EVACUATION – TIME TO GO

BOABC CONFERENCE – MAY 25, 2026

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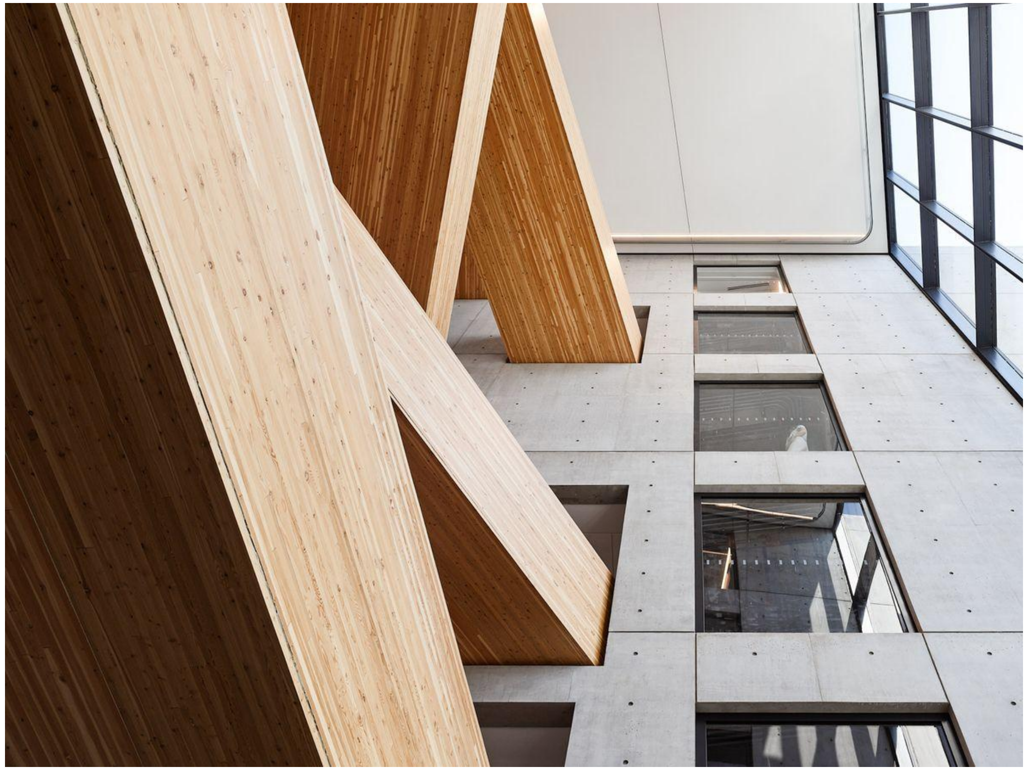
GHL is a consulting firm specializing in fire engineering and Building Code consulting, with a focus on fire safety regulations in Division B, Parts 3 and 9 of the Building Code. Since 1992, we've provided expert guidance and creative solutions for projects ranging from small buildings to large, complex, mixed-use developments. Our team is known for delivering alternate solutions to construction challenges not directly addressed by Codes or Standards. Examples of our work can be found at www.ghl.ca.



As part of J.S. Held, GHL offers clients enhanced access to a global network of technical experts and specialized services. Our expanded team brings deeper expertise in materials science, forensic analysis, and infrastructure safety—ensuring that projects benefit from innovative, compliant, and cost-effective solutions. While GHL's commitment to responsive, collaborative service remains unchanged, our clients now gain the added value of broader resources and multidisciplinary insight to navigate evolving regulatory and design challenges with confidence.

Examples of our work can be found at www.ghl.ca.

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This presentation is intended to be presented by GHL and these slides must not be considered complete or exhaustive.

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- BASc, University of Waterloo, Chemical Engineering
- M Eng, University of Waterloo, Fire Safety Engineering

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  - Transportation / Transit
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  - Industrial
  - Laboratories
  - Residential (high-rise/mid-rise)
  - Healthcare

- Performance-Based Design and Alternative Solutions
  - Spatial Separation / Building-to-Building Fire Spread
  - Radiation Exposure Hazard
  - Evacuation Modelling / Pedestrian Flow Modelling
  - Fire Modelling (Zone / CFD)

GHL's (a Part of J.S. Held) Role

- To know and understand the Building Code.
- To know and understand the fire science behind the Building Code.
- To assist in correct application of the Building Code.
- To develop new solutions based on fire science to enable creative safe buildings.
- To understand the needs of the client and of the Authorities and Emergency Responders.

GHL’s (a Part of J.S. Held) Team

- 16 Engineers
- 3 Architects
- 15 Certified Professionals
- 2 former Building Officials
- 1 Building Code Qualified (BCQ)
- 1 Rick Hansen Foundation Accessibility Certification (RHFAC) Professional

In addition to the expanded J. S Held team bringing expertise in several disciplines.

Building Code Committee Work

- CP Committee (Dean Skalski)
- BC Building Code Appeal Board (Frankie Victor)
- BC Building Code Interpretation Committee (Dean Skalski)
- BOABC Exam Development Committee (Wendy Morrison)
- Canadian Board for Harmonized Construction Code (Claire Yuan, Kevin To, Andrew Harmsworth)

Agenda and Summary

Overview of evacuation concepts, specifically focusing on geometry of rooms, e.g., travel distance, ceiling height, exit capacity, etc in the Building Code, and how this relates to real-life occupant behavior and movement. Additionally, other non-geometrical aspects of evacuation will be discussed.

The presentation will provide examples for potential alternative solutions based on egress hand calculations and egress simulations.

PRINCIPLES OF EVACUATION

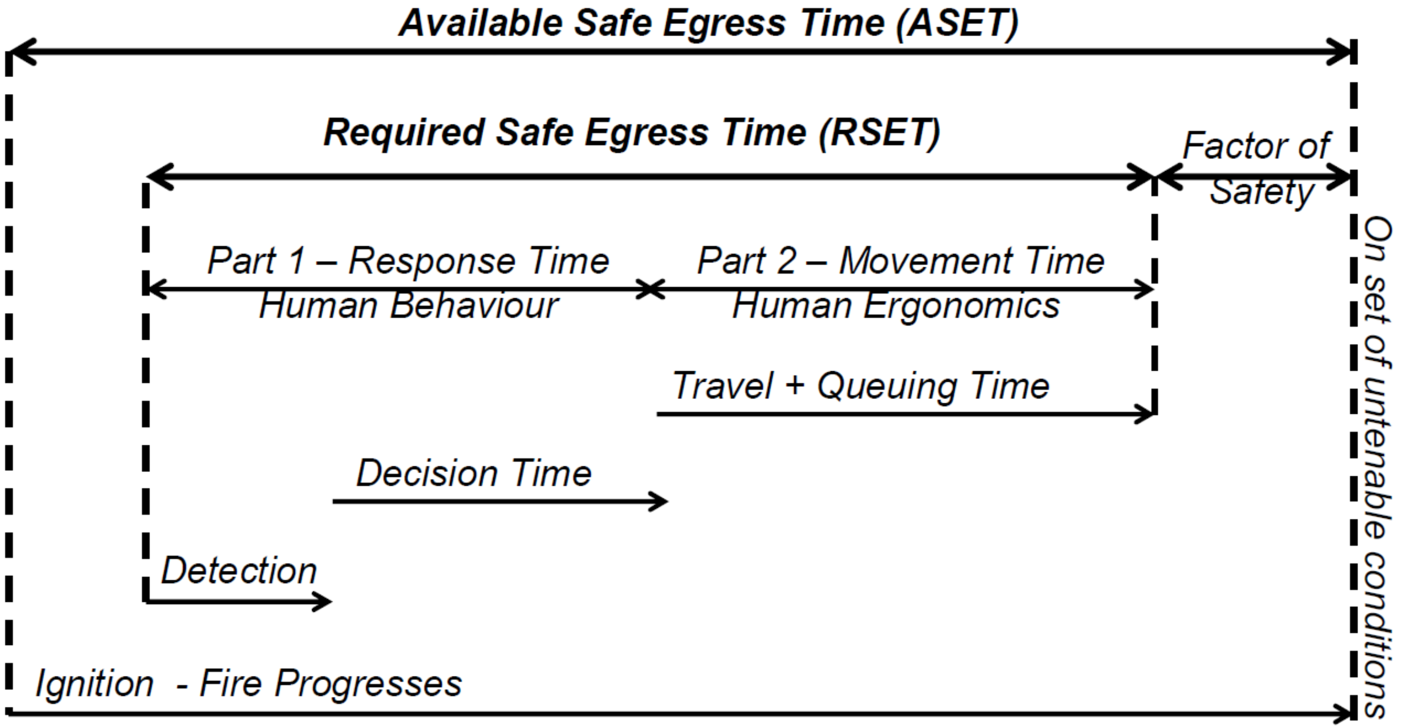
EVACUATION

- Occupant safety in a fire incident can be achieved by:

  - Protecting occupants in place, or
  - Moving occupants to a place of safety (Evacuation)

- Occupants may be exposed to fire / smoke during an evacuation; what is acceptable?

ACCEPTABLE EVACUATION



ASET: The time it takes a compartment to reach untenable conditions such that evacuation is delayed or impeded.

RSET: The time it takes for occupants to move to a place of safety.

ELEMENTS OF EVACUATION

- RSET consists of the following components:
  - Alarm and Detection Time: Time for fire to be detected and occupants to be notified of fire.
  - Pre-movement Time: Time for occupants to start moving towards occupants, i.e., occupants gathering belongs, gathering friends, ignoring alarm, waiting for instructions, etc.
  - Movement Time: Time for occupants to reach pass through exits.
    - Consists of Travel Time to exits and Queuing Time at exits.

The following factors affect the above components:

- Geometry – dimensional and spatial features of the space.
- Demographics – characteristics of occupants; mobility.
- Psychology – potential occupant behaviour in fires.
- Tenability – visibility, breathability, toxicity, heat.

The following presentation focuses on Geometry, which primarily affects the movement time component of evacuation.

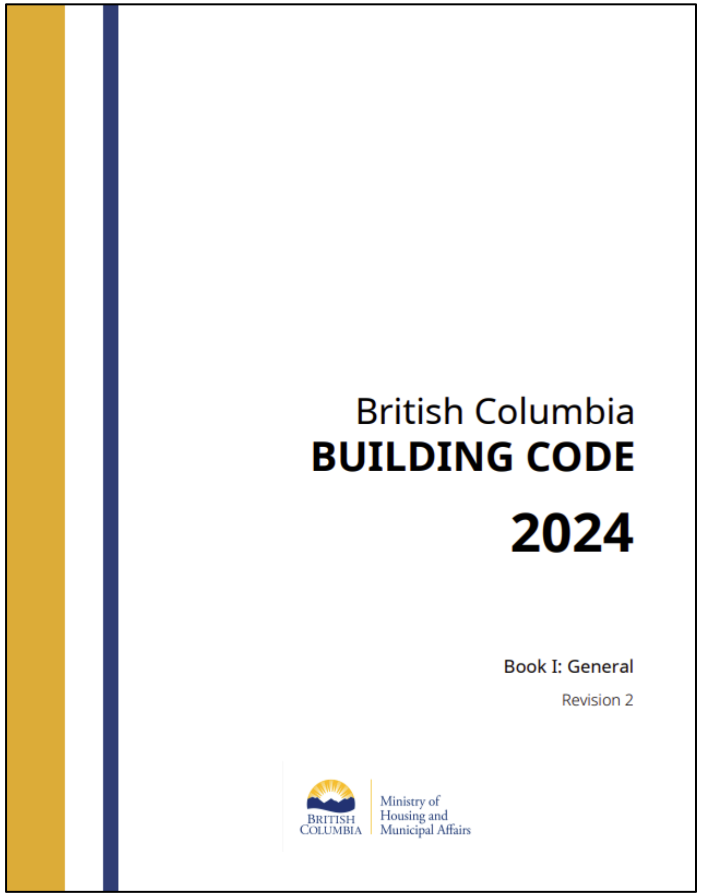
BUILDING CODE'S APPROACH TO EVACUATION

BUILDING CODE APPROACH TO RISK

Buildings are subject to risk:

- Code compliance ≠ no risk.
- Code compliance = risks at an acceptable level.

Compliance with the Building Code does not eliminate risk; compliance limits risk to an acceptable level.



BUILDING CODE APPROACH TO EVACUATION

The following evacuation / egress factors are addressed by the Building Code:

- Number of Exits / Egress Doors
- Exit / Egress Widths (i.e., Capacity)
- Travel Distance to an Exit / Egress Door
- Ceiling Height

Geometry (affects Movement Time)

- Presence of Fire Detection and Notification to Occupants
- Presence of Automatic Fire Suppression System

Factors affecting Pre-Movement Time and ASET

“DEFAULT BUILDING” PER THE BUILDING CODE

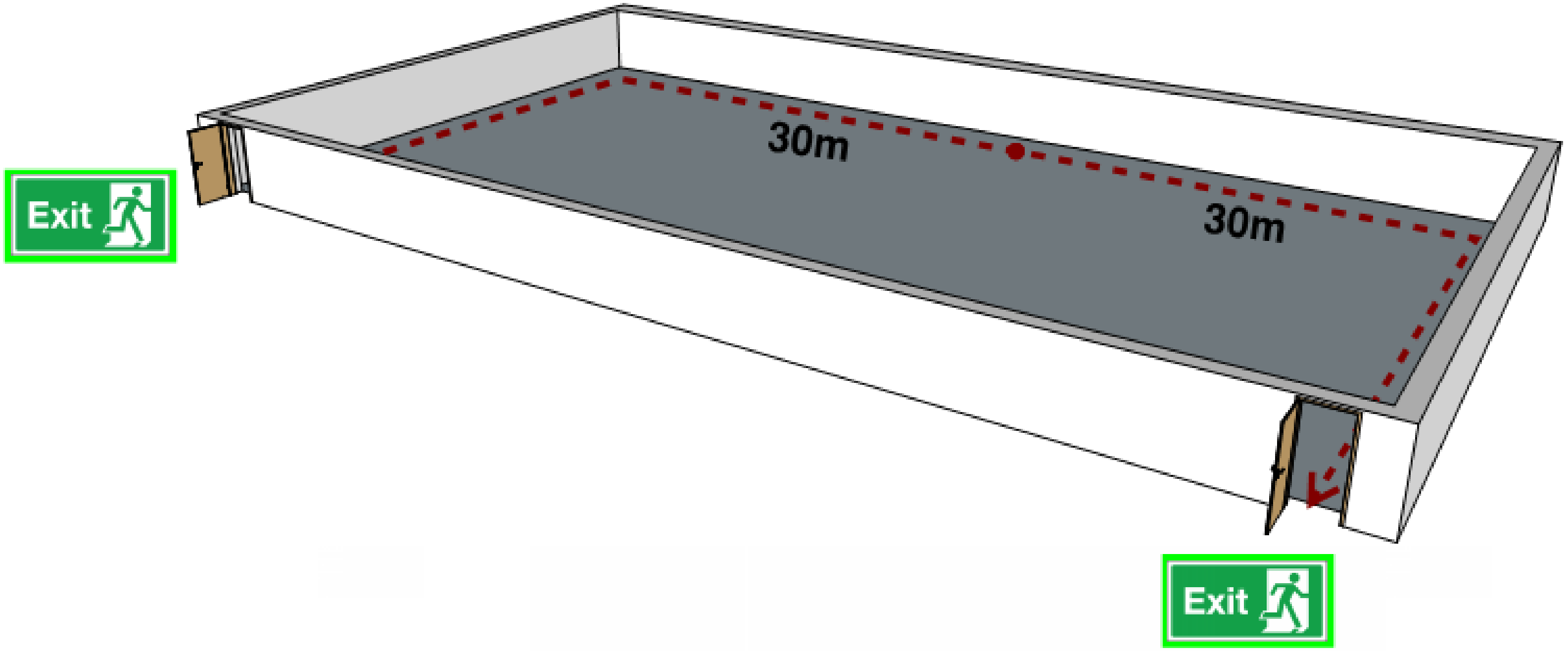
The Building Code’s “default building” has:

- Maximum Travel Distance
- Maximum Occupant Load relative to Exit Capacity (i.e., Minimum Exit Capacity)
- Minimum Ceiling Height
- Up to 6m dead-ends in public corridors

This defines the minimum level of performance of the Division B acceptable solution.

"DEFAULT BUILDING" PER THE BUILDING CODE

Example: 30m travel distance with 2 exits and 2.05m ceiling height.



GEOMETRY AND EVACUATION

GEOMETRY- TRAVEL DISTANCE

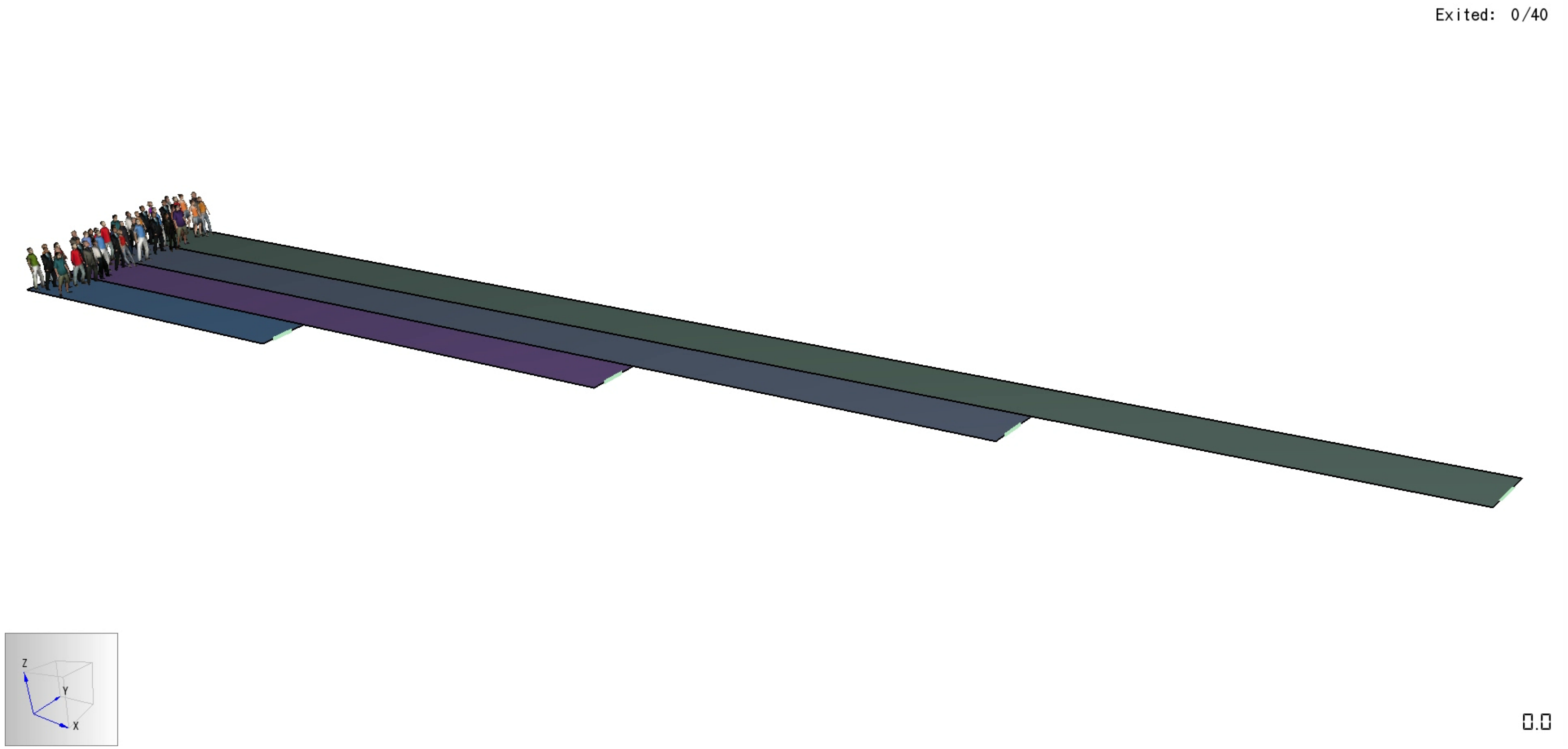
Travel distance translates to the time required to walk to an exit or egress door (Travel Time).

- If all else is equal, increasing travel distance simply increases the total time to evacuate.

The Building Code baseline is an unsprinklered floor area with a 30m travel distance to an exit.

- Sprinkler → + 15m = 45m
- Perimeter exits 60m apart → unlimited travel distance
- Public corridor → measure from suite door to exit instead of from within suite
- “Mall” corridor → + 75m = 105m (50% of occupants)

GEOMETRY- TRAVEL DISTANCE



Pathfinder is an agent-based emergency egress simulator developed by Thunderhead Engineering Inc. It utilizes the floor layout, occupant load and predictable elements of occupant behaviour as input to simulate the movement time. The simulator has been well validated through comparison to hand calculations, real life experiments and other software.

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GEOMETRY- EXIT CAPACITY

Exit capacity (width of exits) translates to time to pass through an exit (e.g., corridor, door, or stair), i.e., Queuing Time.

- If all else is equal, increasing the exit width decreases the total time to evacuate.

Occupant load also determines the Queuing Time.

- A higher occupant load results in a greater queuing time.

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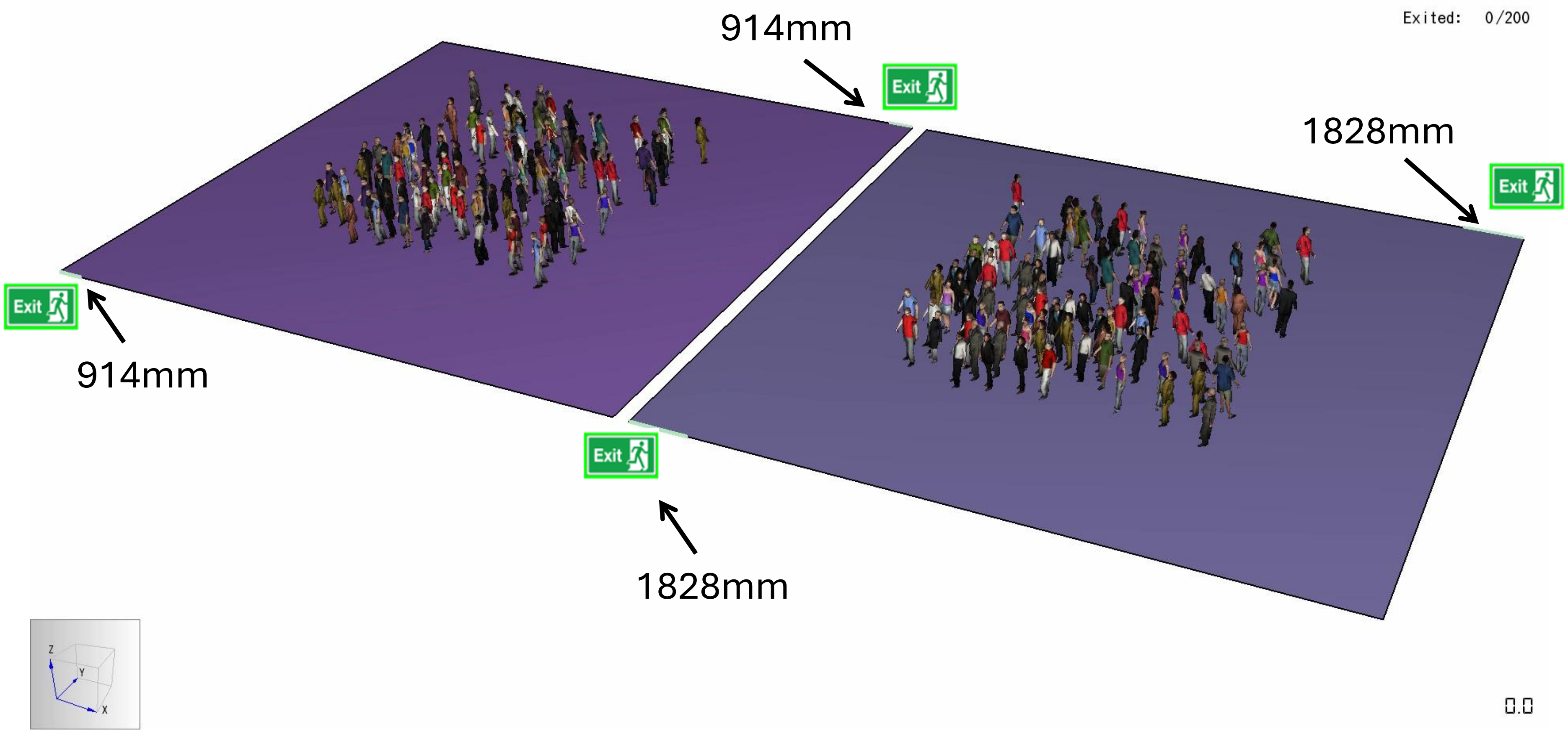
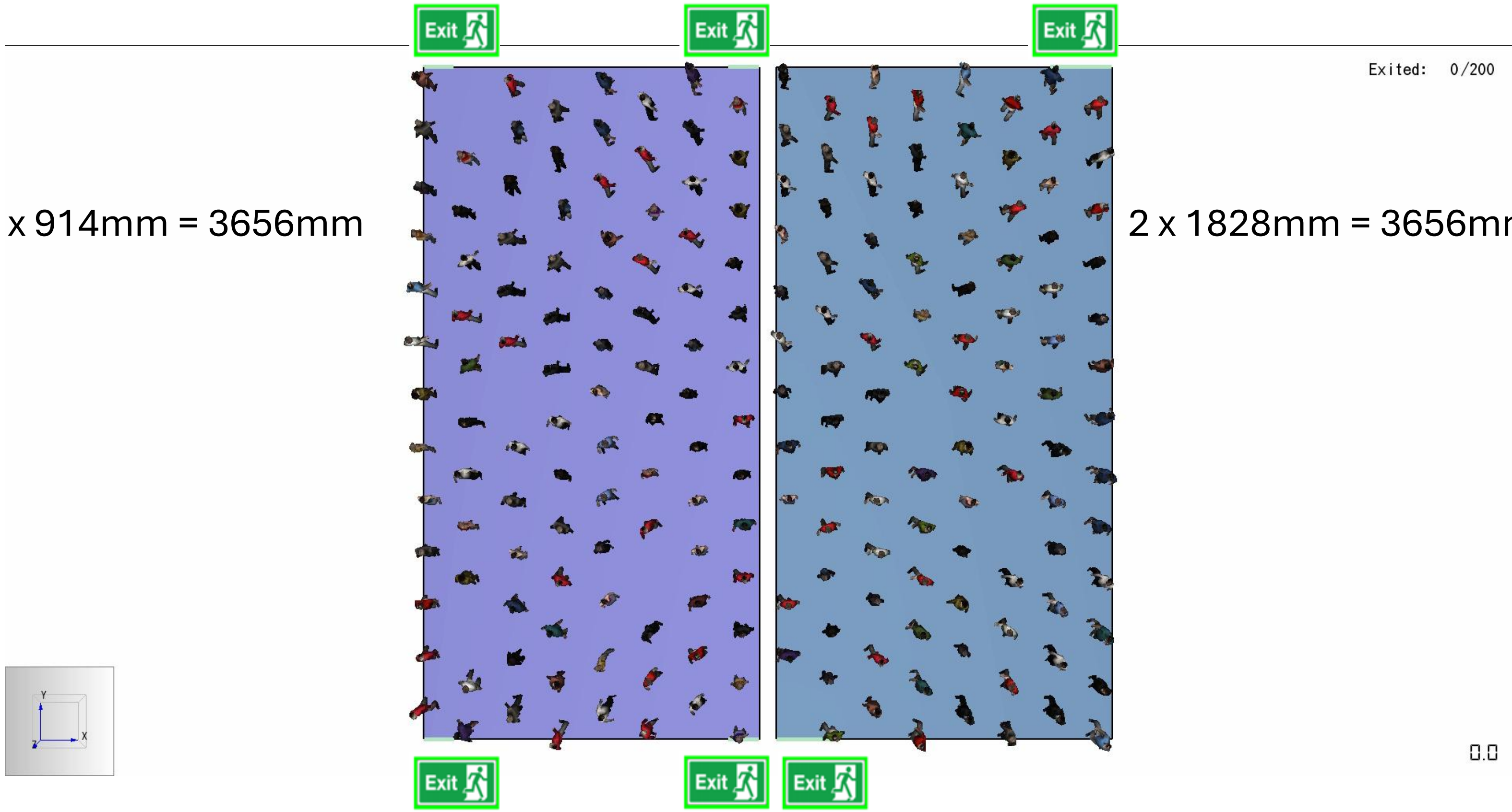
GEOMETRY- EXIT CAPACITY



Same floor area, same occupant load, however, one room has an increased exit capacity resulting in a decreased Queuing Time and Evacuation Time.

GEOMETRY- NUMBER OF EXITS

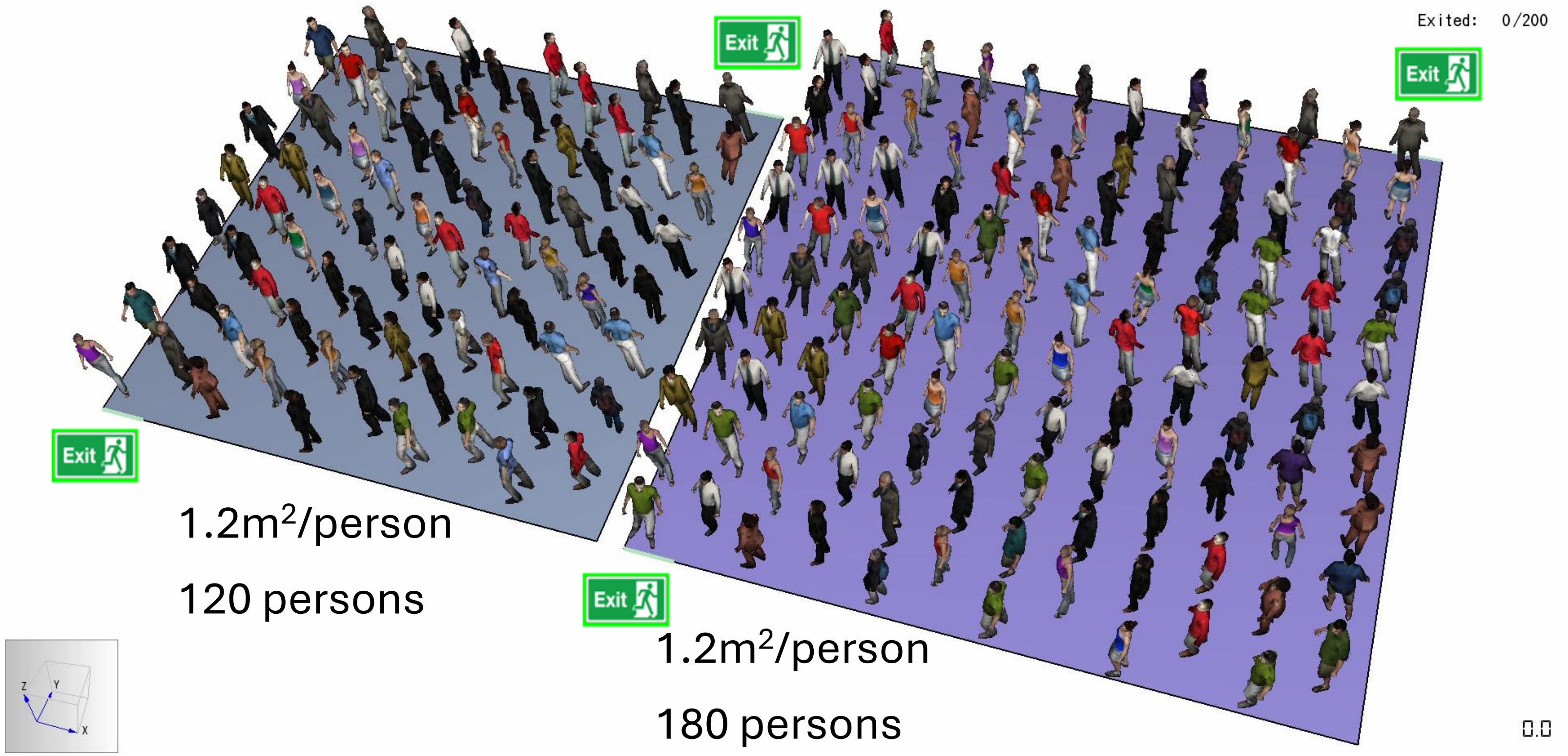
4 x 914mm = 3656mm



2 x 1828mm = 3656mm

Increasing the number of exits without increasing the aggregate exit width does not have a material impact on evacuation time (assuming occupants are evenly distributed).

GEOMETRY- EXIT CAPACITY (OCCUPANT LOAD)



Same floor area, same exit capacity / number of exits, however, one room has an increased occupant load resulting in an increased Queuing Time and Evacuation Time.

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GEOMETRY-CONFIGURATION OF EXITS: PINCH POINTS AND OBSTRUCTIONS

Elements that hinder egress by creating pinch points or reducing capacity of access to exit:

- Vestibules at exits
- Use of entry for ticket collecting, security, displays
- Fare gates and turnstiles (e.g., transit stations)
- Retail anti-theft equipment
- Etc

GEOMETRY- CEILING HEIGHT

Ceiling height translate to time before smoke descends to head level, i.e., increases the ASET.

a) A plume rises, and a ceiling jet starts to form

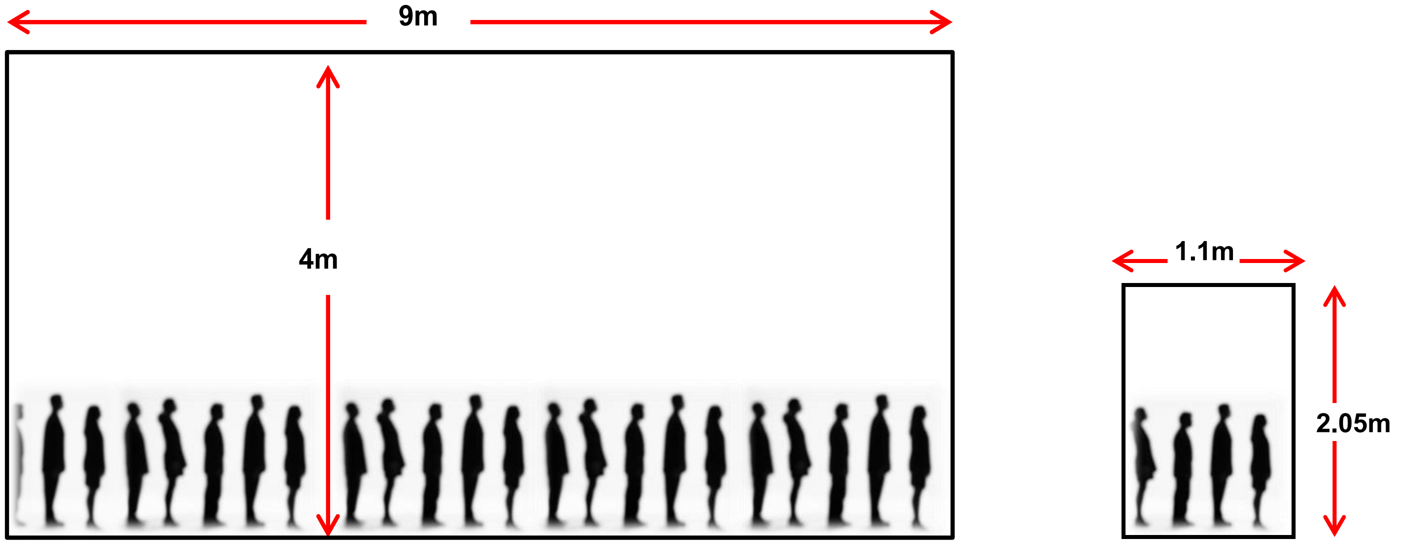
b) When the jet reaches a wall, it turns under

c) The jet flows under to form the minimum smoke-layer depth

GEOMETRY- CEILING HEIGHT

Relationship between ceiling height (i.e., volume of space) and time to egress (based on travel distance) is codified in Sentence 3.4.2.5.(1):

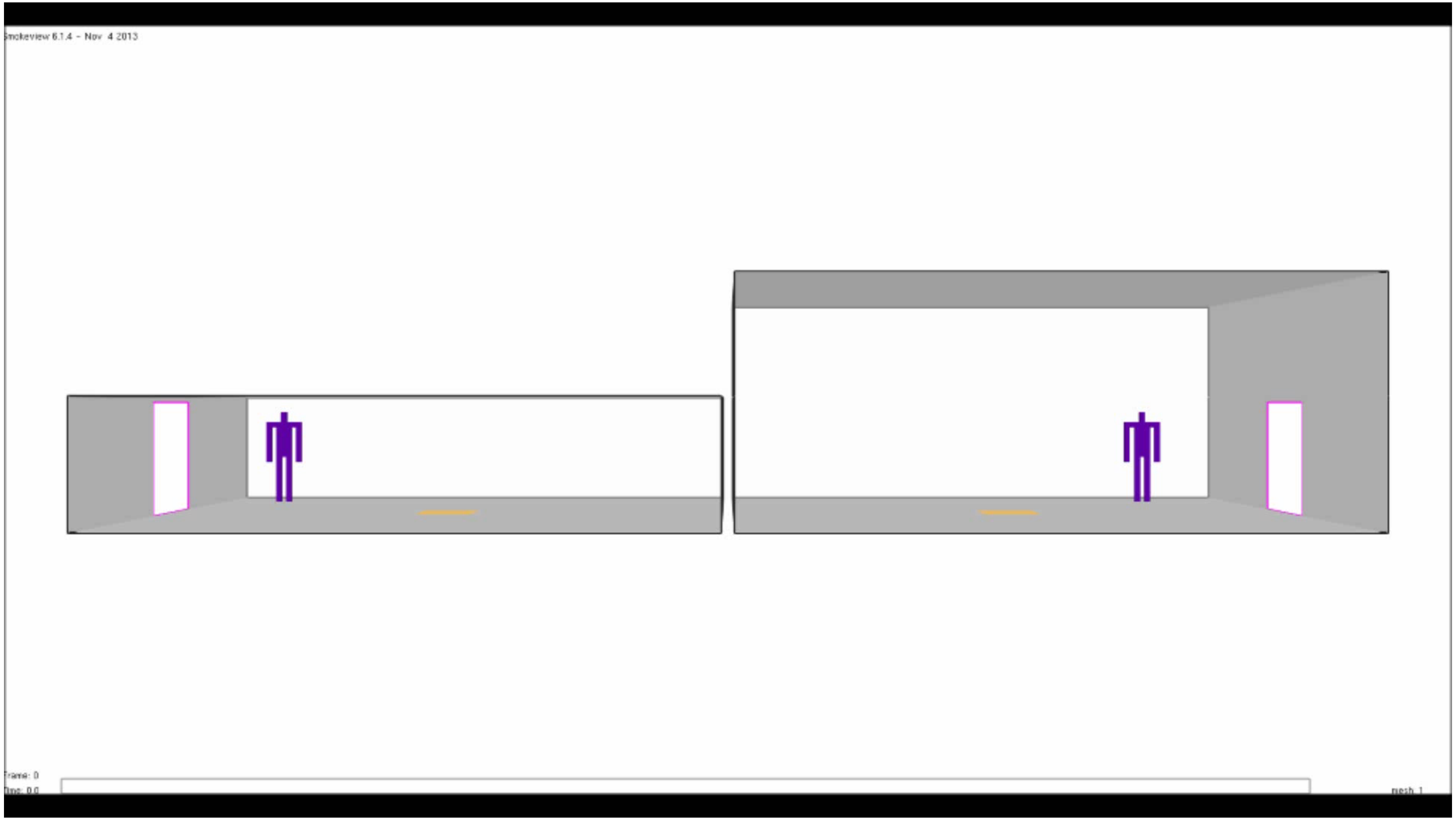
- Corridor: 1100mm x 2050mm -> Max travel distance of 45m
- Corridor: 9000mm x 4000mm -> Max travel distance of 105m



Travel Distance 105m

Travel Distance 45m

GEOMETRY- CEILING HEIGHT



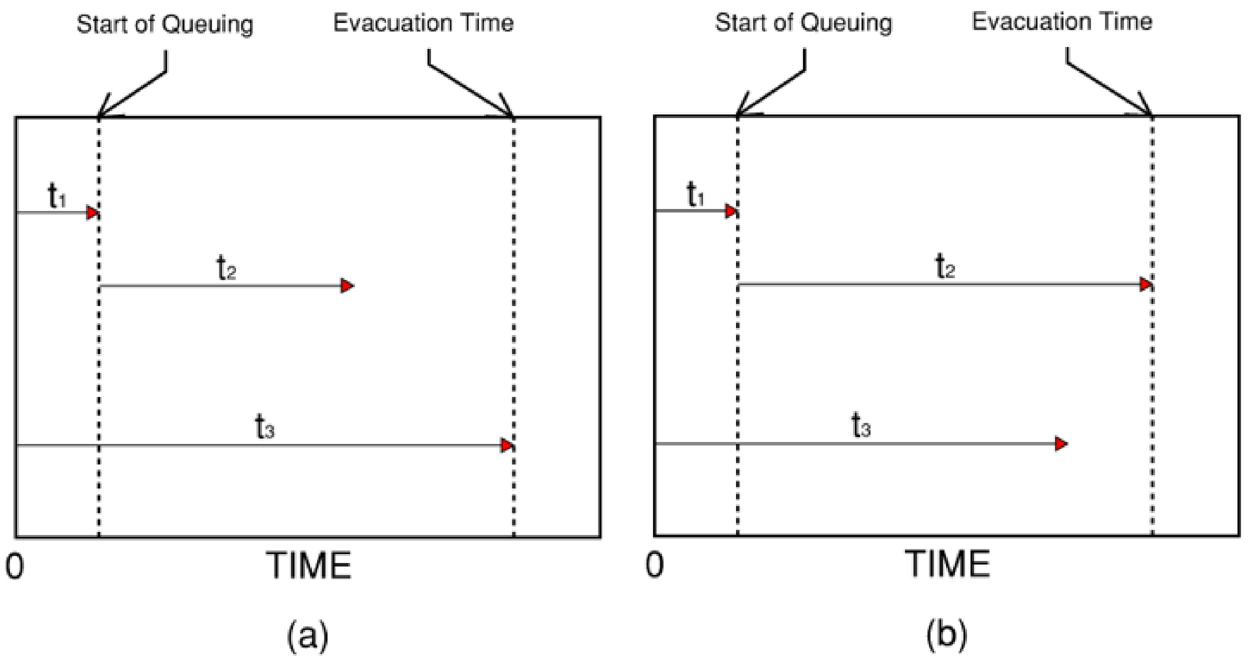
HOW CRITICAL IS TRAVEL DISTANCE?

Is travel distance the governing factor in evacuation?

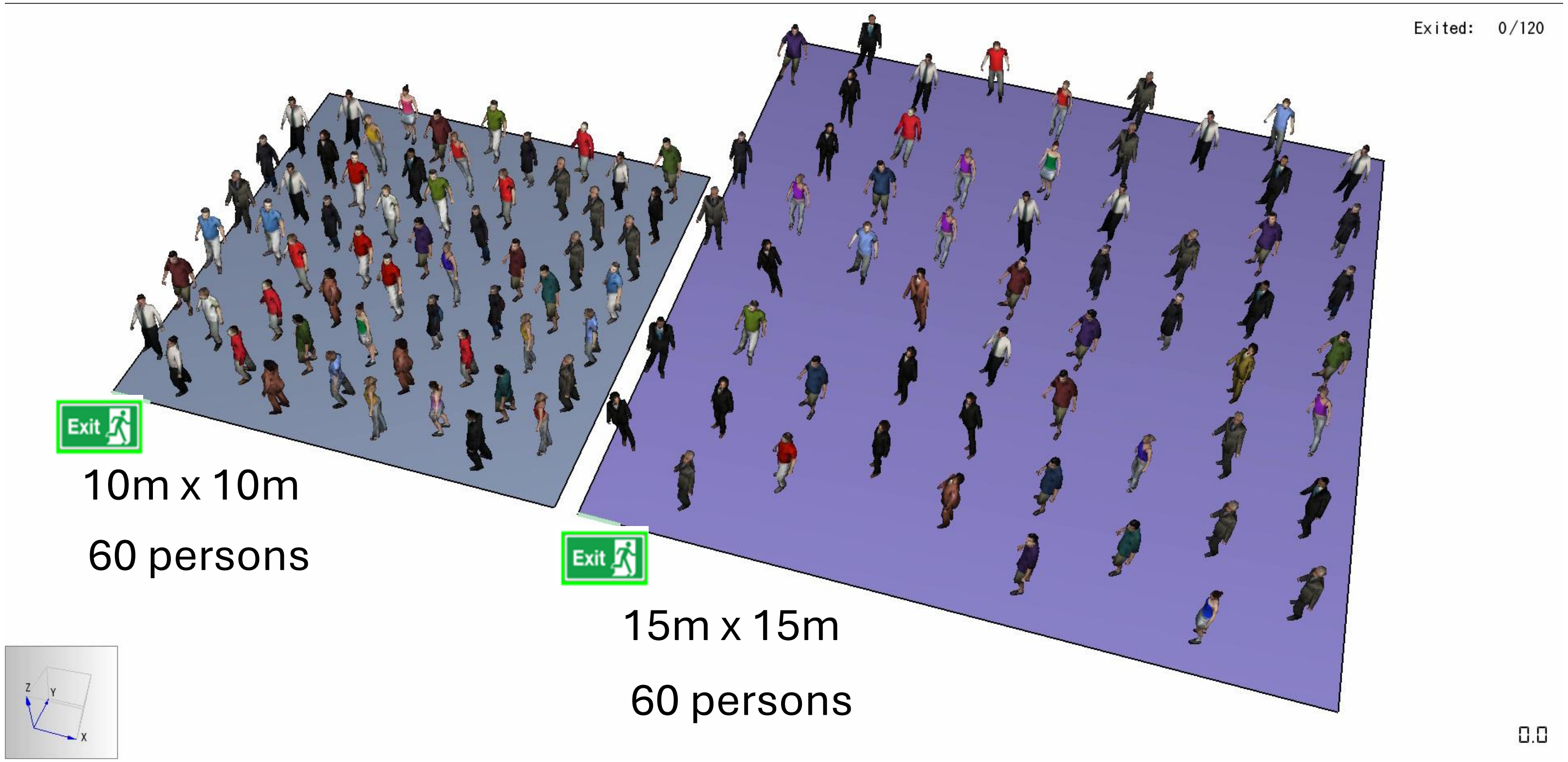
Not always.

If Queuing Time is governing, then Travel Time does not affect overall Evacuation Time

Travel Time 1st Occupant (T1)	Time for first person to reach an exit
Queuing Time (T2)	Time for all persons to pass through the exits
Travel Time Last Occupant (T3)	Time for last person to each an exit
Evacuation Time	MAX (T1 + T2, T3) as illustrated in below figure



TRAVEL TIME VS QUEUING TIME



Same exit capacity / number of exits, same occupant load, however, one room has an increased travel distance resulting in an increased Travel Time, however, a similar total evacuation time.

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COMPARISON TO OTHER CODES (IBC / NFPA 101) (SPRINKLERED)

Occupancy	BC	IBC	NFPA 101
Assembly	45m	76m	76m
Care	45m	76m	61m
Business / Service	45m	90m	91m
Residential	45m	76m	61m
Retail	45m	76m	76m
Industrial F1/F2/F3	25m/45m/45m	23m/76m/120m	30m/122m/unlimited

NRC REPORT: EVALUATING TRAVEL DISTANCE PROVISIONS IN THE NBC

Evaluating travel distance provisions in the National Building Code of Canada: history, assumptions, current practices, and recommendations for future directions

Section 5 of this report provides historical context of travel distance requirements and concludes that "**historical analysis reveals that these values were not derived from science, but rather from practical judgement, precedent, and possibly influenced by other industries**".

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NRC REPORT: EVALUATING TRAVEL DISTANCE PROVISIONS IN THE NBC (EXCERPTS)

In the early 20th century, the United States began adopting specific egress-related fire safety standards. In New York City's 1901 Tenement House Act, insurance engineering proposed that occupants should not have to travel more than 100 ft to reach an exit. These early recommendations gained momentum with the 1913 NFPA Committee on Fireproof Construction, which echoed this 100 ft travel distance as a general guideline for safe egress. These informal standards were reflected in codes like the 1922 NBFU Recommended Building Code and later in the 1927 NFPA Building Exits Code, which codified the 100 ft limit as a rule for maximum allowable travel distance to an exit.

The rationale for these distances was heavily shaped by firefighting capabilities and limitations at the time. This is seen in the 5,000 ft^2 area cap, typically configured as a 50 ft × 100 ft rectangle and became the standard maximum undivided floor area for practical firefighting.

5.8 Summary: Bridging history and evidence

Travel distance limits were originally introduced for administrative simplicity and consistency, not scientific accuracy. While they served a valid function in early code enforcement, modern evidence demonstrates that life safety is determined by total evacuation time, not just the linear distance to an exit.

NON-GEOMETRY FACTORS AND EVACUATION

DEMOGRAPHICS

Occupant demographics affect:

- Movement (walking) speed
  - Persons with disabilities, mobility devices, firefighters carrying equipment, other impairments?
  - SFPE Handbook 5th Edition provides movement speeds based on experiments.
- Do occupants wait for instructions before evacuating, even if the alarm is ringing?
- Do occupants try to gather friends / family before evacuating?
- Is evacuation managed by staff (e.g., school, daycare, care facility, hospital, etc)?
- Are occupants impaired (e.g., night clubs, bars, sports stadiums, etc)?

PSYCHOLOGY – HUMAN BEHAVIOR IN FIRE

Human behaviour can be predicted to a degree:

- Behaviour upon alert to a hazard depends on occupancy:
  - Nightclub – unfamiliar, dark, crowded, impaired, noisy.
  - Home/work – familiar, sense of ownership, protective of others.
  - School – familiar, additional preparedness, leadership.
  - Weather, gender, commitment to a task, alone or in a group, focal point/leader.

PSYCHOLOGY – HUMAN BEHAVIOR IN FIRE

An egress analysis may consider psychology and human behaviour in fire; however, this can be addressed through comparison of similar factors (i.e., keep the following conditions the same in comparative analysis):

- People
- Space
- Conditions

EXAMPLE: Division B vs Acceptable Solution for Extended Travel Distance (keep all factors related to psychology the same, i.e., demographics).

PSYCHOLOGY – HUMAN BEHAVIOR IN FIRE (PANIC)

- What is panic? An overwhelming fear, with or without cause, that produces an **irrational response** and may spread through a group.
- When do people panic? When they can see no way out of a situation.
- When does it matter? When it causes action without assessment of safety
- What do people mean when they say panic?

Real panic in an emergency is rare; experts considered it a myth since about 1970…but the movies and news channels like it.

SFPE Handbook of Fire Engineering, 5th Edition includes **"Panic Behaviour" as a "Discard Theory in Human Behaviour in Fire"** (see excerpt)

Therefore, the use of the concept of panic must be separated from the use of the terms *anxiety* or *fear*. These are natural emotions in emergency situations that do not necessarily lead to competitive, injudicious flight behavior (i.e., panic). Additionally, research has shown that survivors of fire emergencies (or other disasters) may mistakenly categorize their own behavior or the behavior of others as panic, whereas further description of actual actions barely reflect panic behavior [12, 24]. Ramachandran [25], in his review of

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PSYCHOLOGY – HUMAN BEHAVIOR IN FIRE (PANIC)

Article from SFPE Europe on Panic as Myth or Reality - Excerpt

The main cause of the belief that panic occurs is that the behaviour of others is viewed without a complete understanding of their situation. In many cases, panic is attributed to a specific individual based on observed behaviour, but the individual typically has a perfectly sensible explanation for that behaviour. Fahy, Proulx and Aiman (2009) present one useful example, basing their description on behavioural data from fatal residential fires (Brennan, 1998). Fahy, et. al. (2009) describe how a group of elderly people trapped by fire and smoke on the third floor of a building were described by an observer as 'panicking'. At one point, an elderly man even threw a chair out of a window, which might seem quite illogical and 'panicky'. However, he threw out the chair to test if it would break, which it did. He then concluded that he would be seriously injured if he attempted to jump from the window. From an external observer's perspective, it might look like the man was acting in panic. However, throwing out the chair was hence a clever scientific experiment, which suggest rational decision-making in spite of a stressful situation.

(NOT IRRATIONAL)

https://www.sfpe.org/publications/periodicals/sfpeeuropedigital/sfpeeurope8/issue8feature1

EXAMPLE EVACUATION CALCULATIONS

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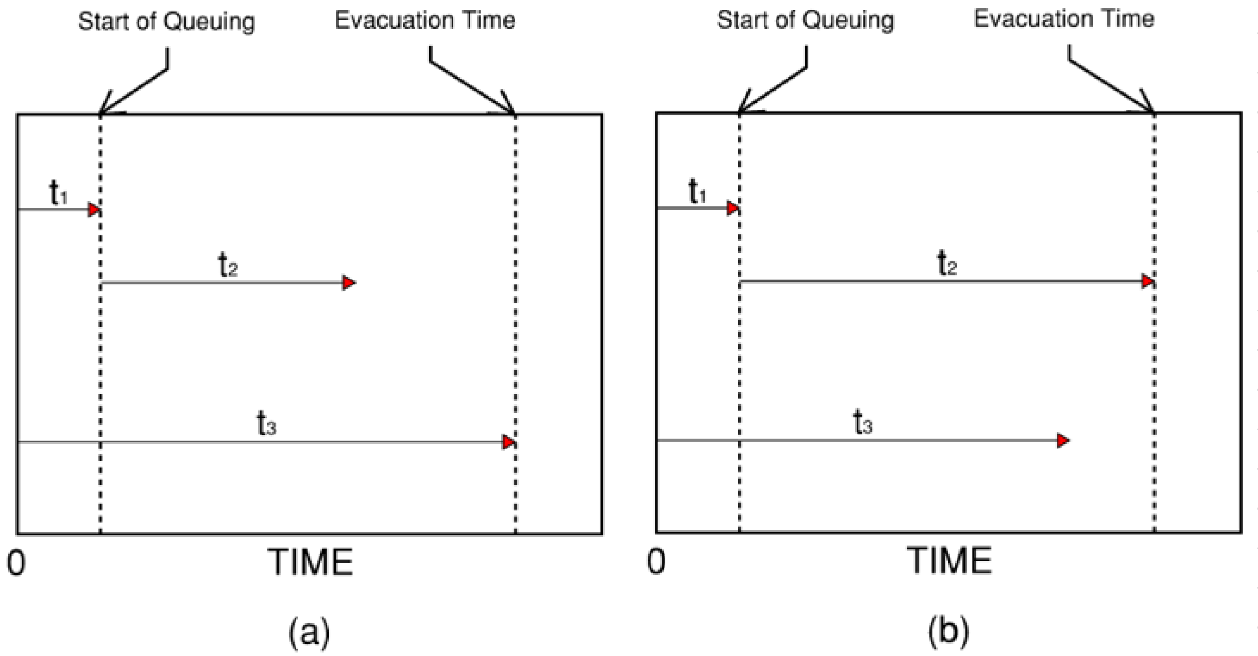
HAND CALCULATION USING HYDRAULIC MODEL

SFPE Guide to Human Behaviour in Fire, 1st Edition - Hydraulic Model Paramaters		
Walking Speed (m/s)	1.24	- For occupant with no disability on level walking surface per SFPE Table 6
Door Flow Rate (p/s-m)	1.32	- SFPE Table 8
Variables		
Travel Time 1st Occupant (T1)	Time for first person to reach an exit	
Queuing Time (T2)	Time for all persons to pass through the exits	
Travel Time Last Occupant (T3)	Time for last person to each an exit	
Evacuation Time	MAX (T1 + T2, T3) as illustrated in below figure	



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HAND CALCULATION USING HYDRAULIC MODEL (EXAMPLE)

Division B Acceptable Solution		Comments
Occupant Load (p)	1311	- Based on exit capacity per Building Code (6.1mm/person)
Egress Door Width (m)	8.0	- 10 x 800mm doors
Effective Egress Width (m)	5.0	- Subtract 300mm boundary layer from each door per SFPE Table 7
Egress Door Flow Rate (p/s)	6.6	- Door flow rate x effective egress width
Queuing Time (T2) (s)	198.6	- Occupant Load / Egress Flow Rate
Travel Time 1st Occupant (T1) (s)	4.0	- Assume 1st occupant is 5m from the door
Travel Distance (m)	45	
Travel Time Last Occupant (T3) (s)	36.3	
Evacuation Time (s)	**202.7**	- MAX(T1 + T2, T3)

TENABILITY

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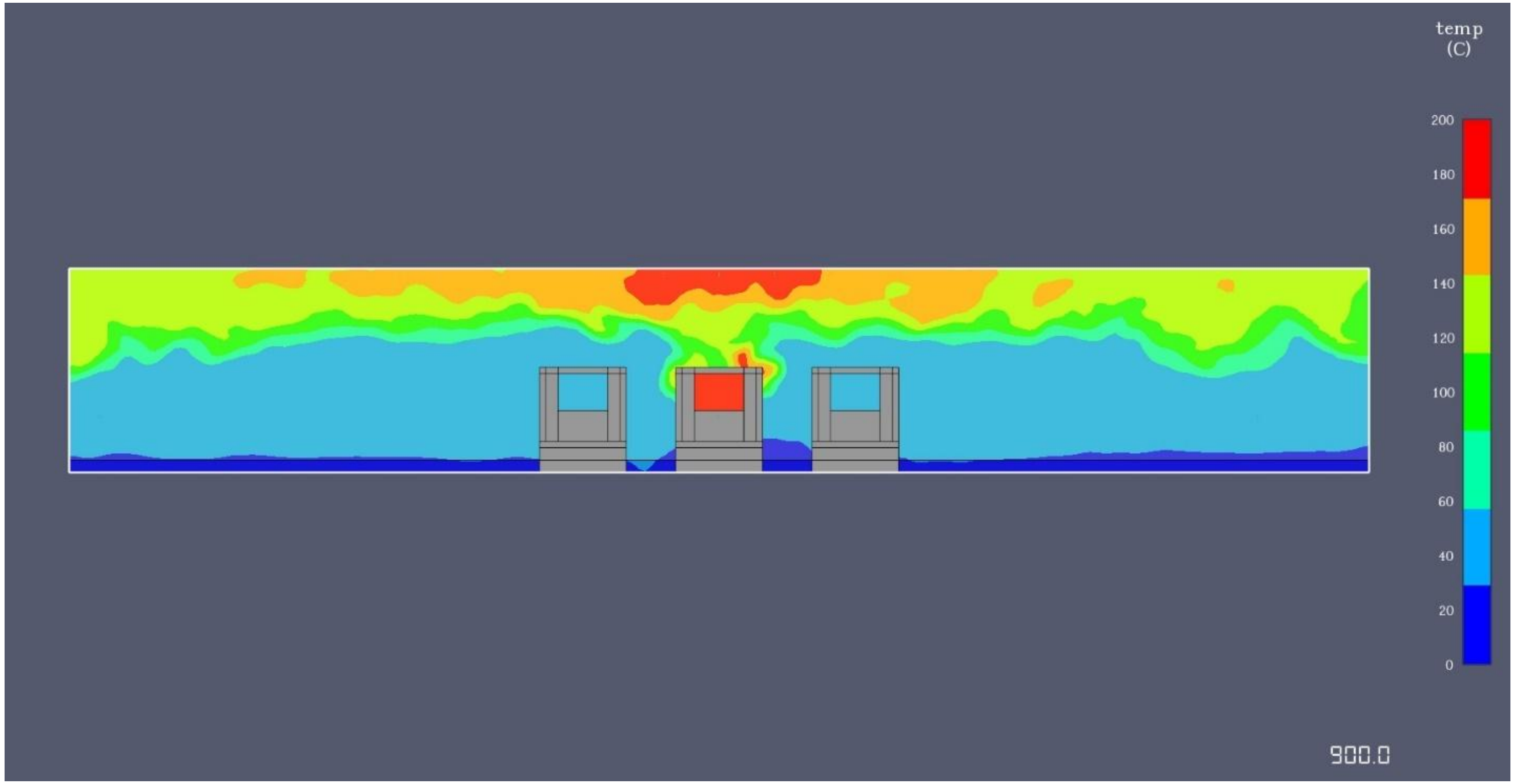
TENABILITY

- Available Safe Egress Time (ASET) is essentially the time that the evacuation route remains tenable (i.e., safe for occupants to evacuate).
- Multiple Factors determine Tenability:
  - Visibility: Ability for occupants to see self-illuminating signs through the smoke and is calculated by the obscuration of the smoke, which is a function of the soot yield.
  - Toxicity: Fire releases toxic compounds, e.g., soot, carbon monoxide, and carbon dioxide which can result in injuries and/or fatalities if occupants are exposed to excess quantities during evacuation.
  - Radiation: Exposure to thermal radiation over an extended period of time can result in pain and injuries depending on the time of exposure and the degree of incident radiant heat flux.
  - Temperature: Exposure to high temperature convection over an extended period of time can result in pain and injuries

TENABILITY

- Tenability can be determined by modelling:
  - Zone Modelling
  - CFD Modelling



TENABILITY (WHEN TO CONSIDER)

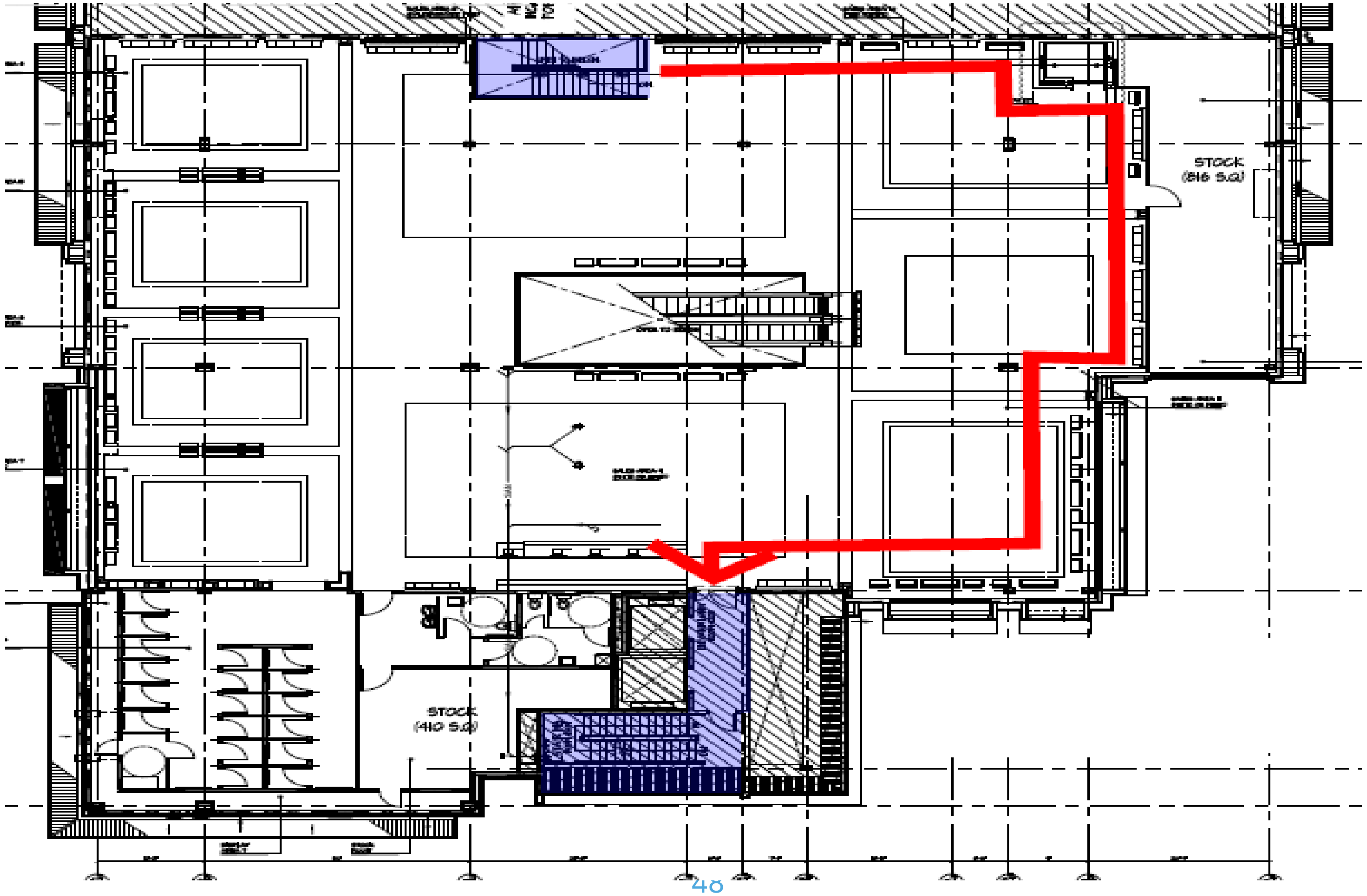
- Where an alternative solution cannot be directly compared to a Division B acceptable solution for evacuation, a tenability analysis may be necessary for comparison to the evacuation analysis.
  - Open stairs for egress
  - Converging egress routes
  - Evacuation of an interconnected floor space

- Alternatively, a comparison of ASET/RSET for the Division B acceptable solution and alternative solution may be feasible. This can occur if the alternative solution is provided with features that improve tenability to address deviation from certain egress related provisions in the Building Code.

EXAMPLE PROJECT CASE STUDIES

EX 1: SINGLE EXIT AND OPEN EGRESS STAIR

- Single Exit and Open Egress Stair



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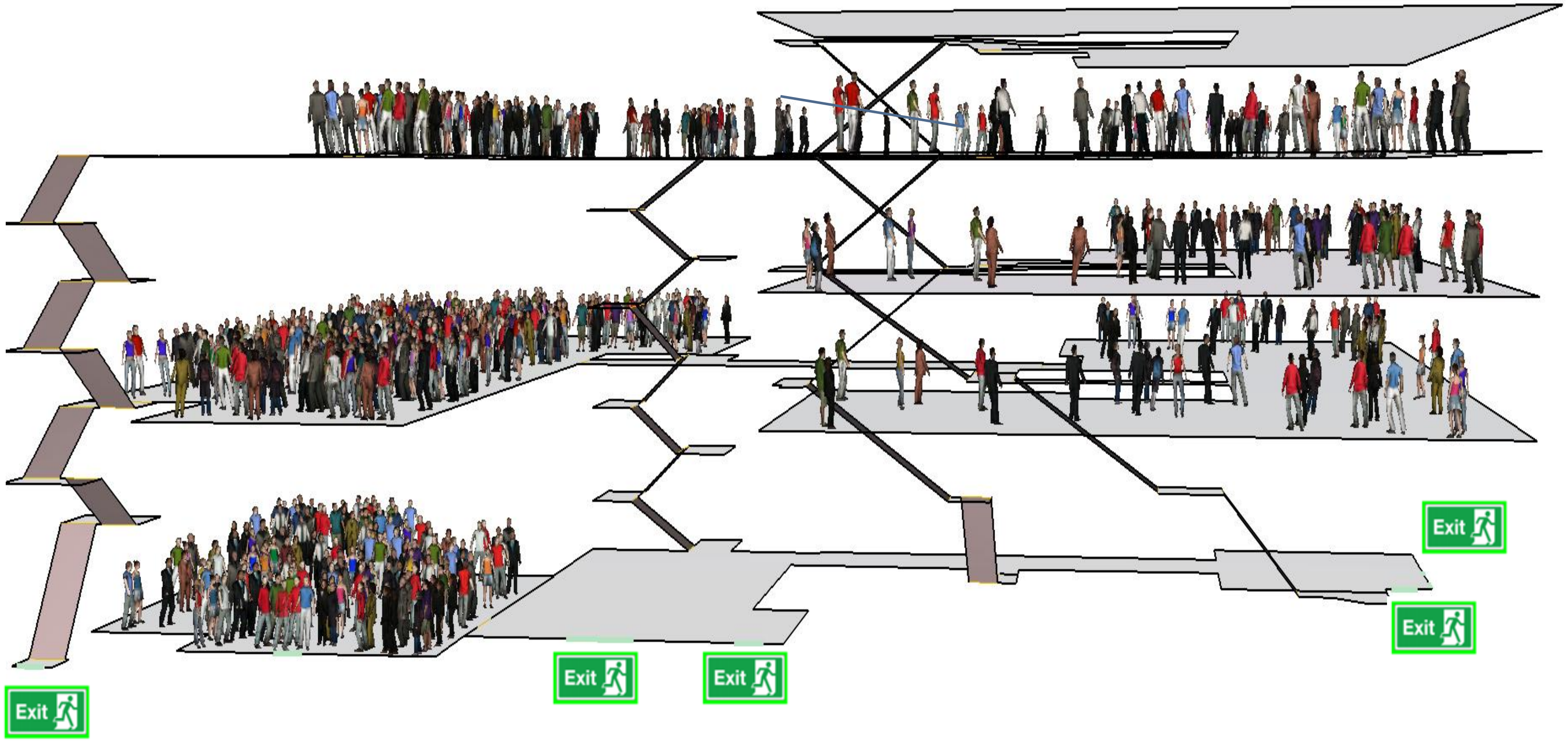
EX 1: SINGLE EXIT AND OPEN EGRESS STAIR

- Sentence 3.4.2.1.(1) - at least two exits required
- Travel distance and exit capacity met by exit stair. Open stair provided second egress route.
- Timed egress, smoke model to confirm tenability.
- Additional features included smoke detection for early alert.

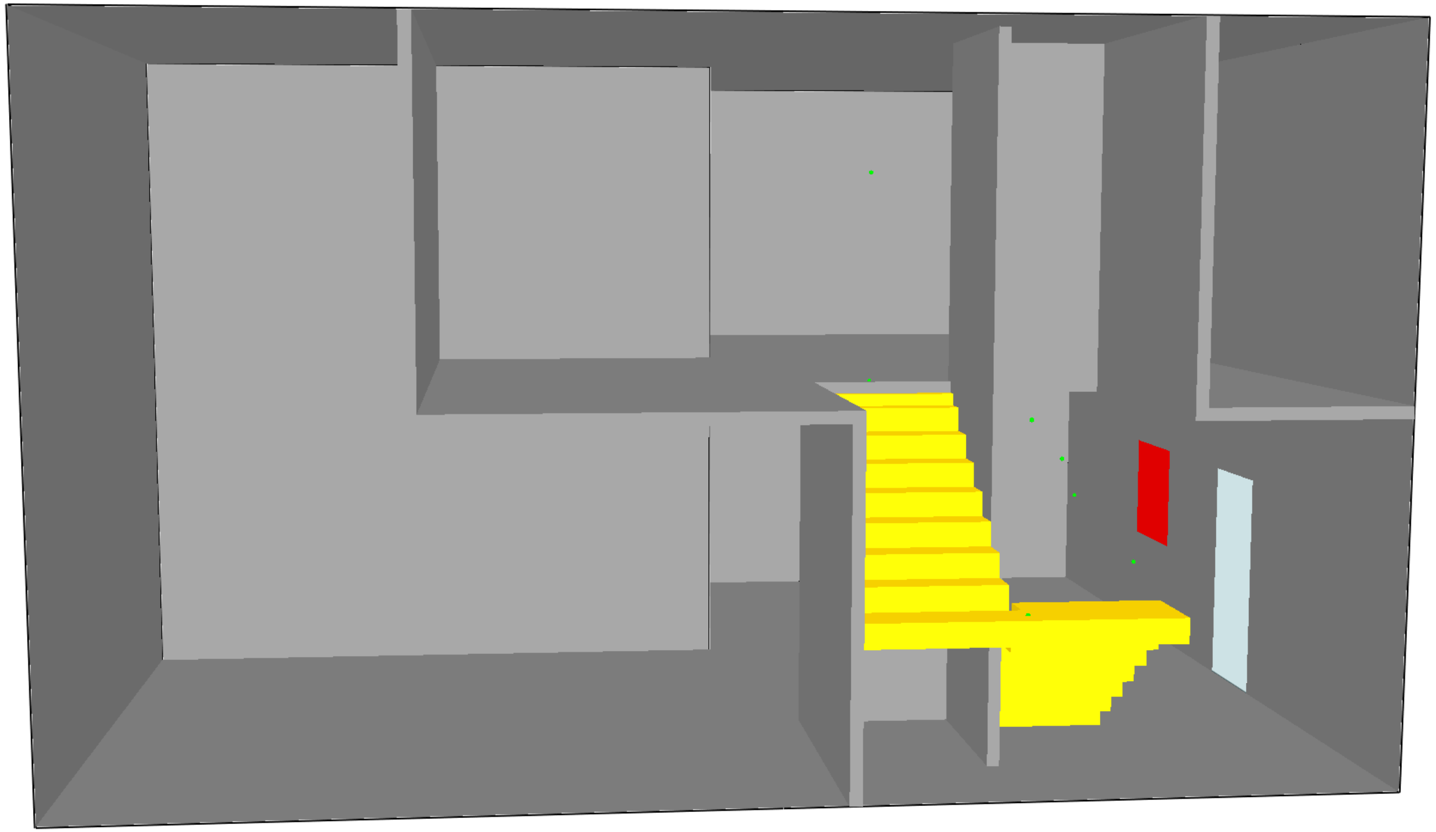
EX 2: CUMULATIVE EXITING



EX 2: CUMULATIVE EXITING

- Sentence 3.4.3.2.(6) - Exit stairs serving interconnected floor space based on cumulative occupant load.
- Cumulative exiting not met.
- Used convenience stair leading to exit on 1st storey as a means of egress.
- Timed egress, smoke model to confirm tenability.
- Additional features included smoke detection and smoke exhaust to keep open stair tenable.

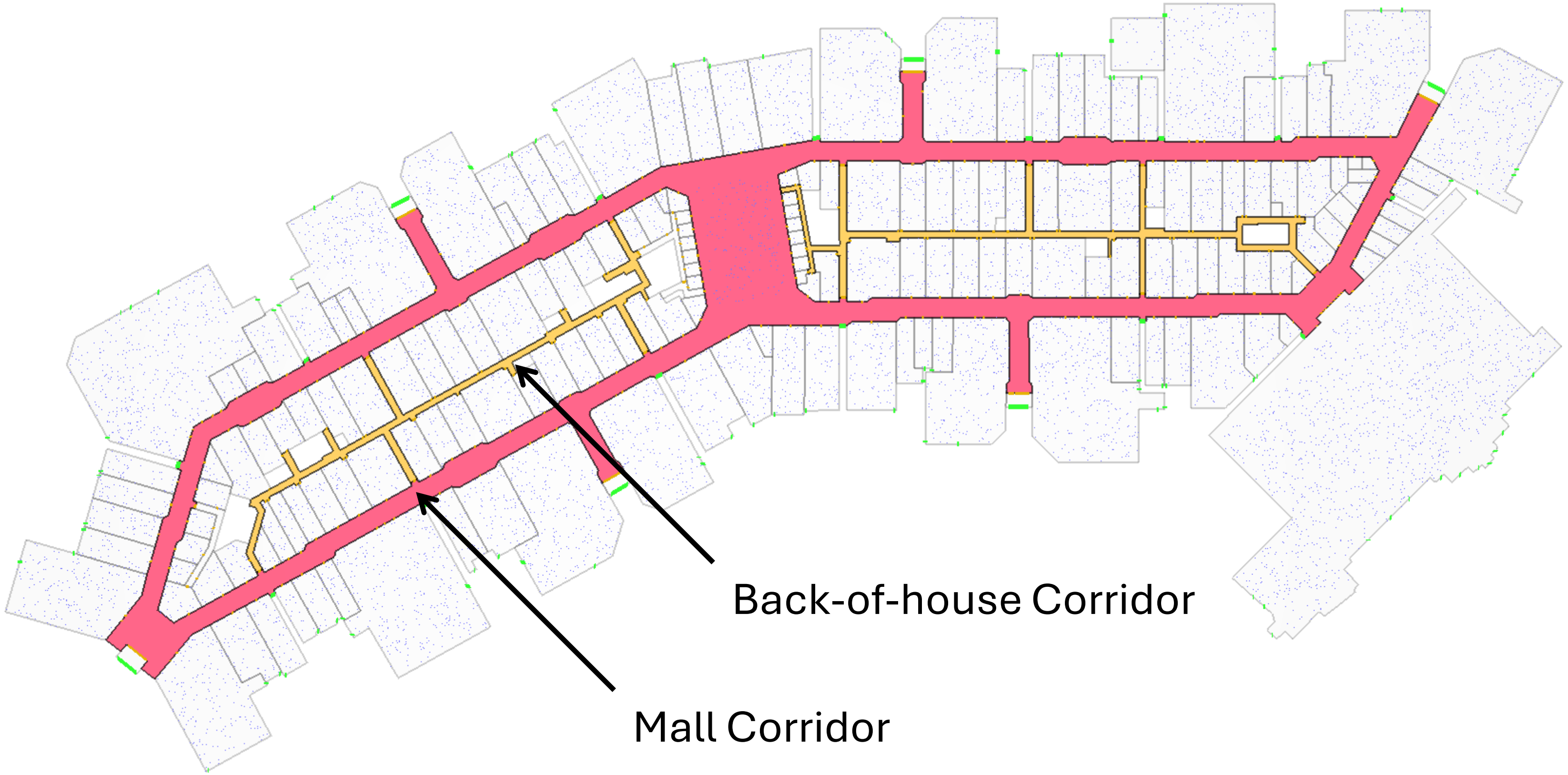
EX 3: EGRESS FROM 2-STOREY DWELLING UNIT



EX 3: EGRESS FROM 2-STOREY DWELLING UNIT

- Sentence 3.3.4.4.(2) - describes egress doors in multi-level dwelling units at both the upper and lower storeys.
- Egress door was not provided at the upper storey
- Timed egress confirmed increased egress of 3 seconds.
- Concern was tenability at route from upper storey.
- Smoke model confirmed tenable conditions.
- Draft stop was necessary.
- Additional features included smoke alarms for early alert, emergency lighting linked to smoke alarm.
- Fire alarm annunciation – both storeys at lower.

EX 4: CONVERGING EGRESS



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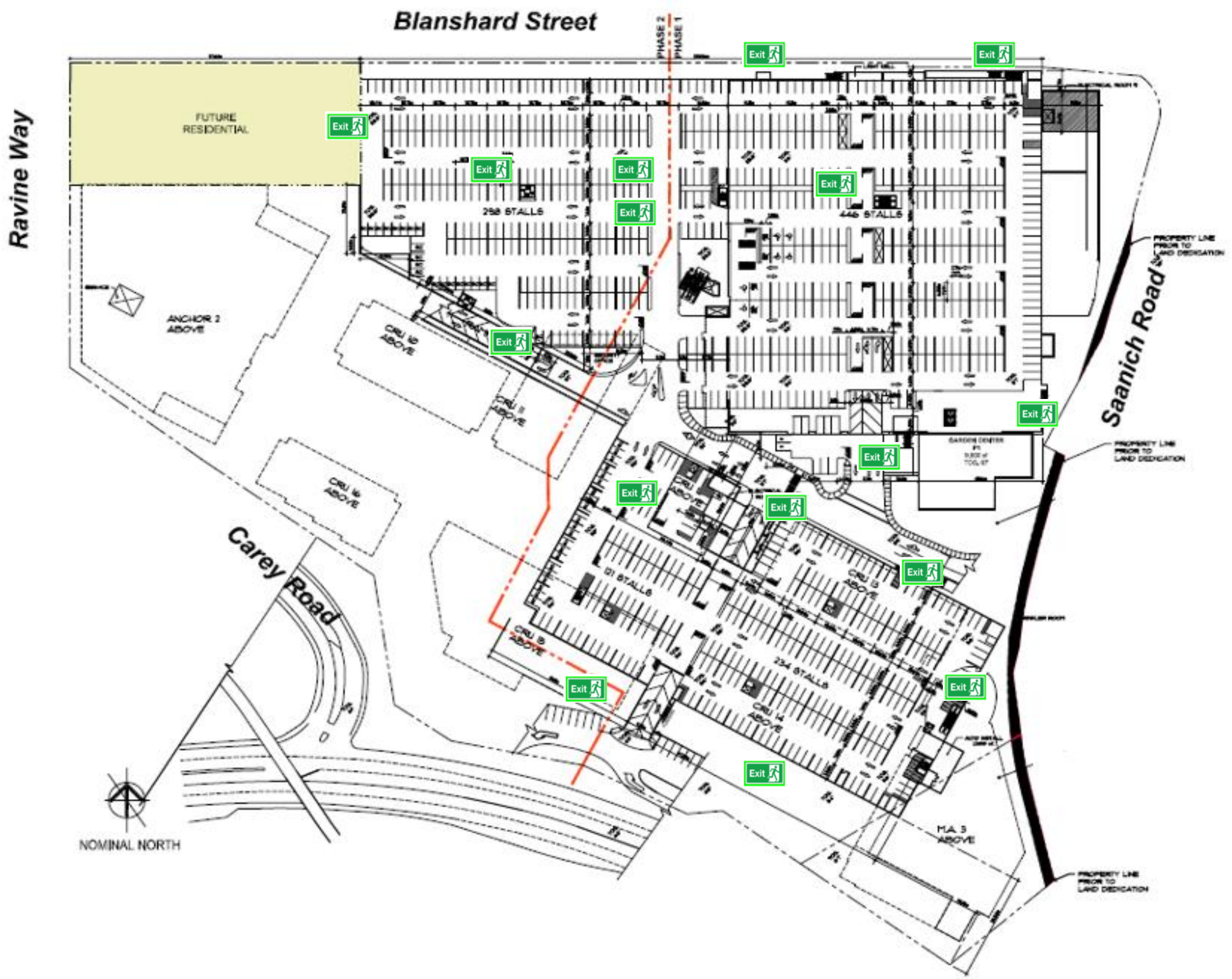
EX 4: CONVERGING EGRESS

- Clause 3.4.2.5.(1)(d) - 50% of occupants exit via mall corridor with travel distance of 105m.
- Rear corridor converged with mall corridor.
- Used mall corridor as a means of egress for 100% of occupants.
- Timed egress, smoke model to confirm tenability.
- Additional features include passive smoke venting to maintain tenability.
- Code compliant solution = tunnel out of the building. Are people willing?

EX 5: STORAGE GARAGE WITH 70M TRAVEL DISTANCE



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EX 5: STORAGE GARAGE WITH 70M TRAVEL DISTANCE

- Sentence 3.4.2.5.(1) - prescribes 45m travel distance.
- Increased travel distance from centre areas.
- Increased exit width (extra doors).
- Low occupant load; no queuing at exits.
- Timed egress.
- Additional features include exit signage, increased light levels.

Scenario	Number of Occupants per Exit (persons)	Maximum Travel Distance (m)	Time to Evacuate (sec)
1. Code Minimum using full door capacity	149	45	219
2. Proposed Scenario	54	70	110

EX 5: STORAGE GARAGE WITH 70M TRAVEL DISTANCE (COMPARISON OF BCBC TO IBC AND NFPA 101, SPRINKLERED)

Occupancy	BC	IBC	NFPA 101
Assembly	45m	76m	76m
Care	45m	76m	61m
Business / service	45m	90m	91m
Residential	45m	76m	61m
Retail	45m	76m	76m
Industrial F1/F2/F3	25/45/45m	23/76/120m	30/122/unlimited

SUMMARY

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SUMMARY

- Building Code limits - travel distance, ceiling height, exit capacity - define a space, create a scenario.
- Real-life scenarios are compared to Building Code scenario.
- Human behaviour is predictable / unpredictable.
- Can reduce detection / alert stage by smoke detection (operate earlier than sprinklers).
- Can ‘buy time’ by increasing ceiling height or exit capacity.
- Travel distance is not necessarily the element having the greatest impact on time to egress.

QUESTIONS?

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