The use of sprinkler systems as a compensatory measure for building fire safety

A case study from the UK

3rd October 2017

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EUROPEAN FIRE SPRINKLER NETWORK

Agenda

Performance and benefits of sprinklers

Gains from designing buildings with sprinklers

Case study – UK

Fire Sprinkler International 2018

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But first, Grenfell Tower

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Grenfell Tower

- At least 80 dead – worst peacetime fire in UK in over 100 years
- Building recently refurbished with new insulation and cladding to improve thermal performance and aesthetics
- Fire started in a refrigerator in a kitchen on fourth floor
- Fire brigade extinguished the fire and was leaving when saw external fire
- Common corridors and escape staircase were filled with smoke
- Single staircase, individual smoke alarms in apartments
- **No sprinklers** – built in 1970s before sprinklers required

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Grenfell Tower

- Public enquiry, chaired by a former judge of the Court of Appeal, reporting to the Prime Minister, to address:
  - The design, construction and refurbishment of Grenfell Tower
  - The scope and adequacy of the relevant regulations relating to high-rise buildings
  - Whether the legislation and guidance were followed
  - The actions of the local authority and other bodies before the tragedy
  - The response of the London fire brigade to the fire
  - The fire prevention and fire safety measures in place on 14 June
  - The response of central and local government in the aftermath
- Enquiry began 15 August, interim report by Easter 2018
- Final report much later

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Grenfell Tower

- Independent review of building regulations, reporting to Communities Secretary and Home Secretary (Interior Minster)
  - Look at regulations and their enforcement
  - Interim report by end 2017
  - Final report mid 2018
  - Clearly some overlap with the public enquiry
- Meanwhile over 500 buildings are being retrofitted with sprinklers

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Performance and benefits of sprinklers

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Performance of sprinklers

- Sprinkler systems control or extinguish fires, so that they become minor events (nobody killed or hurt, little damage)
- This is because sprinklers apply water while the fire is small
  - Sensitive thermal element which detects heat
  - Fire extinguished or growth stopped – less damage and toxic smoke
  - Less water needed to deal with fire – less water damage
- Statistical analyses from NFPA and insurers show that fire deaths, injuries and property losses are reduced by over 80% *(77% of the few victims set clothing/bedding on fire)*

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Performance of sprinklers

- Each sprinkler responds individually
- Liquid in the glass bulb heats and expands until the bulb breaks
- No connection between sprinklers
- Only sprinklers near the fire operate
- Cigarette smoke, burnt toast or water vapour will not operate a sprinkler

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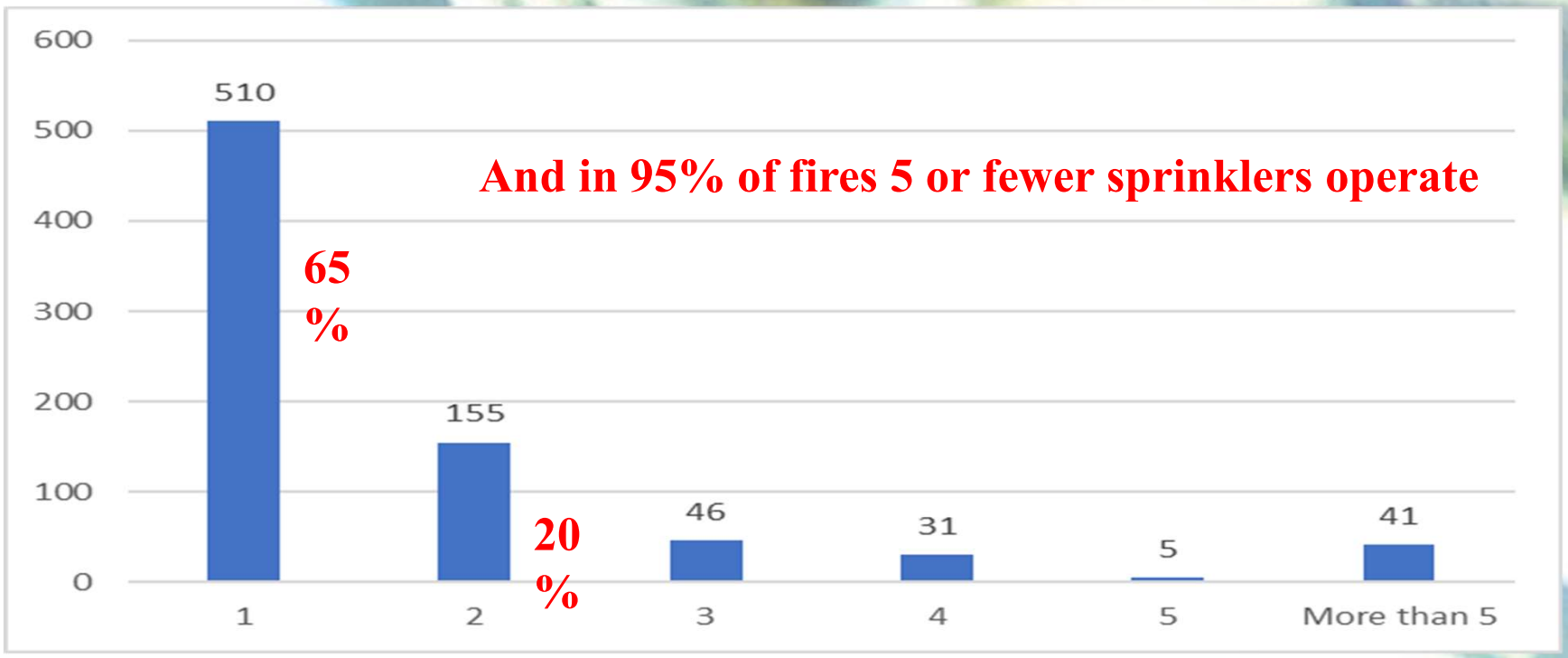
In 85% of fires only 1 or 2 sprinklers operate

Number of sprinklers operated in UK fires



Source: UK fire brigades 2011-2016

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Benefits of sprinklers

Temperature is maintained at a safe level

- No flashover
- Gas pressure falls so smoke does not pump past doors and walls

Fire is extinguished or kept small

- Fire does not leave room of origin
- Toxic gases are maintained at a safe level outside the room of fire origin and often within it as well

- Proven in research for US, UK and Flemish governments

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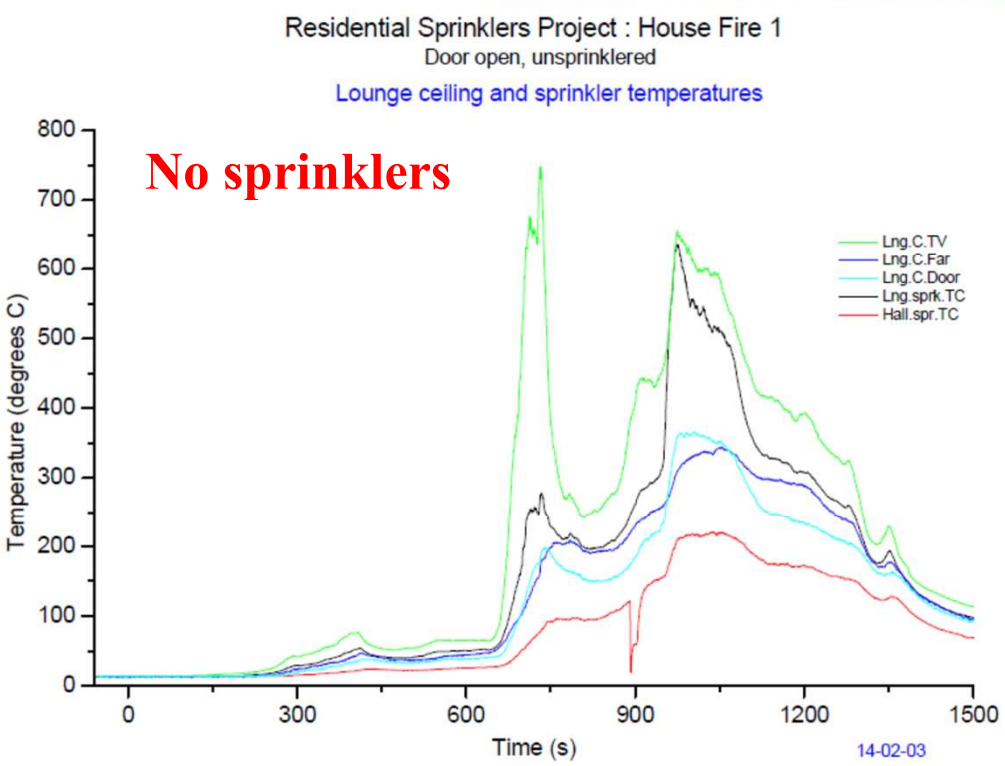
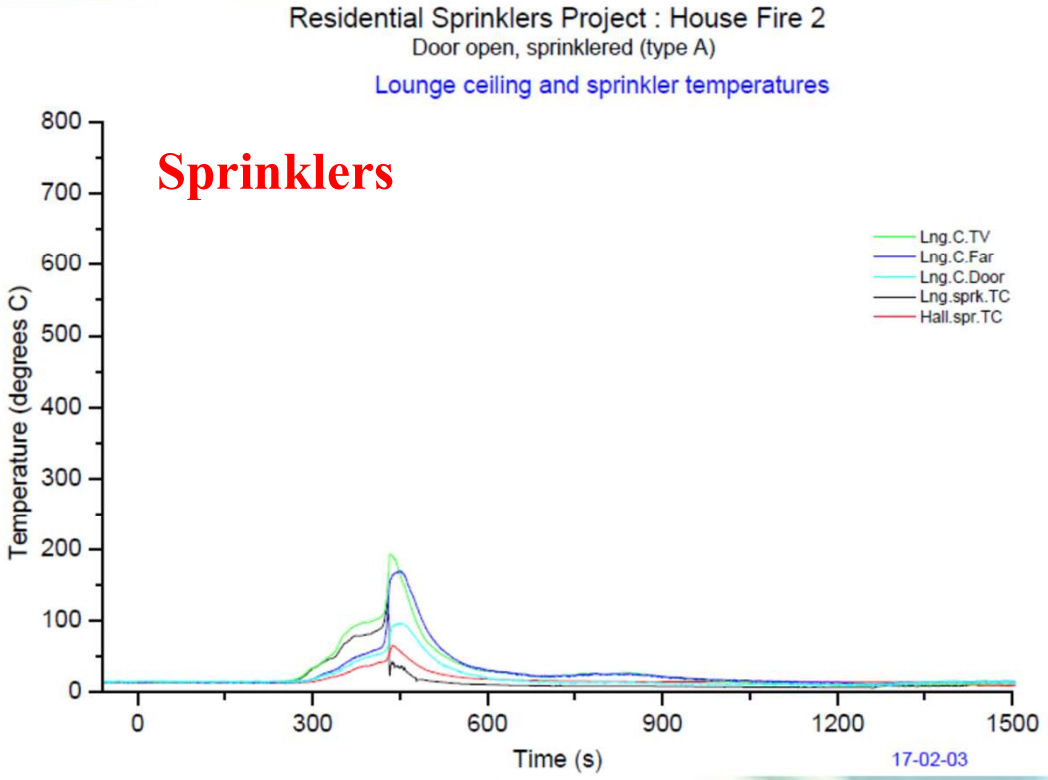
Benefits of sprinklers – temperature reduction





Source: BRE tests for British government

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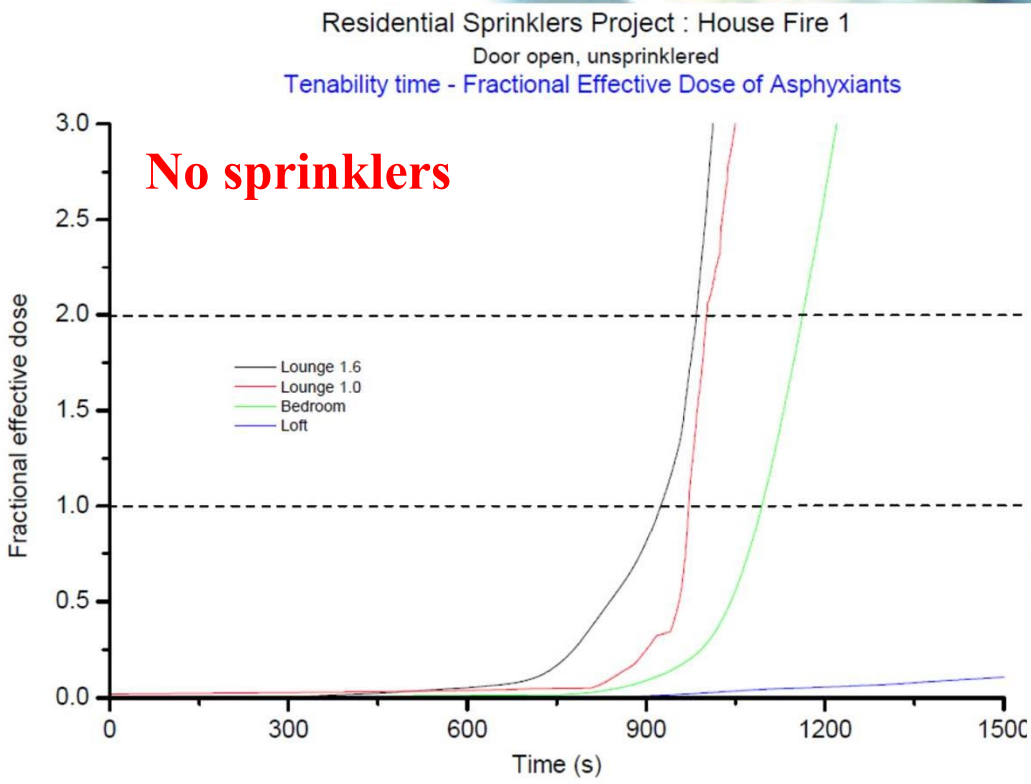
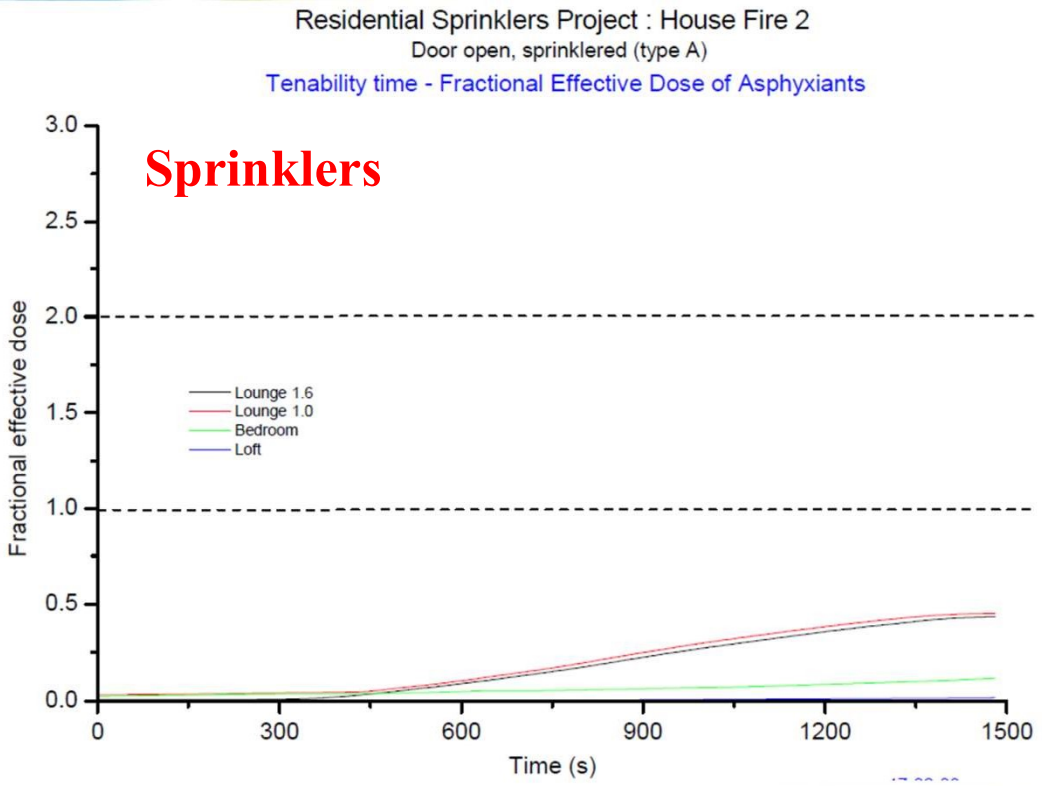
Benefits of sprinklers – less toxic gases





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Gains from designing buildings with sprinklers

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Sprinklers permit relaxations in other measures

- Temperatures limited – less fire resistance needed
- Fire growth stopped – less urgent for fire brigade to apply water so fewer hydrants and diminished FB access acceptable
- Less smoke – more time to escape so routes can be longer
- US: NFPA 101 – no need for refuges in ambulatory healthcare buildings, hotels and dormitories, apartment buildings, mercantile occupancies and business occupancies

⇒ It is cheaper to build with sprinklers!

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Fire engineering modelling with sprinklers

- Conservative: constant heat release rate after sprinkler operates
- Research: in most fires sprinklers reduce the HRR, except for fires that are large when the sprinkler operates
- Swedish government: if the HRR is < 5 MW when the sprinkler operates, assume constant HRR for 1 minute, declining to 1/3 of that HRR in the 2nd minute

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Case study – UK

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Regulatory situation

- English building regulations are short statements:

  "**B1**. The building shall be designed and constructed so that there are appropriate provisions for the early warning of fire, and appropriate means of escape in case of fire from the building to a place of safety outside the building capable of being safely and effectively used at all material times."

- They are interpreted through regulatory guidance
- Other approaches offering equivalent safety are permitted

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BS 9999:2017

Incorporating Corrigendum No. 1

BSI Standards Publication

Fire safety in the design, management and use of buildings – Code of practice

bsi.

BS 9991:2015

BSI Standards Publication

Fire safety in the design, management and use of residential buildings – Code of practice

bsi.

...making excellence a habit.™

BS 9999 and BS 9991

- Not government documents but officials attended every meeting and do not object to the guidance in these standards
- BS 9999 derives all guidance from risk profiles, comprising the occupant (awake/asleep, familiar/unfamiliar with the building) and the potential fire growth rate
- BS 9991 only considers dwellings, so the risk profile is constant and the guidance more prescriptive

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BS 9999 Occupancy characteristics

Table 2 **Occupancy characteristics**

Occupancy characteristic	Description	Examples
A	Occupants who are awake and familiar with the building	Office and industrial premises
B	Occupants who are awake and unfamiliar with the building	Shops, exhibitions, museums, leisure centres, other assembly buildings, etc.
C	Occupants who are likely to be asleep:	
Ci [A)]	• Long-term individual occupancy	Individual flats without 24 h maintenance and management control on site
Cii [A)]	• Long-term managed occupancy	Serviced flats, halls of residence, sleeping areas of boarding schools
Ciii	• Short-term occupancy	Hotels
D [B)]	Occupants receiving medical care	Hospitals, residential care facilities

[A)] Occupancy characteristics Ci and Cii are included for completeness within this table but are covered in more depth in BS 9991.

[B)] Currently occupancy characteristic D, medical care, is dealt with in other documentation and is outside the scope of this British Standard.

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BS 9999 Fire growth rates

Table 3 **Fire growth rates**

Category	Fire growth rate [A]	Fire growth parameter [B] kJ/s³	Description	Typical examples [C]
1	Slow	0.003	Evenly distributed low level fire load, small discrete packets of fuel or material of limited combustibility [D]	Reception areas, concourses (without concession outlets) and halls with limited fire load such as sports stadia and foyers
2	Medium	0.012	Evenly distributed low to mid-level fire load comprising a mix of combustible materials	Offices, lounges, classrooms, auditoria, seating areas, galleries and car parks [E]
3	Fast	0.047	Stacked combustibles (on or off racking and shelving but excluding high rack storage), some small quantities of materials other than materials of limited combustibility [D] (or where larger quantities are stored in separate fire-resisting enclosures), process, manufacturing or storage of combustible materials	Shop sales areas [F], workshops, factories and small storage buildings
4 [G]	Ultra-fast	0.188	Medium to large quantities of materials other than materials of limited combustibility [D], high racked storage, flammable liquids and gases or where rapid uncontrolled fire growth could occur	Warehousing [H], processing plants and car parks [E] utilizing a car stacker or similar method where there is no fire separation between stacked cars

BS 9999 Risk profiles

Table 4 **Risk profiles**

Occupancy characteristic (from Table 2)	Fire growth rate (from Table 3)		Risk profile
A (Occupants who are awake and familiar with the building)	1	Slow	A1
	2	Medium	A2
	3	Fast	A3
	4	Ultra-fast	A4 [A)]
B (Occupants who are awake and unfamiliar with the building)	1	Slow	B1
	2	Medium	B2
	3	Fast	B3
	4	Ultra-fast	B4 [A)]
C (Occupants who are likely to be asleep)	1	Slow	C1 [B)]
	2	Medium	C2 [B)]
	3	Fast	C3 [B), C)]
	4	Ultra-fast	C4 [A), B)]

A) These categories are unacceptable within the scope of BS 9999. Addition of an effective localized suppression system or sprinklers will reduce the fire growth rate and consequently change the category (see **6.5**).

B) Risk profile C has sub-categories (see Table 2).

C) Risk profile C3 is unacceptable under many circumstances unless special precautions are taken.

BS 9999 Variation of risk profile

6.5 Variation of risk profile

Automatic sprinkler systems can provide an efficient means of fire control within a building compartment. Such provision restricts fire growth, prevents fire spread, limits heat and smoke generation, and can extinguish the fire. This means that if sprinkler systems are installed, the fire growth rate can be reduced by one level in Table 4.

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BS 9999 Effect of reduced fire growth rate

Reduced fire alarm specification

Table 7 **Minimum level of fire detection and fire alarm system for premises**

Risk profile	Minimum acceptable detection and alarm system
A1	M
A2	M
A3	L2
A4 [A)]	Not applicable [A)]
B1 [B)]	M
B2 [B)]	M
B3 [B)]	L2
B4 [A)]	Not applicable [A)]

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BS 9999 Effect of reduced fire growth rate

Increased maximum travel distances

Table 11 **Maximum travel distance when minimum fire protection measures are provided**[A)]

Risk profile	Travel distance, in metres (m)			
	Two-way travel [B)]		One-way travel	
	Direct	Actual	Direct	Actual
A1	44	65	17	26
A2	37	55	15	22
A3	30	45	12	18
A4 [C)]	Not applicable [C)]	Not applicable [C)]	Not applicable [C)]	Not applicable [C)]
B1	40	60	16	24
B2	33	50	13	20
B3	27	40	11	16
B4 [C)]	Not applicable [C)]	Not applicable [C)]	Not applicable [C)]	Not applicable [C)]

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BS 9999 Effect of reduced fire growth rate

Smaller exit widths

Table 12 **Exit widths when minimum fire protection measures are provided**

Risk profile	Minimum exit width per person mm
A1	3.3
A2	3.6
A3	4.6
A4 [A)]	Not applicable [A)]
B1	3.6
B2	4.1
B3	6.0
B4 [A)]	Not applicable [A)]
C1	3.6
C2	4.1
C3 [A)]	6.0
C4 [A)]	Not applicable [A)]

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BS 9999 Effect of reduced fire growth rate

Narrower stairs

Table 13 **Minimum width of escape stairs for simultaneous evacuation**

Dimensions in millimetres

Risk profile	Minimum width of stair per person served over total number of floors served [A]									
	1 floor	2 floors	3 floors	4 floors	5 floors	6 floors	7 floors	8 floors	9 floors	10+ floors
A1	3.90	3.40	2.95	2.45	2.15	2.00	1.80	1.70	1.50	1.40
A2	4.50	3.80	3.25	2.75	2.45	2.20	2.00	1.90	1.70	1.60
A3	5.40	4.60	4.00	3.50	3.10	2.80	2.60	2.30	2.10	2.00
A4 [B]	—	—	—	—	—	—	—	—	—	—
B1	4.20	3.60	3.10	2.60	2.30	2.10	1.90	1.80	1.60	1.50
B2	4.80	4.00	3.40	2.90	2.60	2.30	2.10	2.00	1.80	1.70
B3	7.00	6.00	5.30	4.60	4.20	3.70	3.40	3.10	2.80	2.60
B4 [B]	—	—	—	—	—	—	—	—	—	—
C1	4.20	3.60	3.10	2.60	2.30	2.10	1.90	1.80	1.60	1.50
C2	4.80	4.00	3.40	2.90	2.60	2.30	2.10	2.00	1.80	1.70
C3 [B]	7.00	6.00	5.30	4.60	4.20	3.70	3.40	3.10	2.80	2.60
C4 [B]	—	—	—	—	—	—	—	—	—	—

NOTE The widths of stairs have been calculated on the assumption that all floors are evacuating simultaneously. This is conservative, as the occupants on the fire floor are likely to move more quickly than on the other floors.

BS 9999 Effect of reduced fire growth rate

Reduced structural fire resistance

Table 23 **Fire resistance periods for elements of structure (independent of ventilation conditions)**

Risk profile	Minimum periods of fire resistance, in minutes					
	Depth below access level of lowest basement		Height [A] of top occupied storey above access level			
	More than 10 m	Not more than 10 m	Not more than 5 m	Not more than 18 m	Not more than 30 m	More than 30 m
A1	60	60	30	60 [B]	90 [C]	120
A2	90 [C]	60	30	60	90	120
A3	Not allowed	120 [D]	60	90	90	120
B1	60	60 [B]	30	60	90 [C]	120
B2	90 [C]	60	30	60	90	120
B3	Not allowed	120 [D]	60	90	90	120
C1, C2 and C3 (not individual residential)	90 [C]	60	30	60	90 [C]	120

NOTE 15 min fire resistance may be used for open-sided car parks above ground level and with a top occupied storey not more than 18 m above access level (increased to 30 min protecting vertical means of escape).

[A] Buildings above 30 m are not permitted unless they have sprinklers in accordance with BS 5306-2 or BS EN 12845 (see **30.2.2**).

[B] 30 min if sprinklers conforming to BS EN 12845 (new systems) or BS 5306-2 (existing systems) are fitted.

[C] 60 min if sprinklers conforming to BS EN 12845 (new systems) or BS 5306-2 (existing systems) are fitted.

[D] 90 min if sprinklers conforming to BS EN 12845 (new systems) or BS 5306-2 (existing systems) are fitted.

BS 9999 Effect of reduced fire growth rate

Larger compartments

Table 28 **Maximum dimensions of compartments**

Risk profile	Single storey	Multi storey	
	Maximum floor area	Height of top floor	Maximum area of any floor
	m^2	m	m^2
A1	No limit	No limit	No limit
A2	No limit	<30	No limit
		≥30	4 000
A3	No limit	<18	14 000
		18 to 30	4 000
		≥30	Not acceptable
A4 [A)]	Not applicable [A)]	Not applicable [A)]	Not applicable [A)]
B1	No limit	No limit	No limit
B2	No limit	<18	8 000
		No limit	4 000
B3	2 000	<30	2 000
		≥30	Not acceptable
B4 [A)]	Not applicable [A)]	Not applicable [A)]	Not applicable [A)]
C1	No limit	No limit	No limit
C2	No limit	No limit	No limit
C3 [B)]	No limit	Not acceptable	Not acceptable
C4 [A)]	Not applicable [A)]	Not applicable [A)]	Not applicable [A)]

35.2 Unprotected area

35.2.1 General

The following factors should be taken into account when determining the extent of the unprotected area.

a) For life safety, any part of an external façade that has a period of fire resistance less than the appropriate level recommended in Table 22 is counted as unprotected area.

b) Included in the unprotected area calculation is any section of external wall which has the appropriate standard of fire resistance, but has a combustible material more than 1 mm thick as its external surface. However, this section of wall is counted as having an unprotected area amounting to half the actual area of the combustible surface (see Figure 44).

c) The amount of unprotected area in the façades of buildings needs to be restricted according to the distance between these façades and the relevant (or notional) boundaries (see **35.3**).

d) The following do not contribute to the extent of unprotected area:

1) any part of an external wall of a stairway in a protected shaft;

2) parts of the external wall of an uncompartmented building that are more than 30 m above mean ground level. This is relevant for large hall type structures, where the floor area at heights above 30 m is likely to be limited and the fire load is confined to the lower level. Where high rack storage is present in a building or part of a building, the areas containing the high rack storage would not qualify for this exclusion;

3) small unprotected areas in an otherwise protected façade according to the constraints shown in Figure 45.

e) Where a building is provided with automatic sprinklers, the amount of unprotected area may be doubled or the distance to the boundary for a given amount of unprotected area may be halved.

BS 9999 Gains with sprinklers

Reduced boundary distances/increased unprotected areas

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BS 9999 Gains with sprinklers

- Maximum distances from a fire main inside a building may be 60m with sprinklers instead of 45m without sprinklers
- Mechanical smoke extraction plus sprinklers is an alternative to natural venting of basements
- Can use sprinklers to avoid need for REI glazing

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Example: a mid-rise office in London

- AD B and BS 9999 require sprinklers in offices higher than 30 m

➢ This office is below that height

- Office construction costs £1,800-2,500/m^2
- Glazed facades / cladding account for 15-25% of this cost

EUROPEAN FIRE SPRINKLER NETWORK

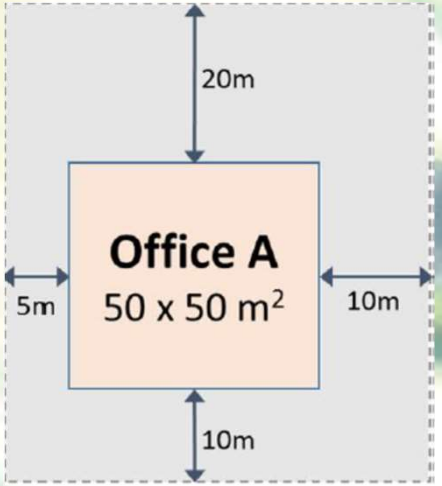
Example: a mid-rise office in London

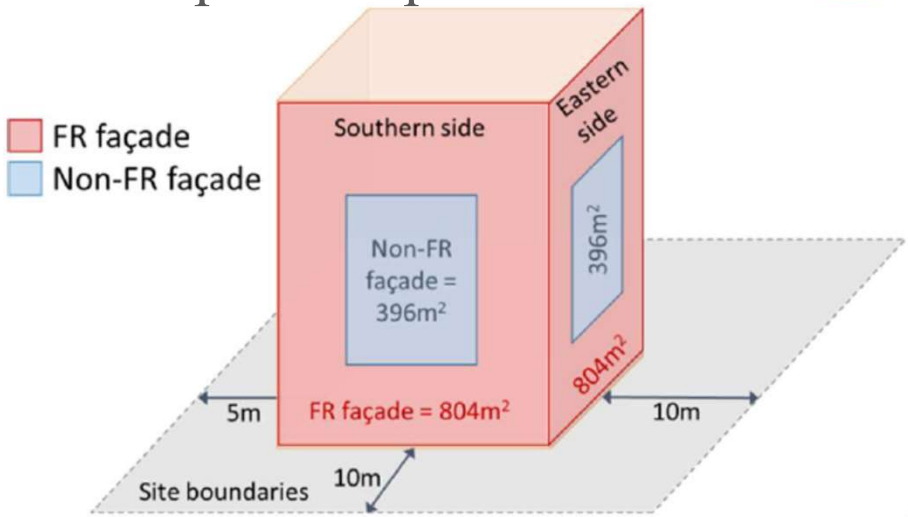
- Savings in structural fire protection costs are likely to cover most of the cost of the sprinkler system
- Increases in net internal area from narrower escape routes mean the building will offer greater rental income
- Possible savings in atrium design (atrium is desirable for Grade A offices)

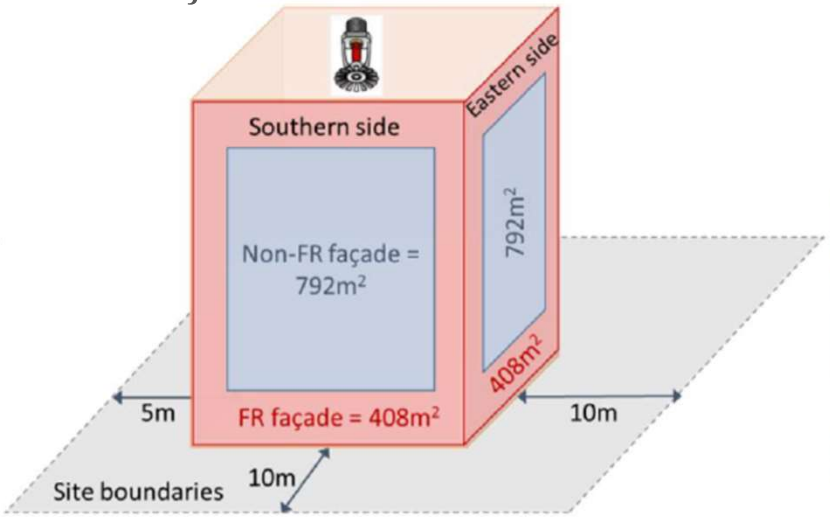
EUROPEAN FIRE SPRINKLER NETWORK

Example: a mid-rise office in London

- Office 50 m x 50 m
- Height 24 m
- Separation distances require fire resistance
- Glazed façade
- 4 staircases
- Impact of sprinklers on fire resistant façade







Impact of sprinklers on fire protection measures

BUILDING A	WITHOUT SPRINKLERS	WITH SPRINKLERS
Fire-rated façade area required	▪ Northern side (17%) = 204 m^2 ▪ Southern side (67%) = 804 m^2 ▪ Eastern side (67%) = 804 m^2 ▪ Western side (80%) = 960 m^2	▪ Northern side (0%) = 0 m^2 ▪ Southern side (34%) = 408 m^2 ▪ Eastern side (34%) = 408 m^2 ▪ Western side (60%) = 720 m^2
Stairs minimum width	1276 mm Stairs area 61.25m^2 per floor	1120 mm Stairs area 53.75m^2 per floor
Structural fire protection rating	90 minutes	60 minutes
Dry risers	3	2

EUROPEAN FIRE SPRINKLER NETWORK

Cost analysis of incorporating sprinklers

BUILDING A	WITHOUT SPRINKLERS	WITH SPRINKLERS
Sprinkler cost	-	£328,750
Façade cost	Non FR façade = 2,028m^2 x £600/m^2 = £1,216,800 90min-FR= 2,772m^2 x £2,200/m^2 = £6,098,400 Total = £7,315,200	Non FR façade= 3,264m^2 x £600/m^2 = £1,958,400 60min-FR = 1536m^2 x £1,700/m^2 = £2,611,200 Total = £4,569,600
Structural fire protection cost	90min-FR = 15,000m^2 x £44.38/m^2 = £665,700	60min-FR = 15,000m^2 x £21.57/m^2 = £323,550
Rental yields derived from changes to net internal area	-	45m^2 x £650/m^2/yr = £29,250/yr
Dry risers costs	3 x £1,500/landing x 6 floors = £27,000	2 x £1,500/landing x 6 floors = £18,000
Total costs	£8,007,900	£5,239,900 - £29,250/yr
Total cost impact of sprinklers	Capital cost impact = £2,768,000 saved by including sprinklers Rental yield = £29,250/yr greater income by including sprinklers	

Fire Sprinkler International 2018

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STOCKHOLM
Fire Sprinkler International 2018

Overview

- Two days: 13-14 June 2018
- Mornings – plenary session; afternoons: three parallel sessions
- Networking event on the first evening
- Gala dinner in Golden Hall on the second evening (optional)
- Large exhibition and many sponsors
- We expect over 300 delegates from 20 countries

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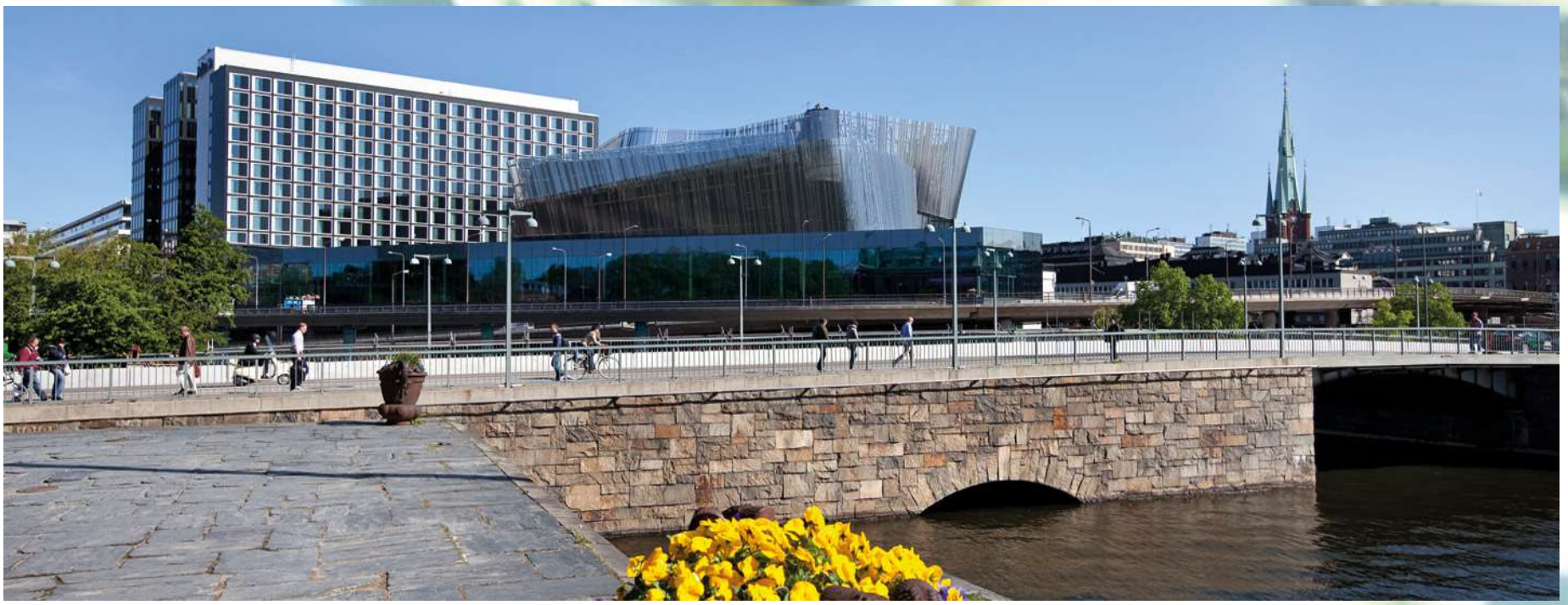
Radisson Waterfront Hotel

Fully-sprinklered!



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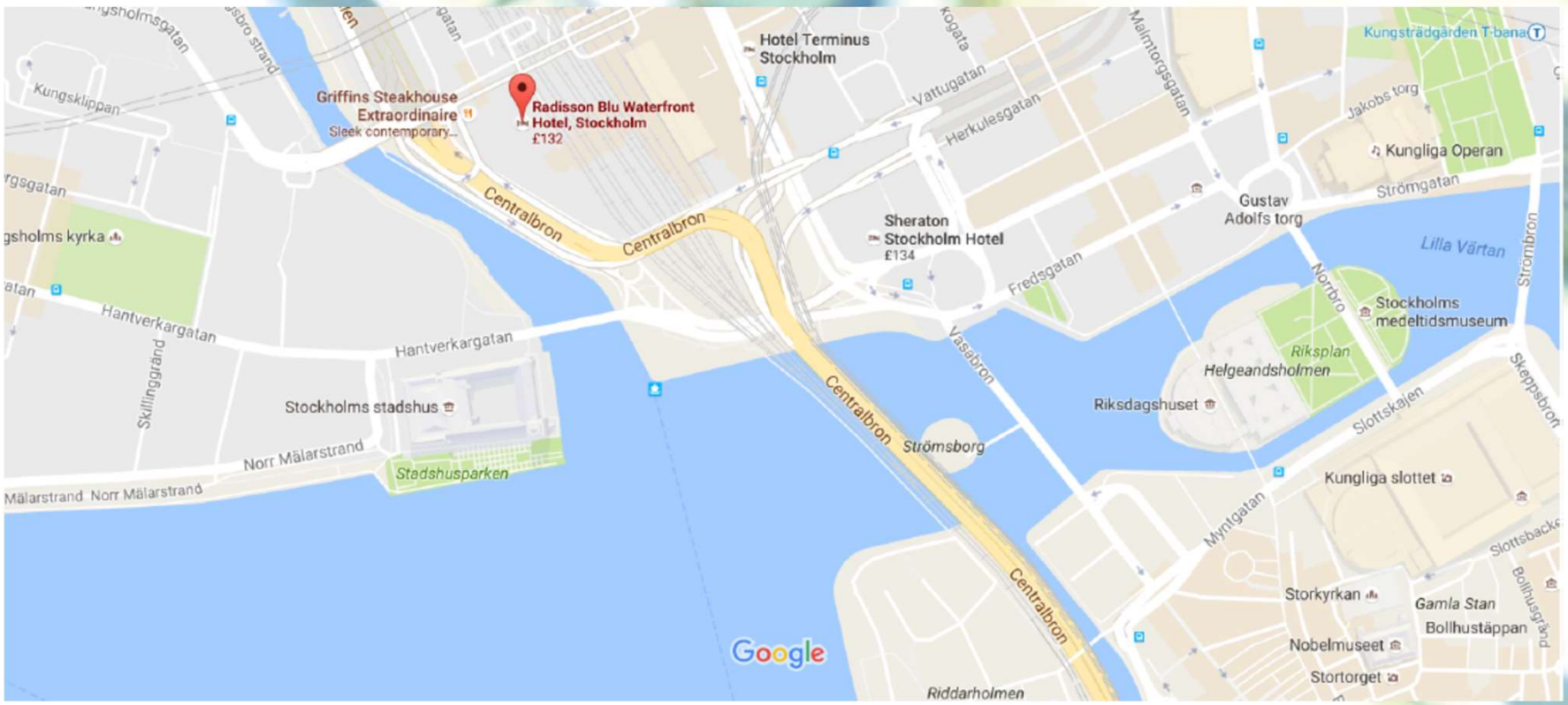
In the heart of Stockholm



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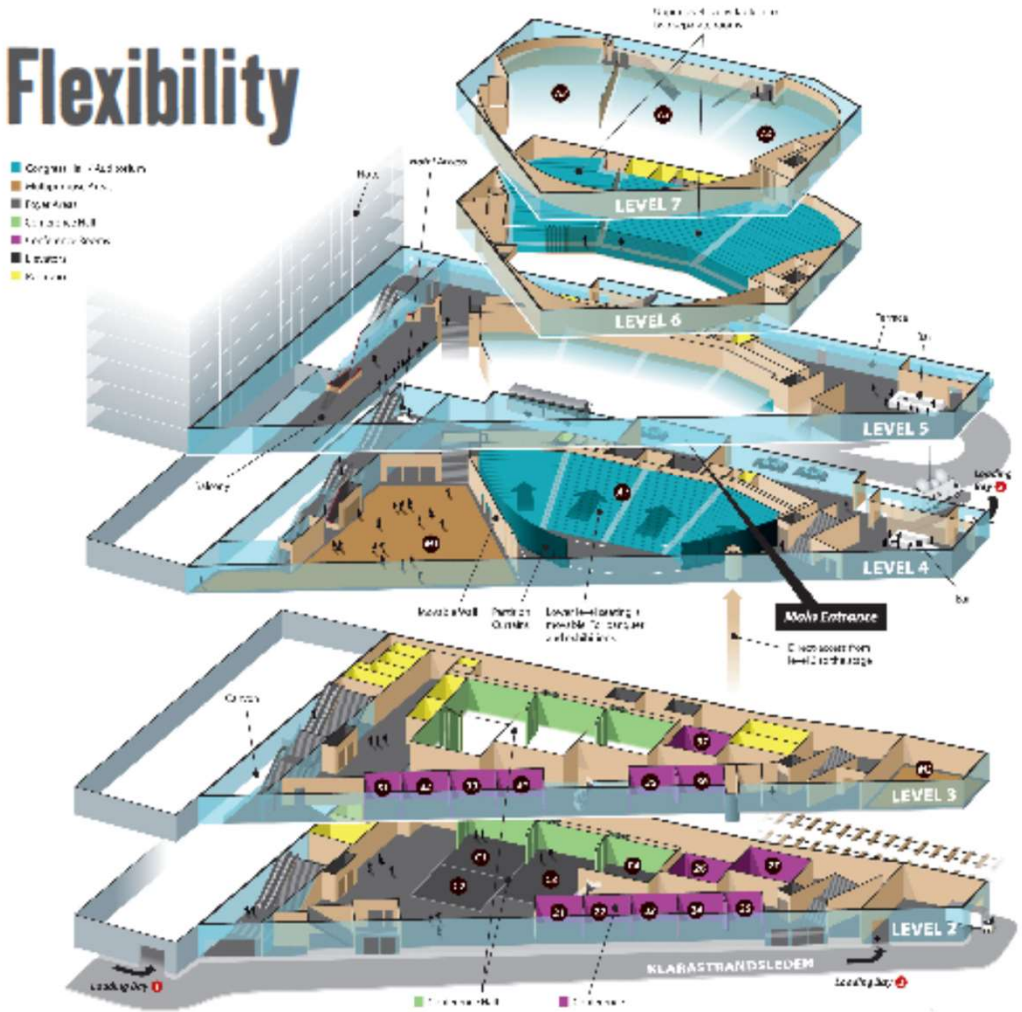

Huge space!

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14th June – Dinner in the Golden Hall

14th June – Dinner in the Golden Hall

Thank you!

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