarily appropriate for super-high rise strategies.

- The consequence of incorrect assumptions is very high.

- **We must consider all relevant design fire scenarios and test against potential system failure.**

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Conclusions

- We have the capability, and the tools but…

- **Fire can no longer be considered in isolation.**

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Great things can happen when, "**all relevant design decisions** have been considered **together** and have been **integrated** into a whole by a well organised **team**."

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Great things can happen when, "**all relevant design decisions** have been considered **together** and have been **integrated** into a whole by a well organised **team**."

Safety is relevant and must be integrated into design.

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