High-rise building evacuation research

8th International Tall Building Conference

2-4 December 2024

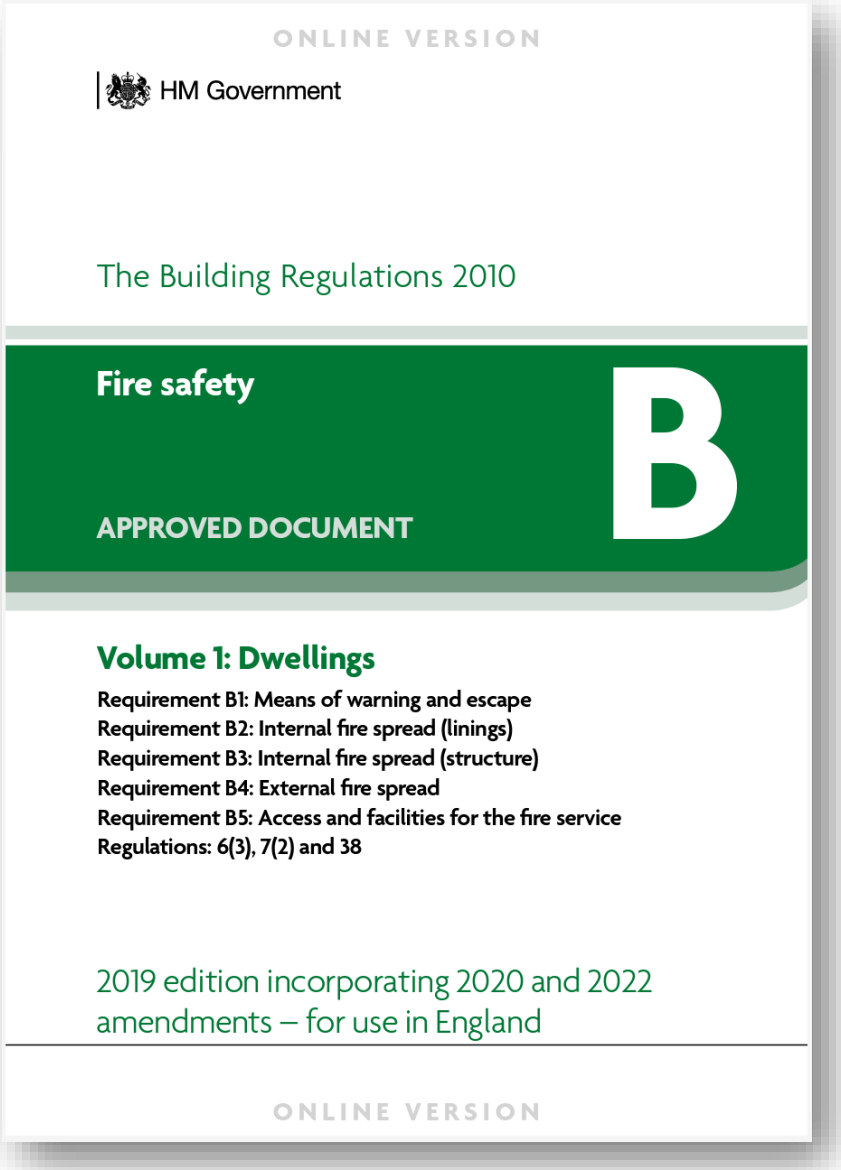
movement strategies

A GHD company

Background

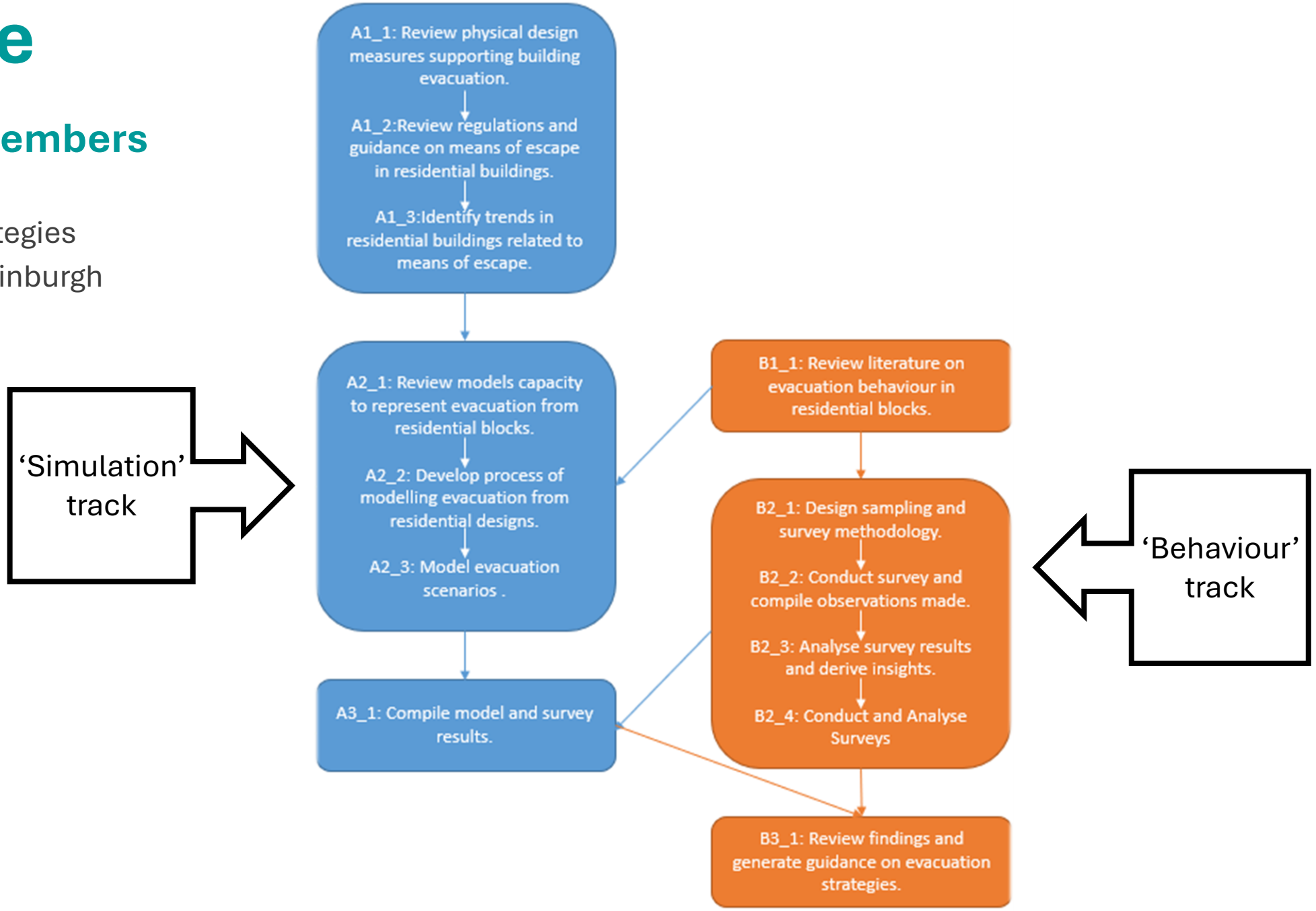
- In response to the Grenfell Tower fire, Dame Judith Hackitt conducted a review of Building Regulations and fire safety in England where she supported the need for "*...further research with the construction industry to understand who uses Approved Documents, how they are used and where they are used to influence how they should be developed in the future...*"

- Research team were commissioned to "*Evaluate evacuation strategies using a robust modelling approach considering the analysis of the effectiveness of physical design measures and human behaviour (including impact of public confidence and perceptions)*" in relation to high-rise residential buildings



Structure

- **Consortium members**
  - OFR
  - Movement Strategies
  - University of Edinburgh
  - Efectis
  - UCL

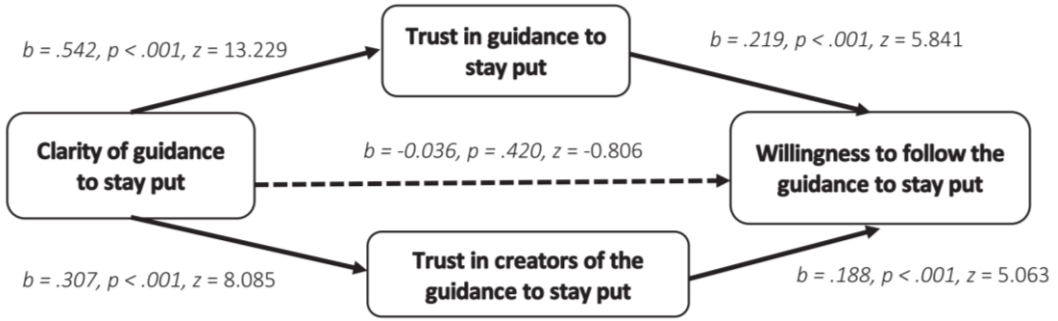


Confidence / trust

- Interviews and surveys of residents of high-rise residential buildings
- Understanding and confidence in stay put guidance

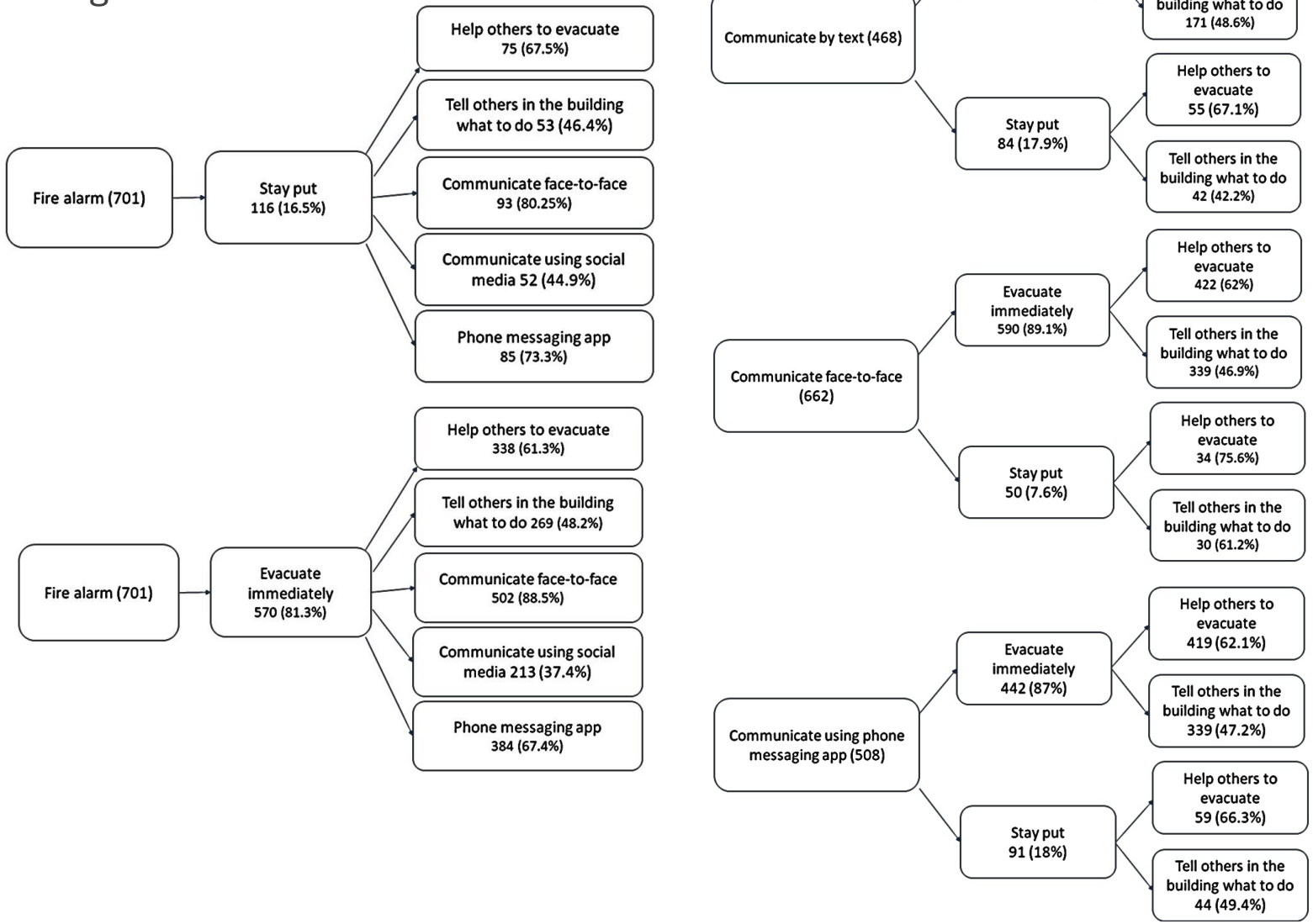
	Strongly disagree				Strongly agree
Stay put guidance	%	%	%	%	%
Clarity of the guidance	1	9.6	17.1	57.1	15.2
Trust in guidance	3.7	13.7	27	42.4	13.2
Trust in creators	3	12.5	31.5	43.1	9.9
Willingness	9.9	19.3	34.5	32.2	4.1
Trust in the building	1.9	11.4	35.9	43.9	6.9
Ability	3.8	11.8	15.4	46.2	22.8
Evacuation guidance	%	%	%	%	%
Clarity of the guidance	5.1	13.8	25.7	44	11.4
Trust in guidance	3.5	6.4	23.8	49.9	16.4
Trust in creators	2.4	8.2	30.2	44.1	15.1
Willingness	1.3	3.9	21	47.8	26
Trust in the building	2.8	11.7	26.6	47.4	11.5

- Willingness to follow the guidance to stay put found to be positively associated with trust in the guidance and trust in the creators of the guidance

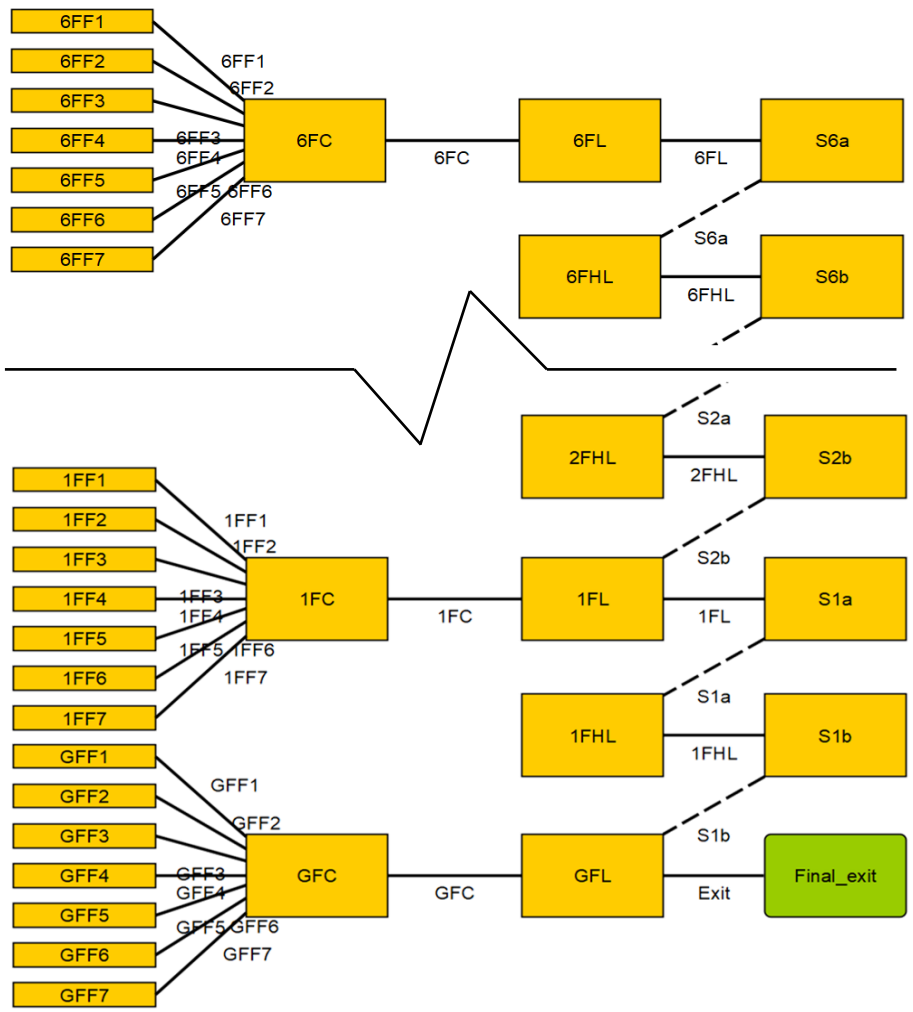


Decision making behaviour

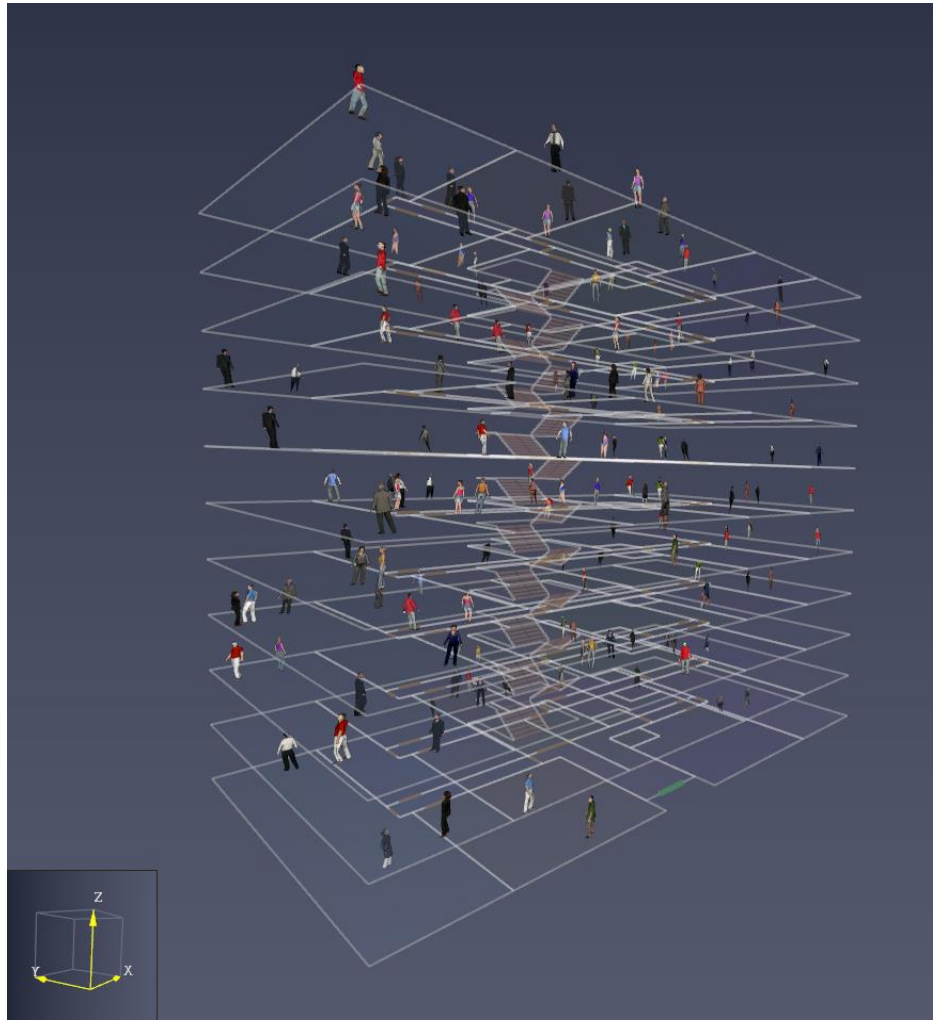
- How would residents behave in a fire in their building



Agent-based simulations

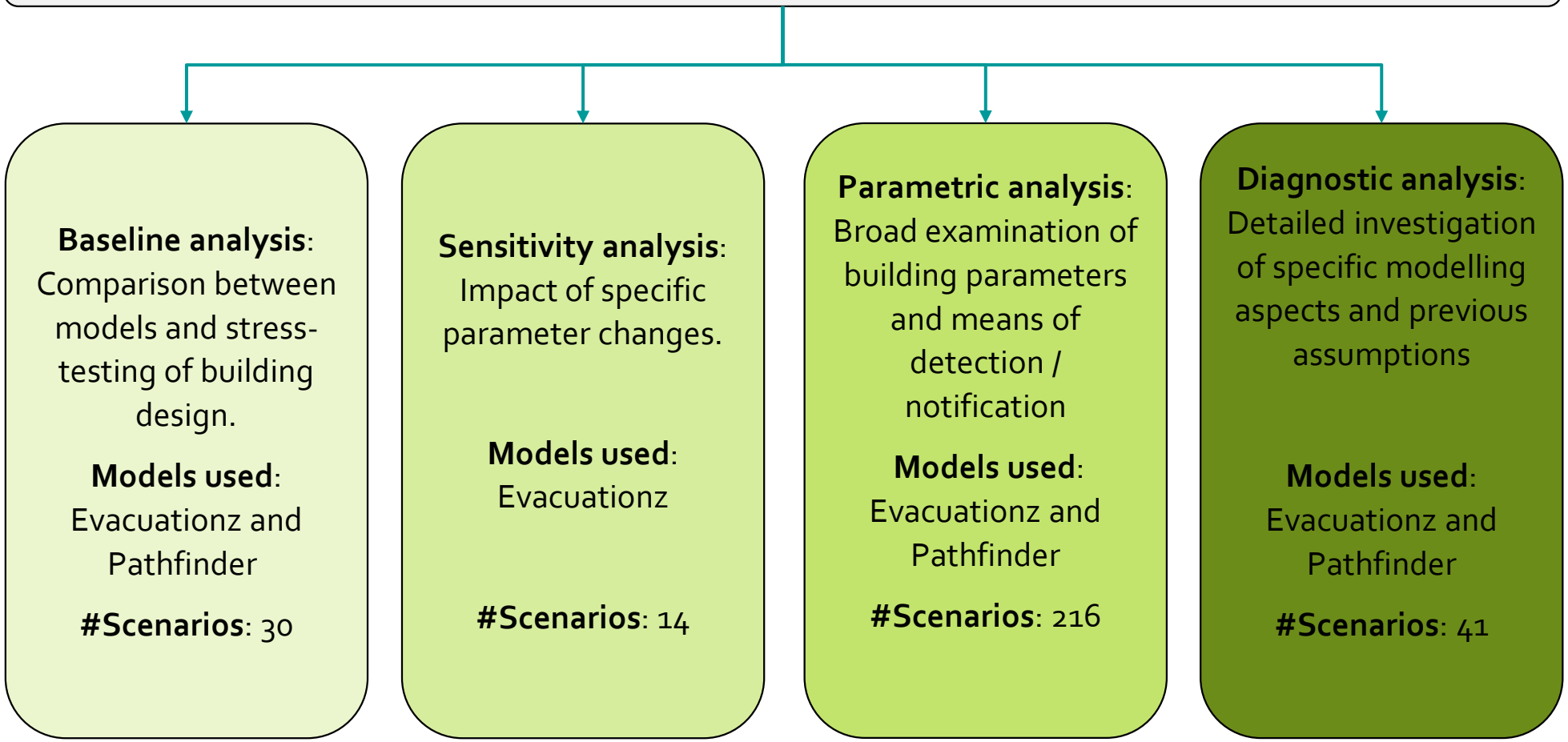


Evacuationz



Pathfinder

Structure of modelling scenarios



Just over 300 scenarios consisting of around 14 000 simulations

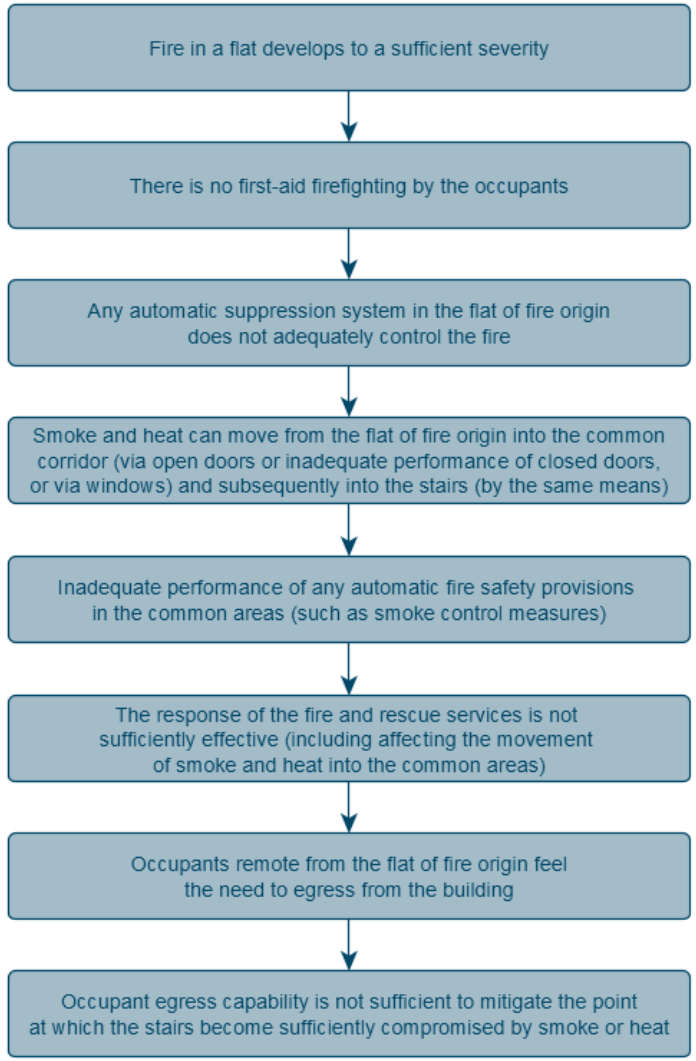
Building configurations

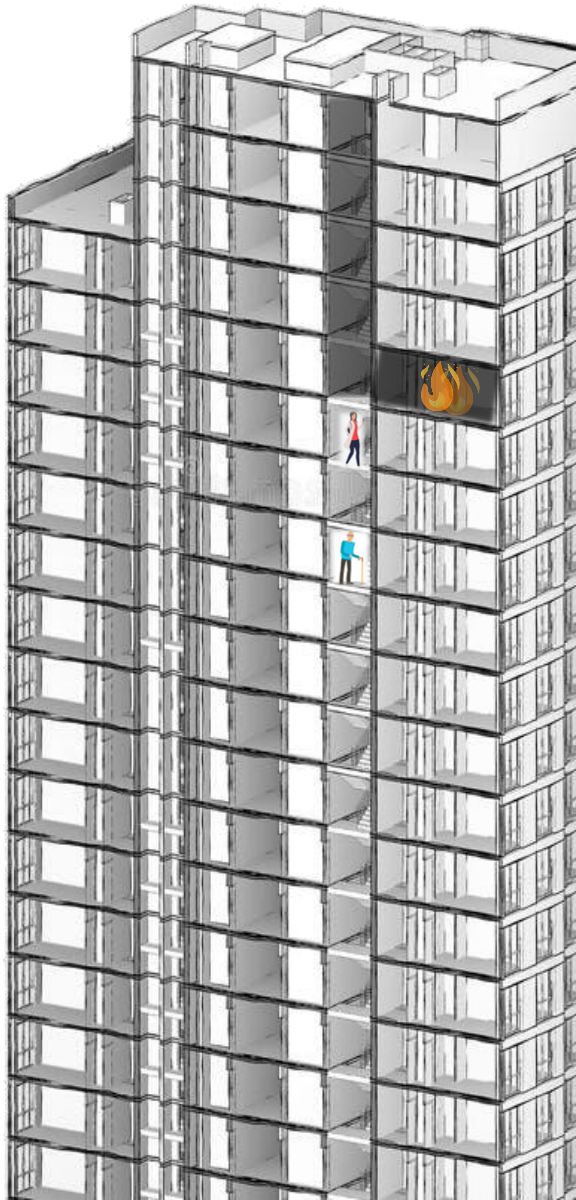
- Exemplar buildings conforming to ADB or not
  - One, two and three bedroom units
  - Heights 11 – 140 m
  - Long and short corridors
  - Lifts
  - Amenity spaces

Building height	Relevant ADB design implications	Occupant load (short or long corridor)
11 m G+4 storeys	The height at which a sprinkler system should be provided in new building construction. The minimum period of fire resistance is increased to 60 min from 30 min.	140 / 420
18 m G+6 storeys	The height at which it is recommended to include a firefighting shaft. The minimum period of fire resistance is increased to 90 min	196 / 588
30 m G+10 storeys	The minimum period of fire resistance is increased to 120 min	308 / 924
140 m G+51 storeys	The tallest proposed (in terms of number of storeys), single stair residential building that could be identified at the time	1456 / 4368

Fire and smoke

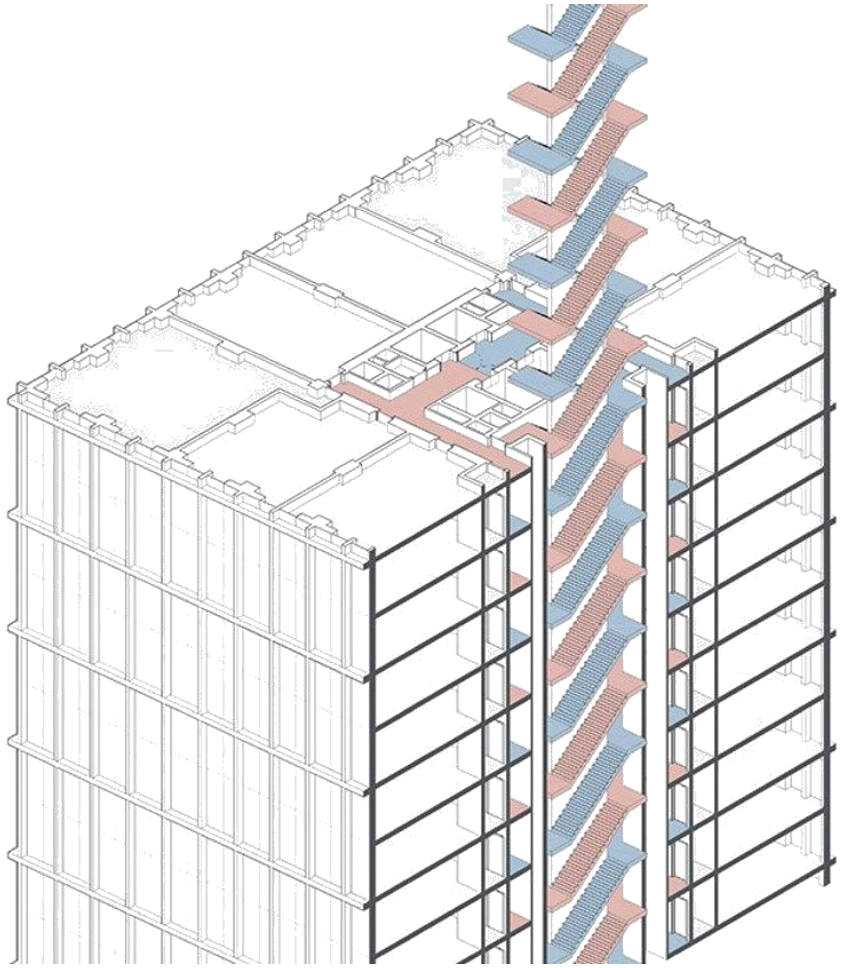
- Simplified and challenging fire and smoke movement assumptions
- Fire doors were assumed to limit the movement of smoke and fire for certain times
- Stairs immediately filled with smoke above the fire floor
- Agent movement was reduced or prevented once smoke and then fire entered an escape path





Stair provisions

- One or two stair buildings
- Varied stair width
- Assumed agents use their nearest exit route
- Agents transferred to alternate stair if the first become smoke logged



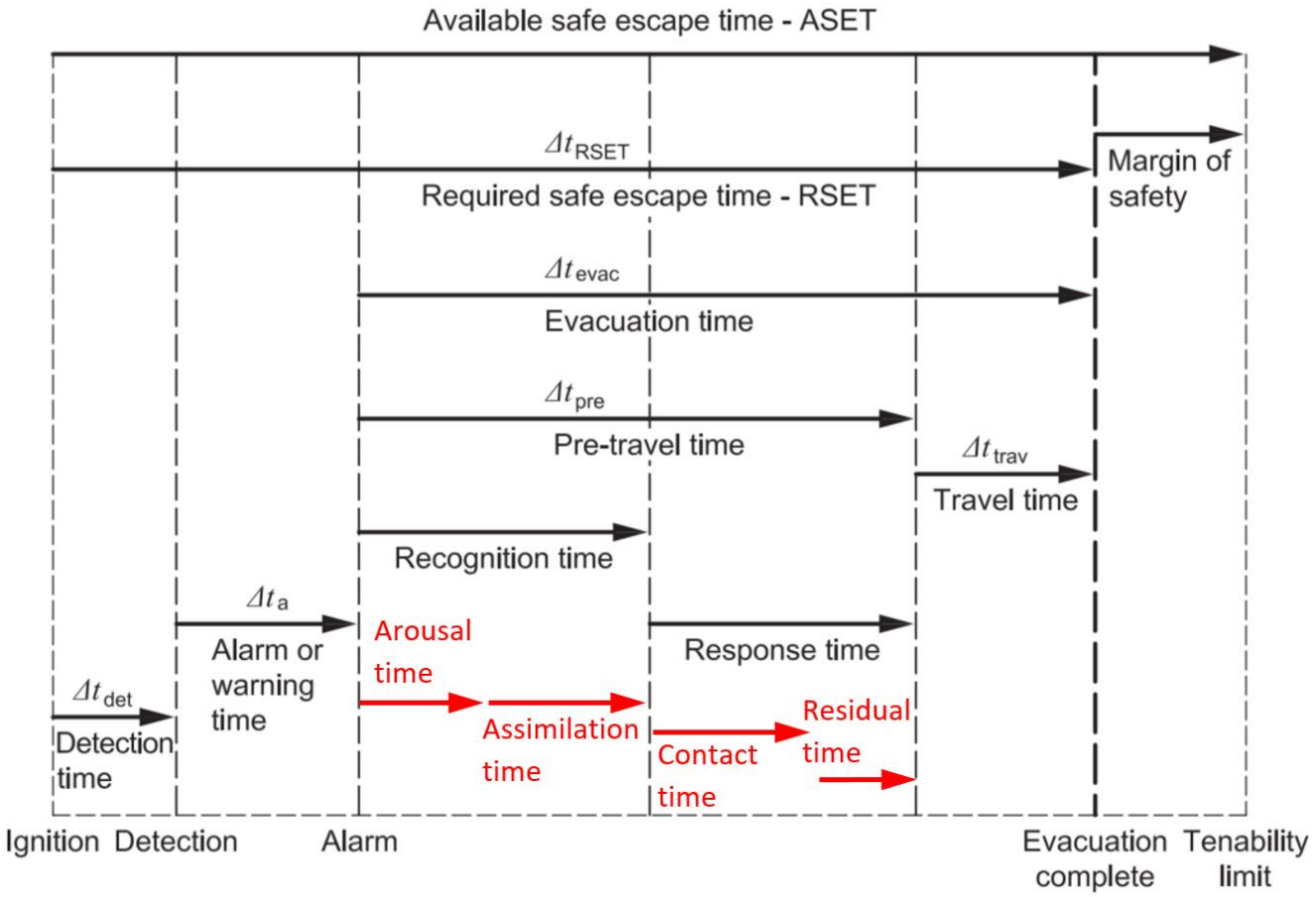
Second staircases: which way now? RIBA Journal, Oct 2023

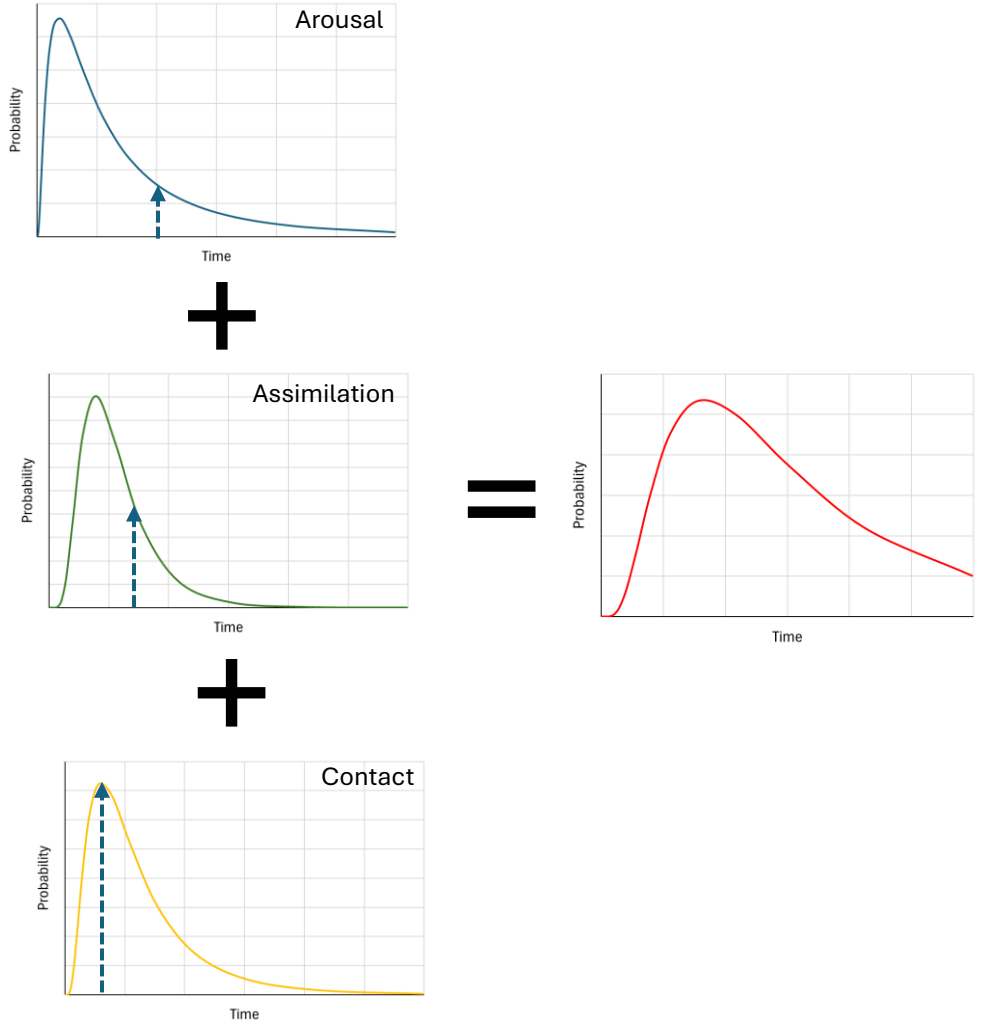
Agent Specification

Agent type		Percent of population	Horizontal speed	Stair descent speed
Non-Movement impaired person (MIP)		80%	Uniform distribution of 1.0 m/s to 1.4 m/s	Calculated through comparison of hydraulic flow method and unimpeded speed or through stair speed fraction
Movement reduced person (MRP)		15%	Uniform distribution of 0.4 m/s to 0.8 m/s	
Movement dependent person (MDP)	 	5%	Uniform distribution of 0.1 m/s to 0.5 m/s	

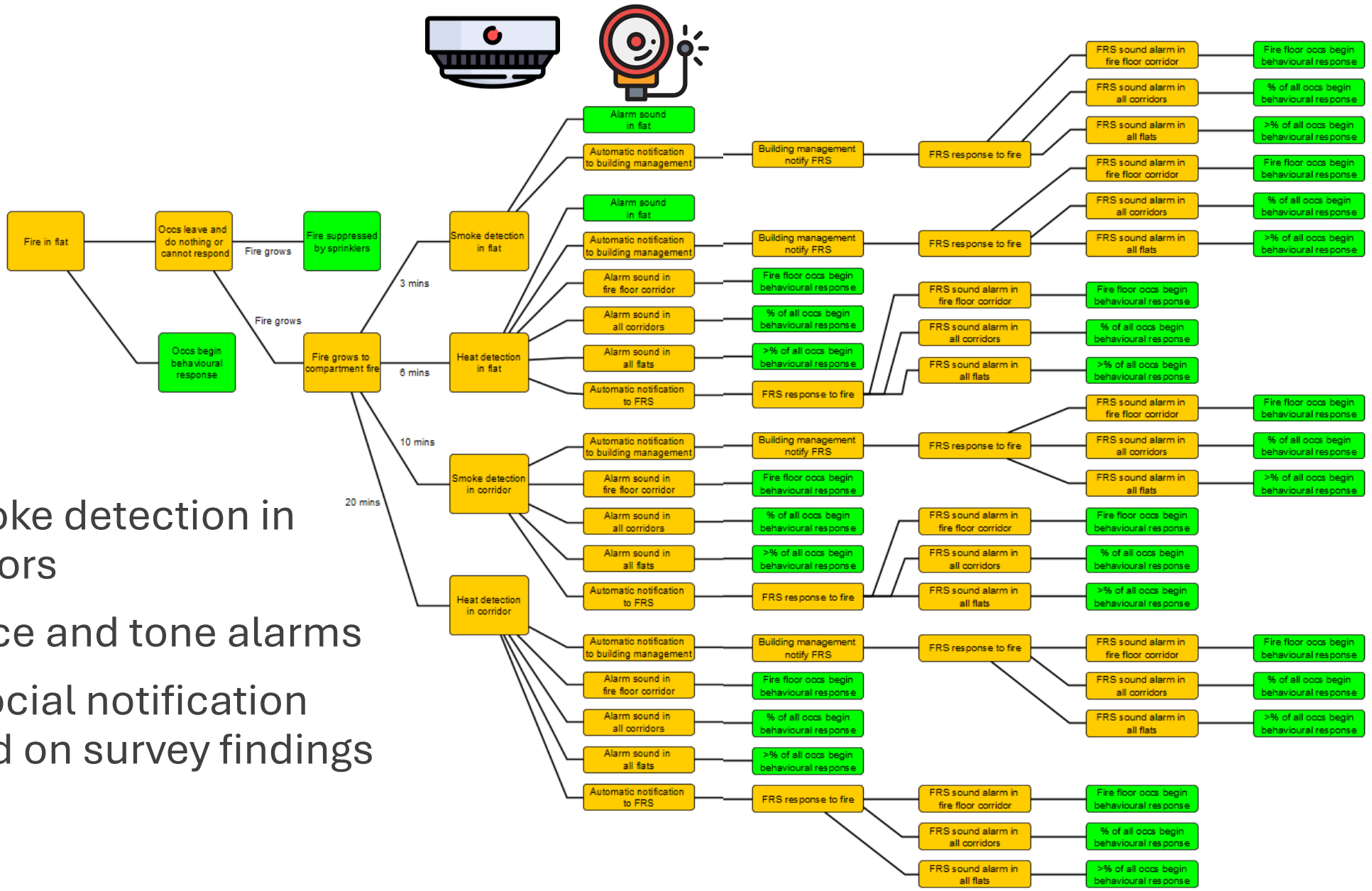
Level of impairment	State	Mean pre-evacuation (pre-travel) time (s)				
		Voice	Tone/Bell	Person	FRS	Smoke cues
Impaired	Asleep	300	600	300	240	240
	Awake	180	300	180	120	120
Unimpaired	Asleep	180	360	180	120	120
	Awake	90	180	90	60	60

Component pre-evacuation times





Detection and notification



- Heat and smoke detection in flats or corridors
- Impact of voice and tone alarms
- Inter-agent social notification alerting based on survey findings

Detection and notification

- Modern means of communication are changing the way stay put works
- Early automatic detection and alarm may impact on the number of residents that decide to evacuate rather than remain in their flat. This may place extra demand on the common escape routes
- Social media reporting may complicate evacuation strategies

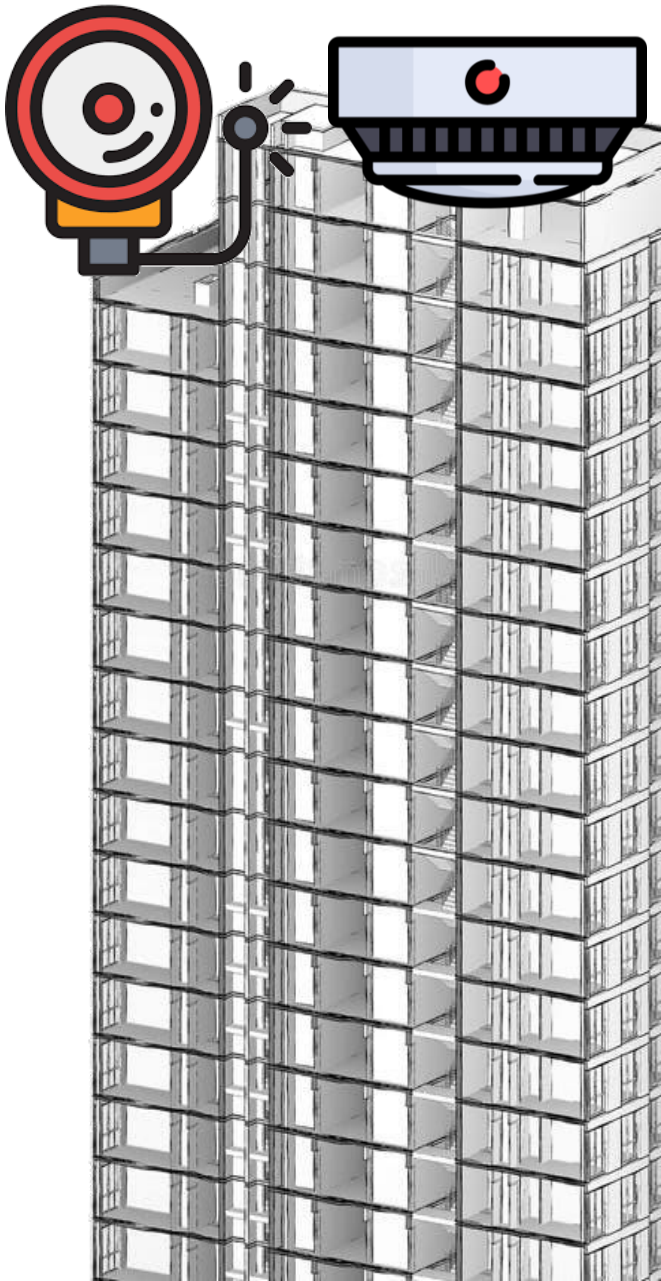
- Compared to where evacuation is initiated by social notification:

Voice alarm and corridor smoke detection	Tone alarm and flat heat detection
-15%	-20%

Voice alarm and flat heat detection		
11 m	18 m	30 m
-31%	-38%	-40%

- All notification / detection combinations trap occupants in 140 m tall building:

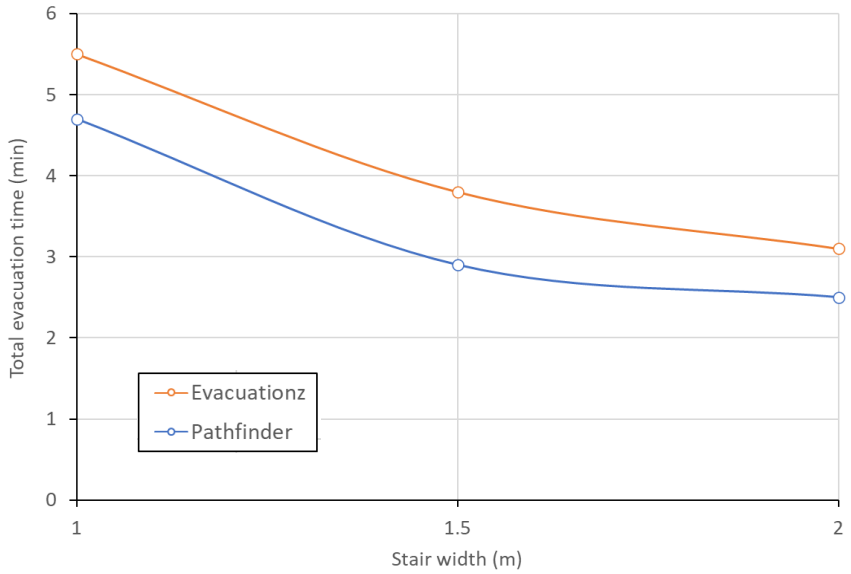
Voice alarm and flat heat detection	Social notification
517	1 200



Stair width

- Can provide an adequate means of evacuation where they act as a place of safety, and they have sufficient accommodation space

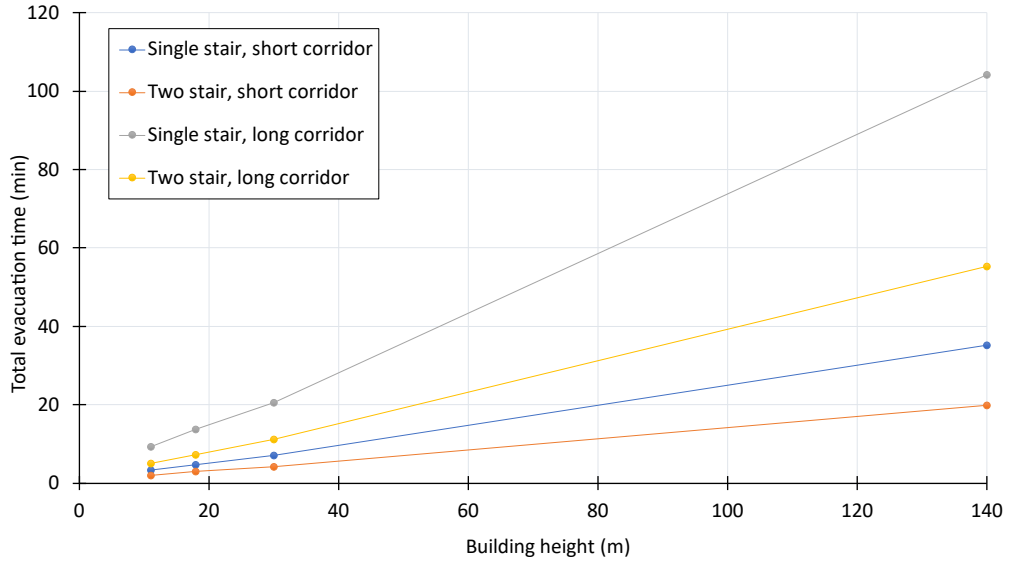
- Given extreme stair demand (no initial delays and unimpaired movement):



- Wider stairs had some benefits for specific circumstances such as where stair space may be restricted by movement impaired occupants or where amenity spaces increase occupant numbers

Multiple stairs

- Reduction in total evacuation time with a second stair:



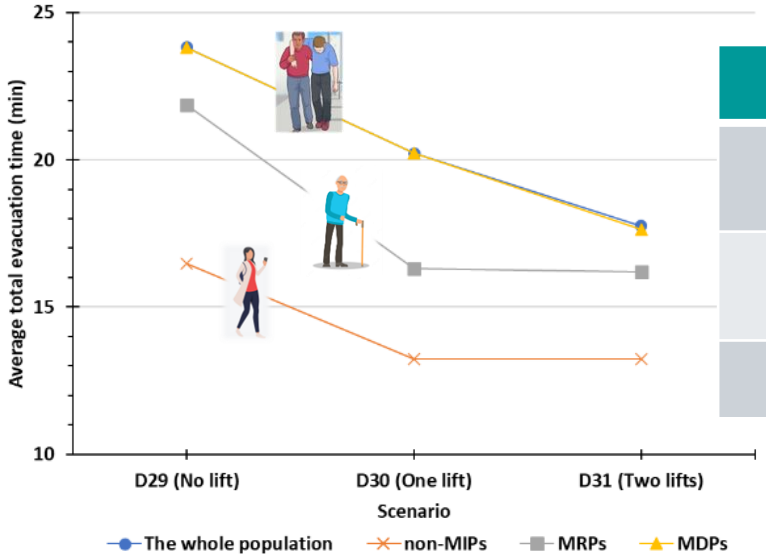
Immediate response of unimpaired agents	Representative pre-evacuation responses and movement capabilities
-36%	-8%

- For very tall buildings the benefit of a second stair may be limited where it is assumed that stairs eventually become compromised by smoke
- Number of trapped residents in the 140 m tall building:

1 stair	2 stairs
1 576	461

Lifts

- Lifts give those with impairments a means of escape while also allowing other residents to more effectively use the stairs
- Operation of lifts in simulations was relatively simple as limited by model capability and lack of applicable guidance
- Reduction in total evacuation time:



	Single lift	Two lifts
Requiring lift use (i.e. MDPs)	-16%	-24%
Those who could use stairs	-19%	-19%
Total	-15%	-23%

- Potentially they are more complex to design and manage and require planned use (e.g. who can operate them, how do they move, who should use them, training, etc.)

Outputs

- Full reports (total >500 pages) available on the .gov website
  www.gov.uk/government/publications/means-of-escape-in-residential-buildings-research
- Various papers in journals etc.
  - S. Gwynne, M. Spearpoint, A. Templeton, M. Arnott, H. Xie, C. Nash, M. Ramsden. 'Assessing the impact of changes to guidance on evacuation from fire in multi-occupancy high-rise residential buildings', Fire and Evacuation Modeling Technical Conference (FEMTC), Brno, Czechia, 12-14 September 2022
  - A. Templeton, C. Nash, M. Spearpoint, S. Gwynne, X. Hui, M. Arnott, 'Who and what is trusted in fire incidents? The role of trust in guidance and guidance creators in resident response to fire incidents in high-rise residential buildings', Safety Science, 164, 2023
  - A. Templeton, C. Nash, L. Lewis, S. Gwynne, M. Spearpoint, 'Information sharing and support among residents in response to fire incidents in highrise residential buildings', International Journal of Disaster Risk Reduction, 92, 2023
  - A. Templeton, C. Nash, M. Spearpoint, S. Gwynne, H. Xie, 'Trusted source, trusted information, trusted support: The role of trust in resident emergency response', SFPE Europe, Issue 27, 2023
  - M. Spearpoint, M. Arnott, X. Hui, S. Gwynne, A. Templeton, 'Comparative analysis of two evacuation simulation tools when applied to high-rise residential buildings', Safety Science, 2024
  - M. Spearpoint, S. Gwynne, X. Hui, A. Templeton, 'A component-based approach to stochastic pre-evacuation delays', Presented at the 4th European Symposium on Fire Safety Science, ESFSS 2024