UNDERSTANDING SOME LIMITATIONS OF VARIOUS EGRESS ANALYSIS TOOLS

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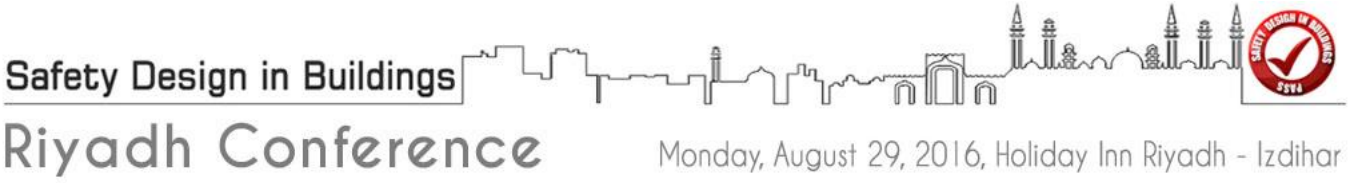

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COURSE DESCRIPTION

With the increased usage of egress analysis in architecturally complex buildings to safe guard occupants, engineers should be aware of the various egress tools, their limitations, cost and validity to choose the appropriate model for the chosen scenario. This presentation introduces the various approaches / tools for conducting a timed egress analysis, some of their strong suits and limitations.

PRESENTER

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BuroHappold Engineering, Senior Fire Engineer

Majed has a Bachelor and Master of Science in fire protection engineering and has been involved in the industry for 13 years.

His experience covers developing and implementing fire protection strategies in various applications, such as hydrocarbon processing plants, high-rise residential/office buildings, training and research.

In addition to working with BuroHappold as a Senior Fire Engineer, he is also a PhD candidate at Worcester Polytechnic Institute pursuing a degree in fire protection engineering. His thesis examines the effects of cultural differences on human behavior during evacuation, and how to implement such differences in egress modeling.

LEARNING OBJECTIVES

1. Introduce the concept of egress analysis (ASET / RSET)
2. Identify different tools used for egress analysis.
3. Pros and Cons of various egress tools
4. How to choose the appropriate modeling tool

OVERVIEW

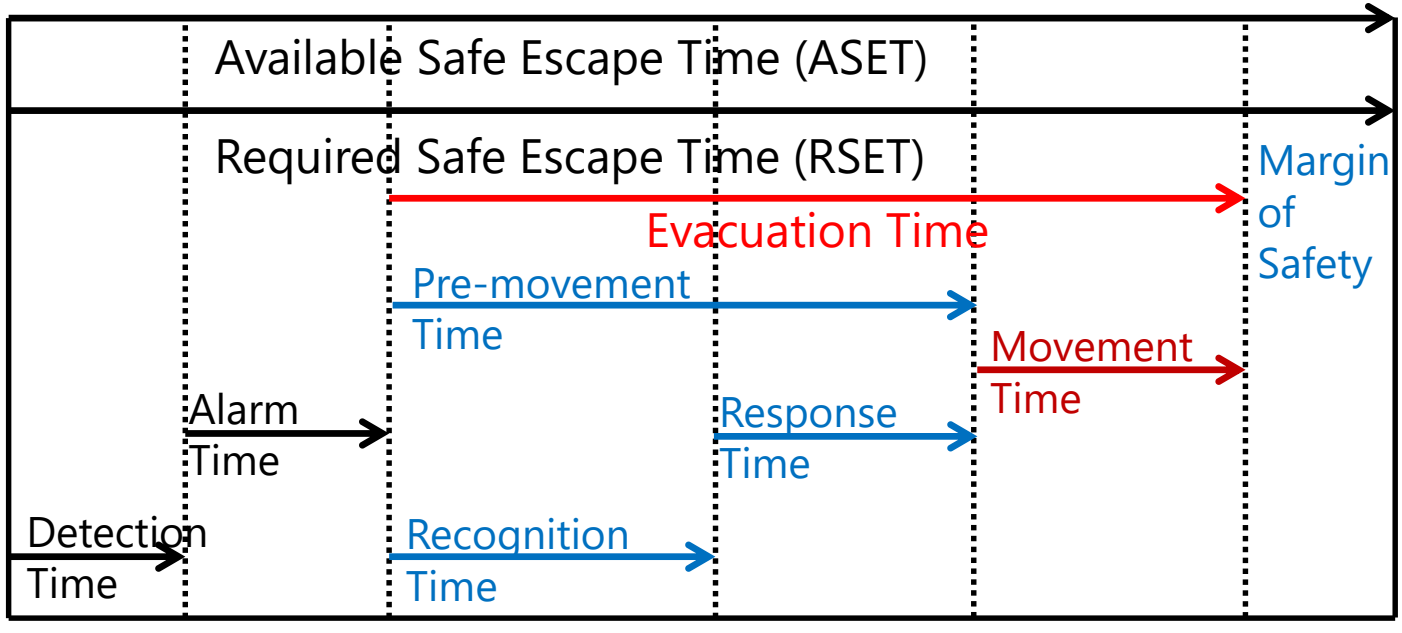
- What is an egress analysis?
- When is it required?
- Why is it important?
- Available tools (w/ Pros and Cons)
- Choosing the appropriate tool
- Challenges with Egress analysis

WHAT IS AN EGRESS ANALYSIS?

- An analysis using a number of tools to demonstrate that occupants will probably be able to evacuate a building / space before a specific time extracted from standards (e.g. NFPA 130, 101) or CFD computer models (time to reach untenable conditions)

WHAT IS A TIMED EGRESS ANALYSIS?

- Egress Analysis



ASET>> RSET

WHEN IS IT REQUIRED?

- NFPA 101, NFPA 5000 for atrium requirement

  8.6.7* Atriums. Unless prohibited by Chapters 11 through 43, an atrium shall be permitted, provided that all of the following conditions are met:

  (5)*For other than existing, previously approved atriums, an engineering analysis is performed that demonstrates that the building is designed to keep the smoke layer interface above the highest unprotected opening to adjoining spaces, or 6 ft (1830 mm) above the highest floor level of exit access open to the atrium, for a period equal to 1.5 times the calculated egress time or 20 minutes, whichever is greater.

- Performance Based Design
- Identifying egress issues in existing buildings

WHY IS IT IMPORTANT?

- Provide some flexibility when meeting the intent of the code (PBD)
- Highlighting any occupant flow issues during design
- Illustrate an acceptable level of safety to the AHJ when complying with code requirements
- Cheaper than conducting an actual fire drill / liability
- Testing evacuation strategy

AVAILABLE TOOLS

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EGRESS ANALYSIS TOOLS

- Provides optimum
- Includes some aspects of
  - Human behaviors (e.g. way finding)
  - Group interaction
- Pre-movement times based on previous incidents/fire drills.

EGRESS ANALYSIS TOOLS

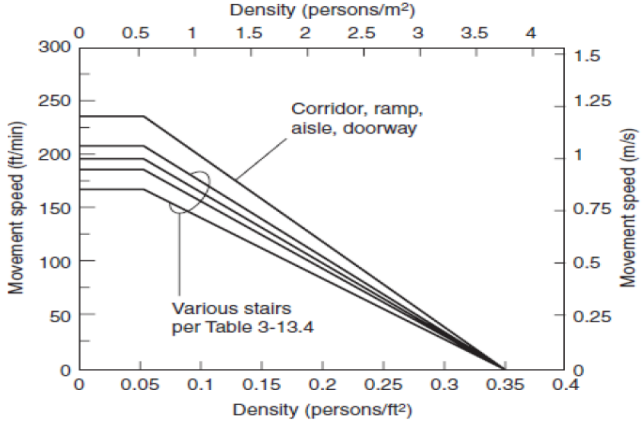
- Hydraulic hand calculation model
- Computer modeling software

HYDRAULIC HAND CALCULATION MODEL

- Estimate minimum movement time
- Based on relationship between speed, flow and density
- Everyone moves at the same time
- $S = k - akD$
- Empirical data

TABLE 5. Velocity Factor in Equations 2 and 3[4]

Egress Component		k (m/s)	k (ft/min)
Corridor, aisle, ramp, doorway		1.40	275
Stair Riser, mm (in.)	Stair Tread, mm (in.)		
190 (7.5)	254 (10)	1.00	196
272 (7.0)	279 (11)	1.08	212
165 (6.5)	305 (12)	1.16	229
165 (6.5)	330 (13)	1.23	242



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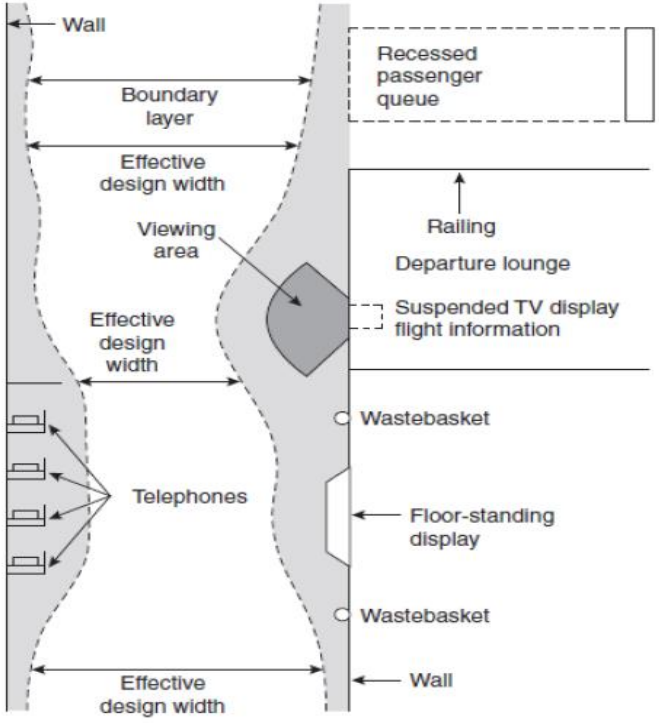
HYDRAULIC HAND CALCULATION MODEL

- Effective width (W_e)
- SFPE HB Table 3-13.5

Exit Route Element	Boundary Layer (in.)	Boundary Layer (cm)
Stairways—wall or side of tread	6	15
Railings, handrails[a]	3.5	9
Theater chairs, stadium benches	0	0
Corridor, ramp walls	8	20
Obstacles	4	10
Wide concourses, passageways	<18	46
Door, archways	6	15

[a]Where handrails are present, use the value if it results in a lesser effective width.



HYDRAULIC HAND CALCULATION MODEL

- SFPE HB Table 3-13.5
- Two types of hydraulic models
  - First order
  - Second order

TABLE 8. Maximum Specific Flows

Egress Component		F_s pers/sec-m of Effective Width (pers/min-ft of Effective Width)
Corridor, aisle, ramp, doorway		1.32 (24.0)
Stair Riser, mm (in.)	Stair Tread, mm (in.)	
190 (7.5)	254 (10)	0.94 (17.1)
272 (7.0)	279 (11)	1.01 (18.5)
165 (6.5)	305 (12)	1.09 (20.0)
165 (6.5)	330 (13)	1.16 (21.2)

HYDRAULIC HAND CALCULATION MODEL

First Order

- Simple
- Concentrates on major components constricting occupant flow

Second Order

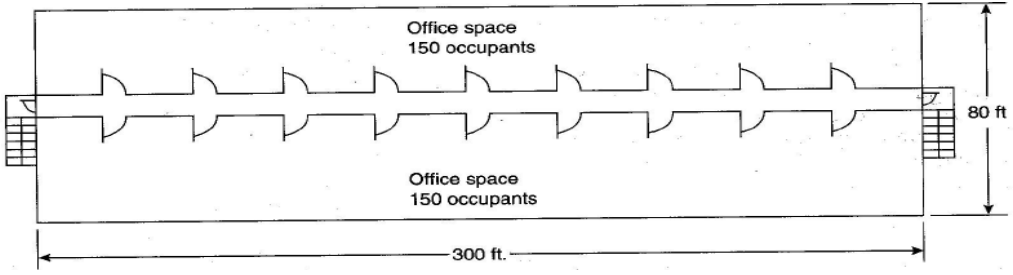
- More complicated
- Occupant flow is calculated between each structural component

HYDRAULIC HAND CALCULATION MODEL

- First vs. Second Order
- Results will be similar in simple geometries.
- Second order will provide more accurate results for complex geometries in addition to
  - Time to evacuate each floor
  - flow/speed through different components
- No consideration for collision avoidance with others and obstacles
- Both assume ideal conditions
- Both approaches are based on studies conducted in the 1960s
  - Changes in people shape and demography

HYDRAULIC MODEL EXAMPLE

- 9 floors, office space, floor to floor height 12 ft.
- First floor occupants use different exit
- 44 in wide stairs, handrails extending 2.5 in. with 4 ft. X 8 ft. landings per floor
- 7 in. riser and 11 in. treads
- Stairway doors are 36 in. are held open
- 8 ft. wide corridor
- 300 people/floor
- First order: 25.4 min.
- Second order: 25.3 min.



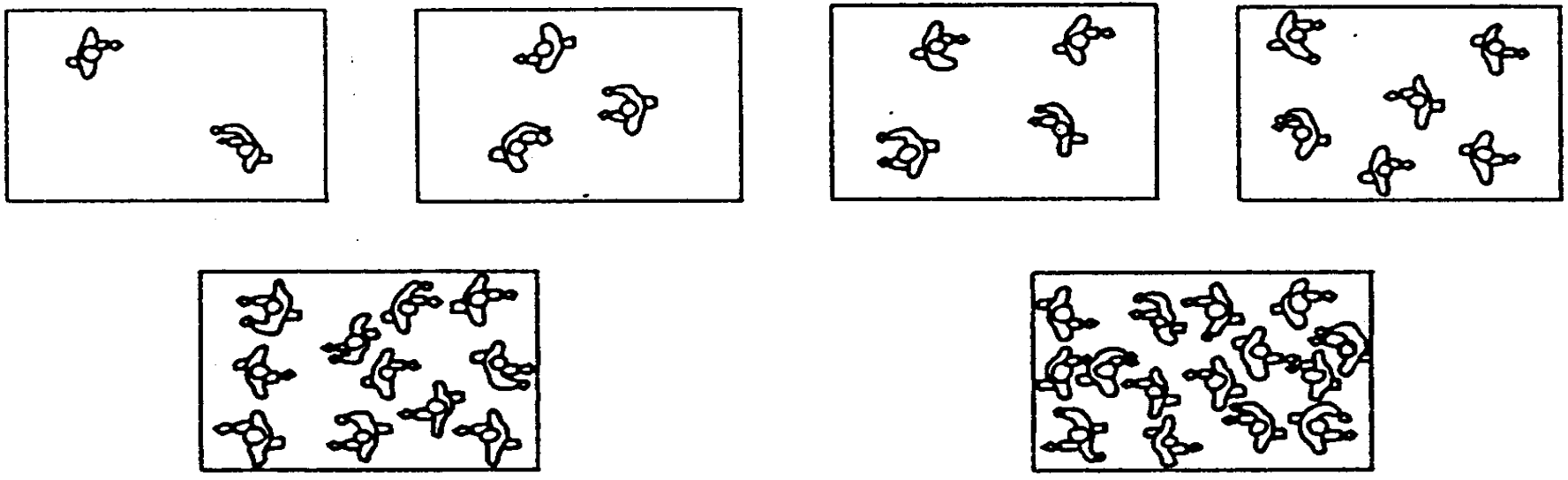
EVACUATION MODELS

- Three main types
  - Coarse Network
  - Fine Network
  - Continuous Network

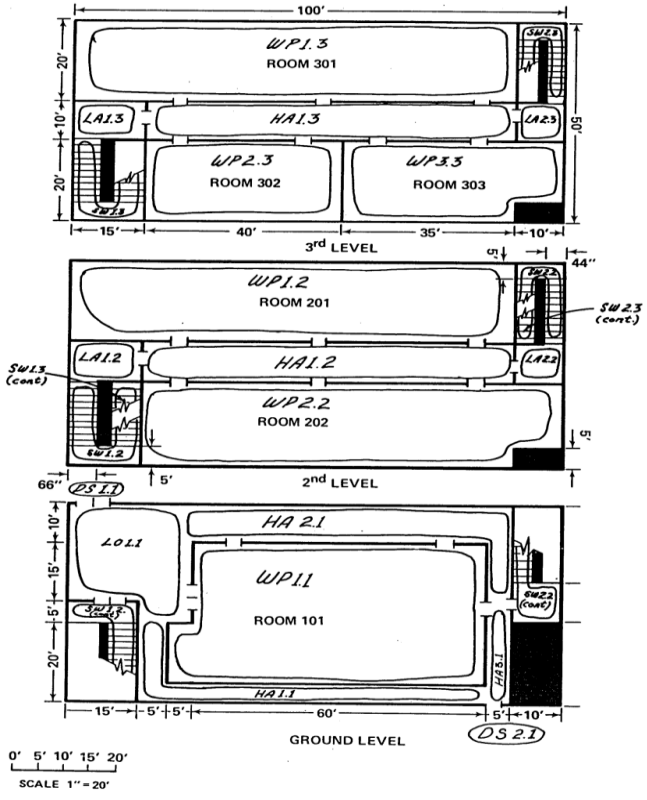
COARSE NETWORK MODELS

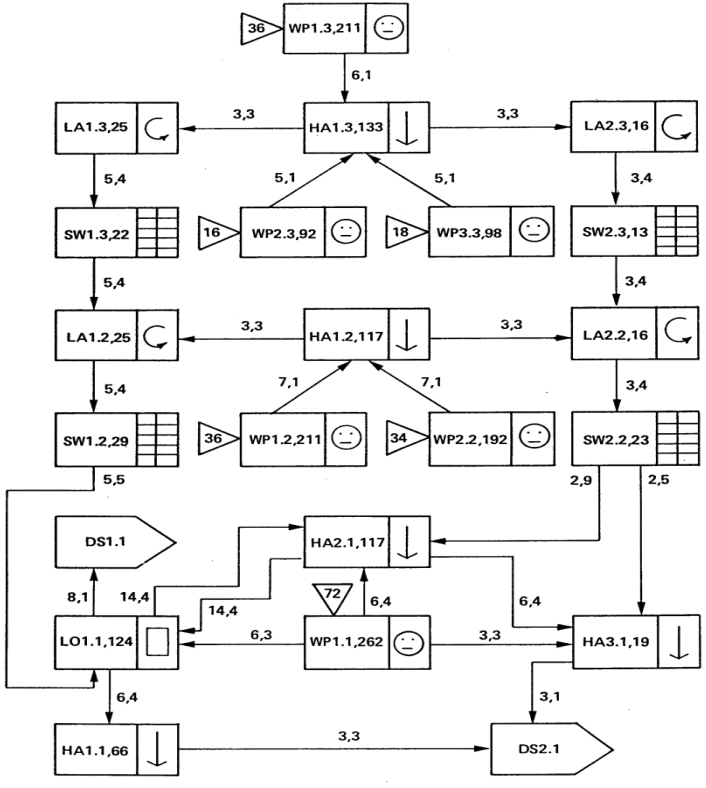
- EVACNET4
- Free, available at http://www.ise.ufl.edu/kisko/files/evacnet/
- Using a network description of a building and information on its initial occupant contents, EVACNET4 produces results that describe an optimal building evacuation
- The network model consists of a set of nodes and arcs. The nodes of the network model represent building components such as rooms, halls, stairs, and lobbies. The initial contents (people) in each node must also be specified. The arcs represent the passageways between the building components.

Levels of service in walkways



EVACNET4





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EVACNET4

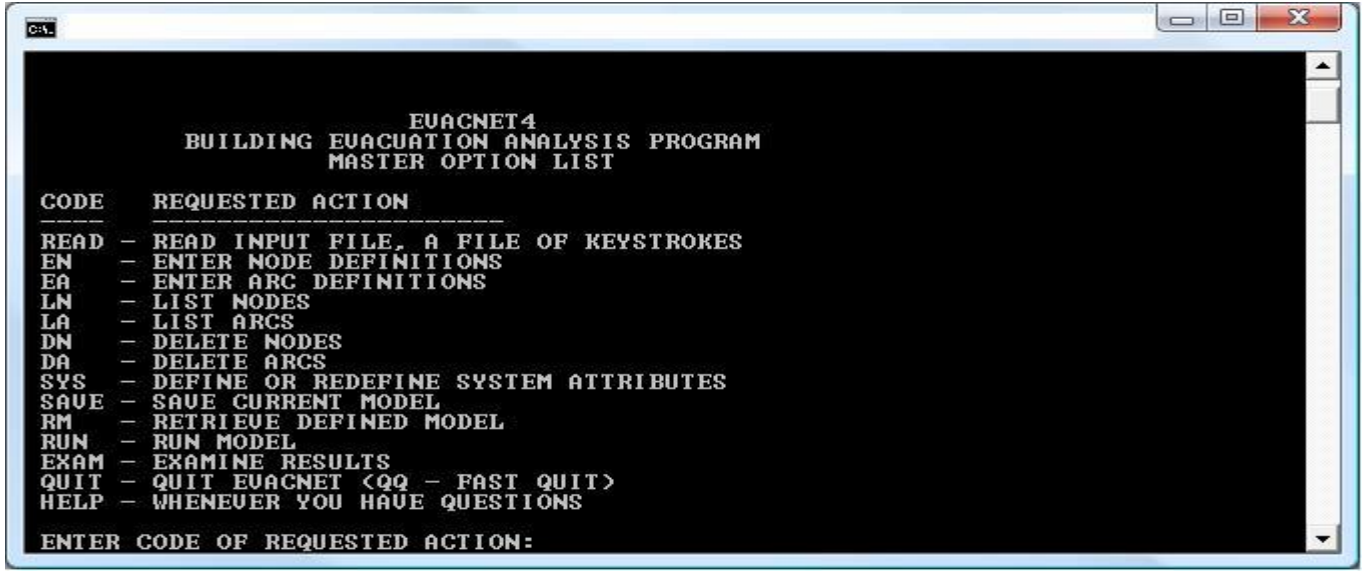
Pros

- Minimum no. of inputs required
- Simplified approach
- Provides reasonable results for simple, open assembly spaces
- Free license in most cases

Cons

- Minimum no. of inputs required
- Focuses on time and flow between arcs (user defined) rather than egress width
- No human behavior simulated
- No demographic breakdown (1 type of occupants)
- Pre-movement is considered as a fixed number by the user
  - Added to the final results

EVACNET4



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FINE NETWORK

- STEPS
- Simulation of Transient Evacuation and Pedestrian Movement

- Divides the space into user specified, identical squares (grid)

- People move from one grid to another based on a scoring system

- Only one person is allowed to be in a grid. A person can occupy more than one grid

STEPS

- Includes some human behaviors
  - Patience
  - groups
- Various user specified inputs
  - Size and height of occupants
  - Grid size
  - Density
  - Groups
- Video

STEPS

Pros

- Incorporates some human behavior (e.g. collision avoidance, familiarity)
- Movement is affected by smoke (FDS file)
- Validate against case studies and other models
- Can be used for normal pedestrian movement simulation

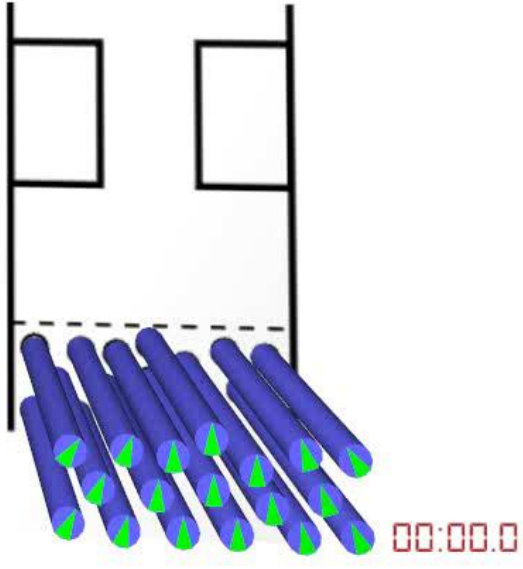
Cons

- Some behaviors have not been validated
- Occupant size can greatly affect model results depending on grid size
- Demographic breakdown depends on the user's experience
- License cost

CONTINUOUS NETWORK

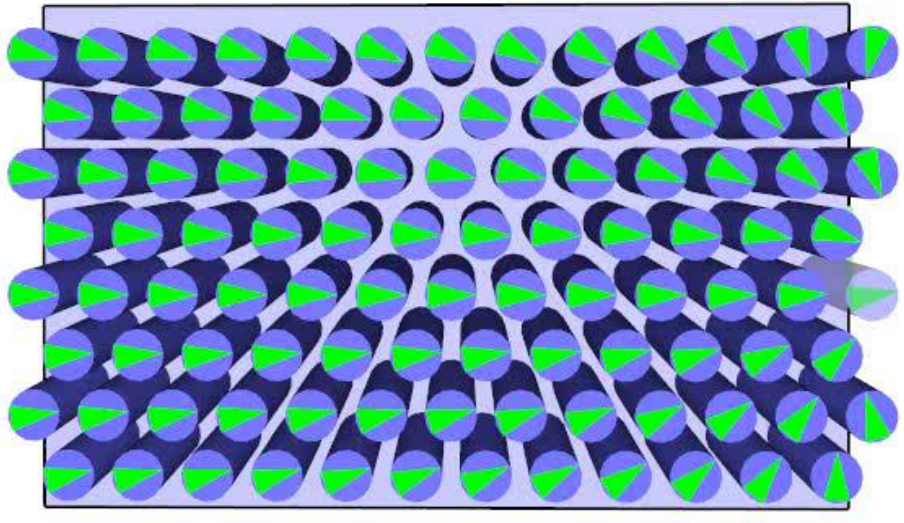
- Pathfinder
  - Space divided into continuous x-y coordinates
    - Modeled occupants can travel freely throughout the space
  - Occupants assess all immediate surrounding cells and chooses the most optimum depending on:
    - Density
    - Speed
    - Distance to exit
  - Consideration for some social behaviors

BOTTLENECKS



PATHFINDER EXAMPLES

IMO_04: 1 door width = 1 m, steering mode



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PATHFINDER

Pros

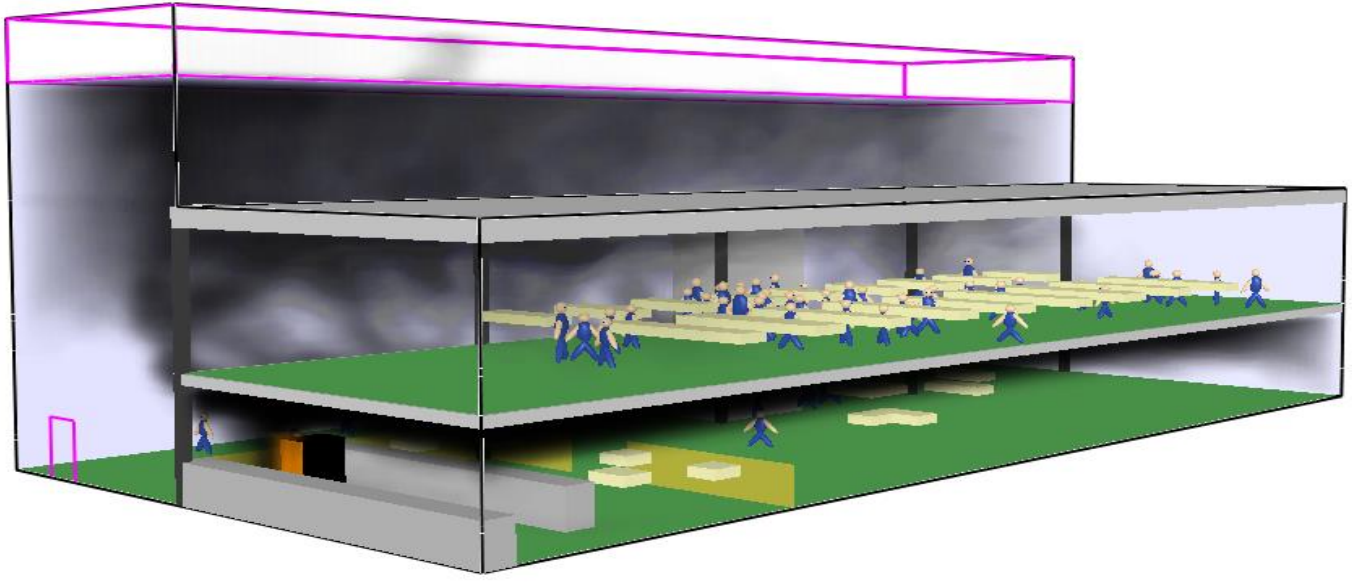
- Incorporates partial human behaviors (e.g. collision avoidance, emerging groups and leaders)
- Results can be extracted for various egress elements
- Easy to learn user interface
- Short period to build model
- Results can be interfaced with FDS / Pyrosim results (smoke does not affect movement)
- Pre-movement input as distribution

Cons

- Does not consider social behaviors
- Default exit is closes exit (can be redefined by user)
- High costs depending on type of license
- Demographic breakdown depends on the user's experience

MODELS INCORPORATING FIRE INCIDENT FACTORS

- **FDS + EVAC**



FDS + EVAC: exit choice

- The familiarity with exits for each agent can be determined by the user.
- FDS+Evac determines the visibility of an exit to an agent by taking into account the blocking effect of smoke and obstacles.

FDS + EVAC: exit choice

Pros

- Easy interface with FDS
- Free license
- Validated against a number of case studies and other models
- Worth using if FDS is part of analysis
- Inputs can be entered as distributions

Cons

- Some behaviors are not validated
- Initial setup and model running times depend on complexity of geometry
- Demographic breakdown depends on the user's experience

CHOOSING A MODELING TOOL

- Project Requirements
  - Scope, available information, deliverables, timing and funding
- Modeled geometry
  - Complex, different occupancies, large number of occupants, occupancy type
  - Simple geometry = Coarse network
  - Complex geometry = Fine network / continuous network
- Modeled Scenario
- Desired output
  - Text, 2D, 3D, speed / flow profile.
- Demographic breakdown
- Model validation

EGRESS ANALYSIS CHALLENGES

- Number of tools / approaches
- Availability of input data
  - If it looks good, it does not mean that it is right
  - Is it applicable for the occupancy / region
- Experienced users
- Cost vs Savings
- Convincing AHJ

QUESTIONS?

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