COUNTERFLOW IN COMPUTATIONAL EVACUATION MODELLING – THE HYDRAULIC MODEL, MODELLING TOOLS AND TRIALS

Matt Arnott, Michael Spearpoint, Steve Gwynne, Anne Templeton

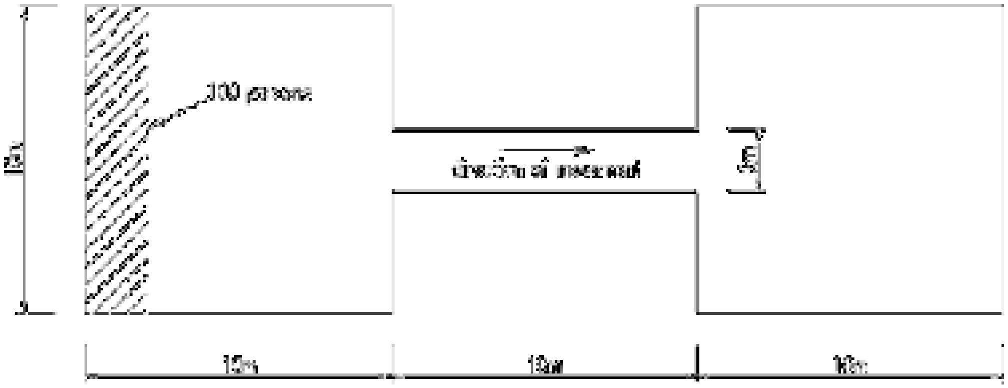
OFR Consultants
Matthew.arnott@ofrconsultants.com

Background and motivation

- Counterflow is not common in fire evacuations
- Sharing escape paths with emergency response personnel
- How should counterflow be modelled?

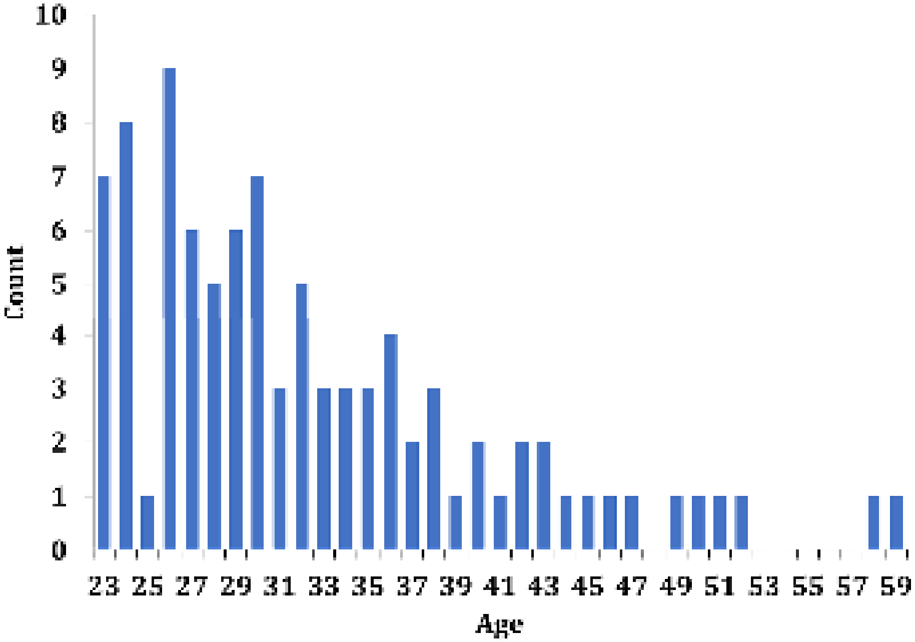
Previous work

- ISO 20414 counterflow verification test in corridor arrangement
- Heliövaara et al. – comparing modelling tools
- Kretz et al. – present the results of counterflow experiments in a corridor
- Isobe et al. and Nagai et al. - investigated counterflow by experiment and simulation for pedestrians walking and crawling along a corridor

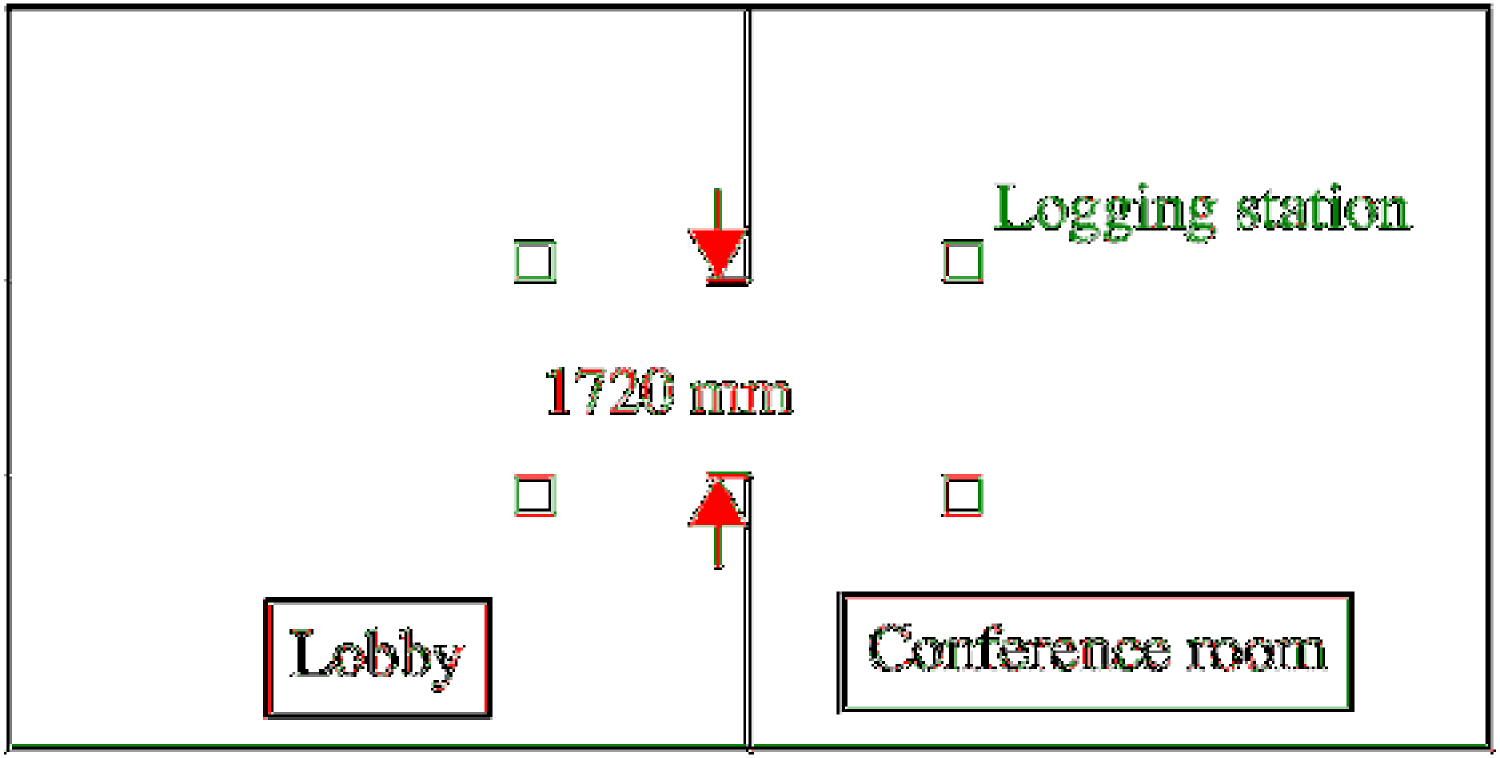


Trial participants

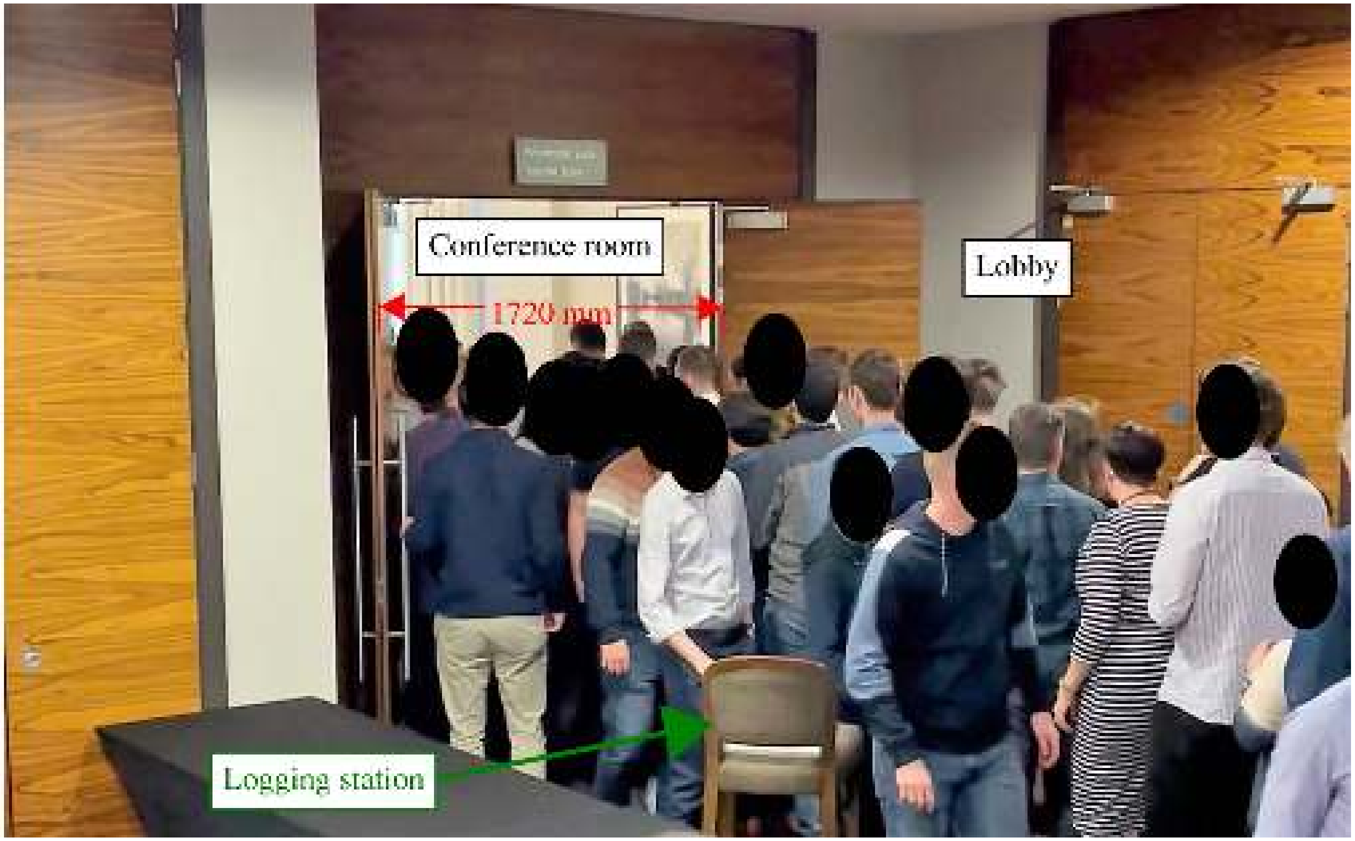
- Part of an author-initiated company team event
- Between 88-91 participants; 72% male, 28% female
- Generally known to each other being from the same working environment



Trial set-up



Trials

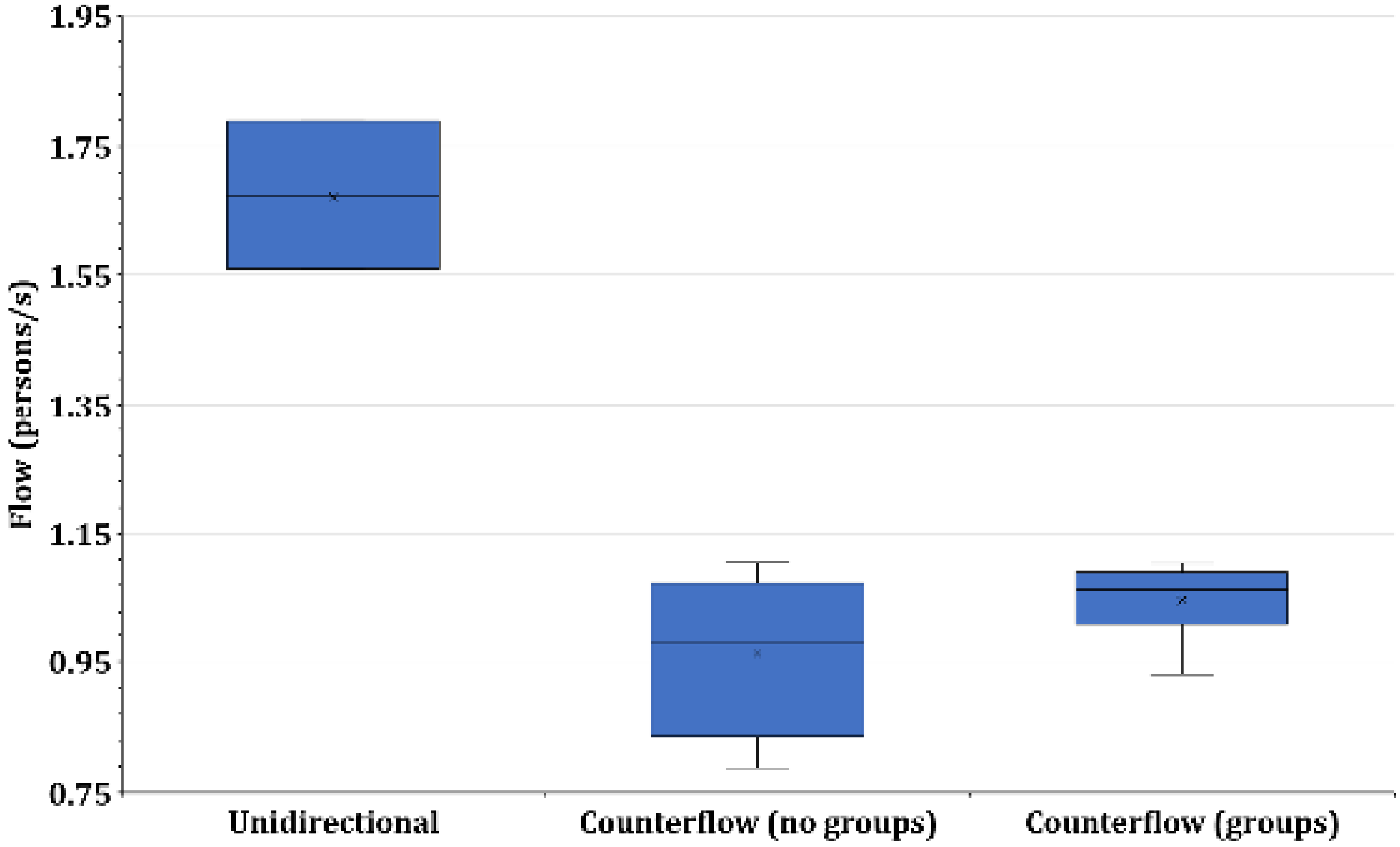


Trials

- 8 trials
  - 2 with unidirectional flow
  - 2 with ‘random’ group counterflow
  - 4 with ‘assigned’ group counterflow
- Investigated the effect of group identity
  - Participants told they were split into groups with distinguishing characteristics
  - In reality, these were again two random groups

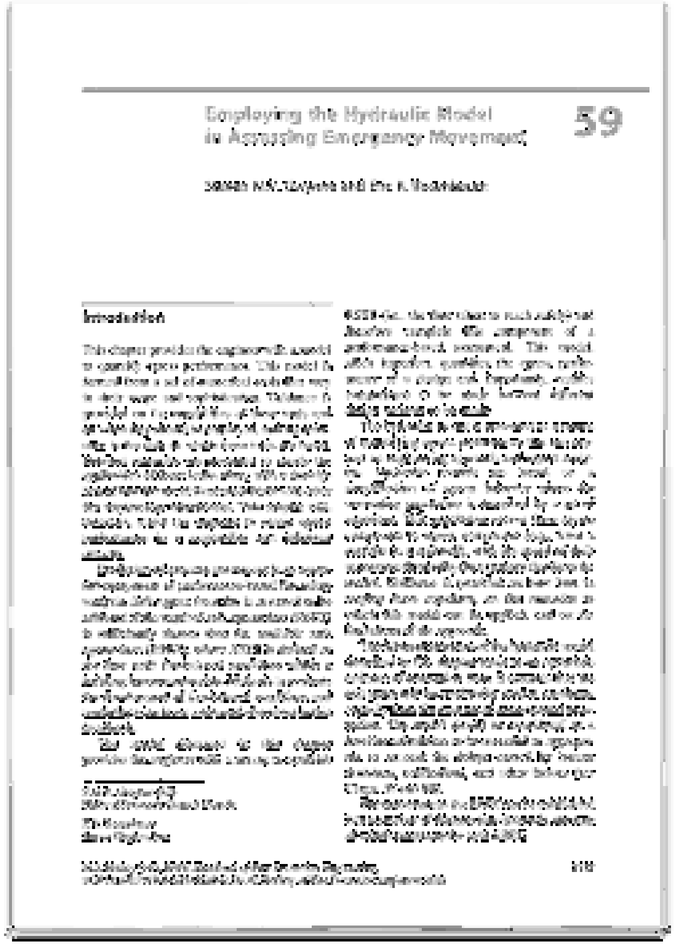
Trials

Trial results



Hydraulic model

- SFPE Handbook describes the hydraulic model in Chapter 59
- Describes the evacuating population using a set of equations
- Calculated unidirectional flow of 1.85 pers/s
- Counterflow taken as half of this, i.e., 0.92 pers/s

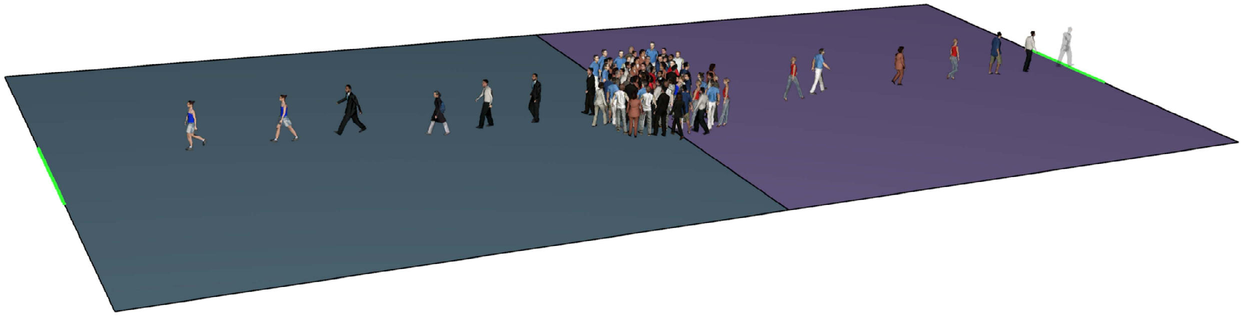


59

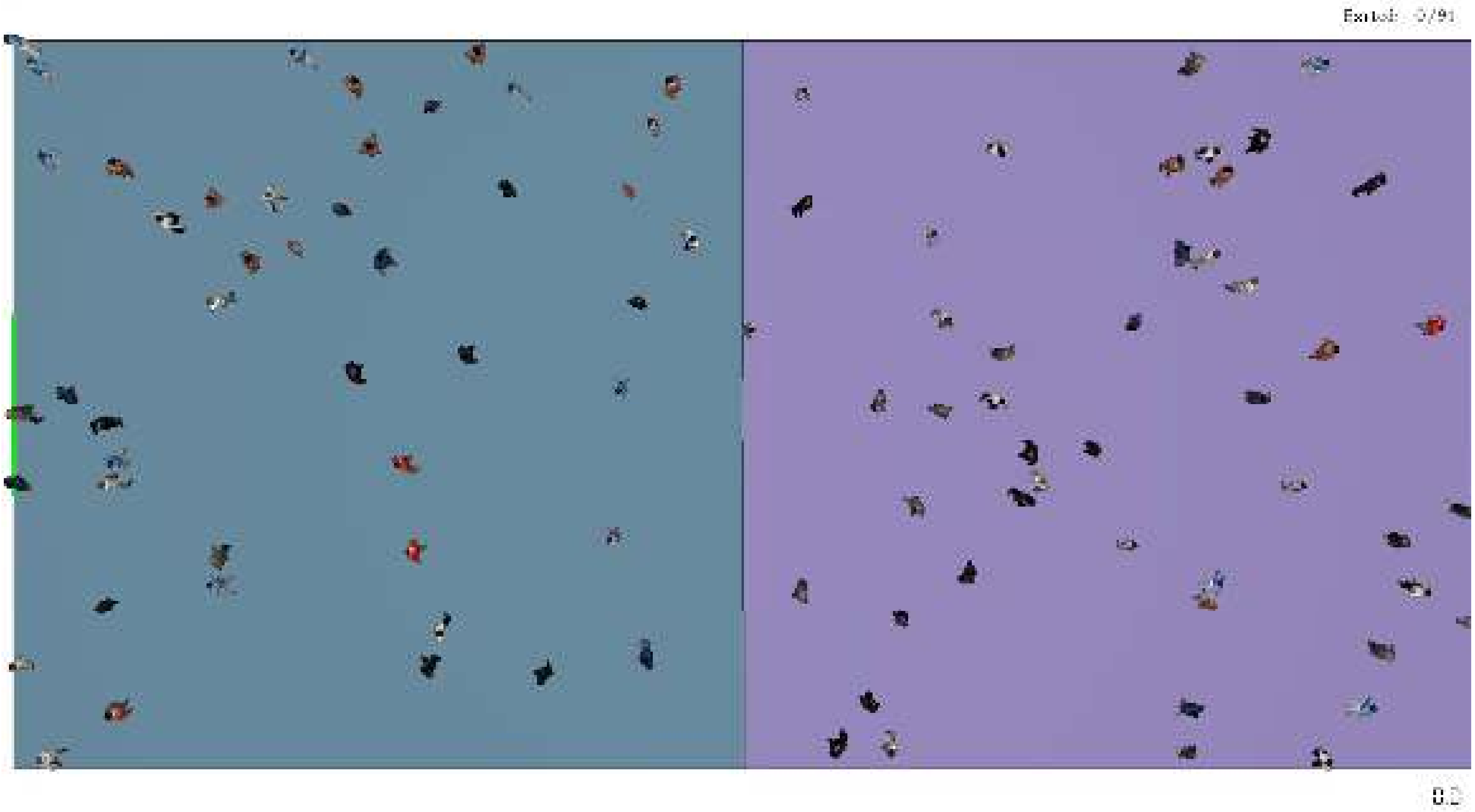
Employing the Hydraulic Model
in Assessing Emergency Movement

Pathfinder

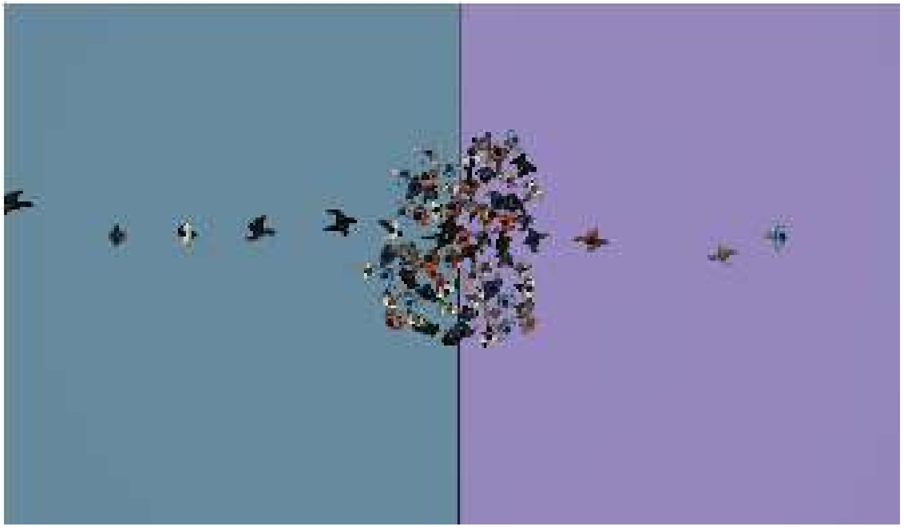
- Two simulation modes
  - Steering – the default in Pathfinder, agents use a steering system to move and interact with other agents in an attempt to emulate human behaviour
  - SFPE - uses a set of assumptions and hand-calculations from the SFPE Handbook, agents make no attempt to avoid one another and can interpenetrate



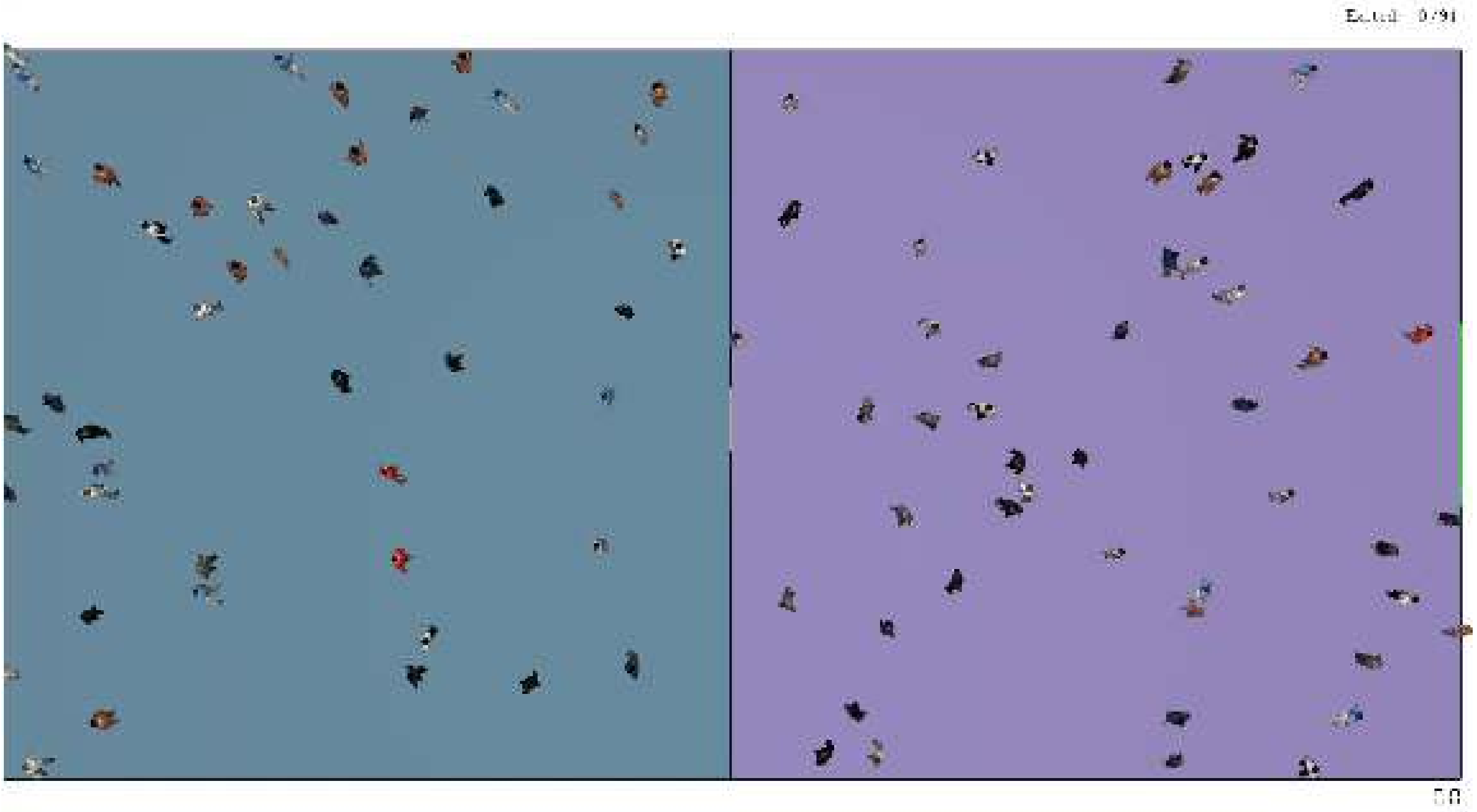
Pathfinder steering mode



Pathfinder steering mode

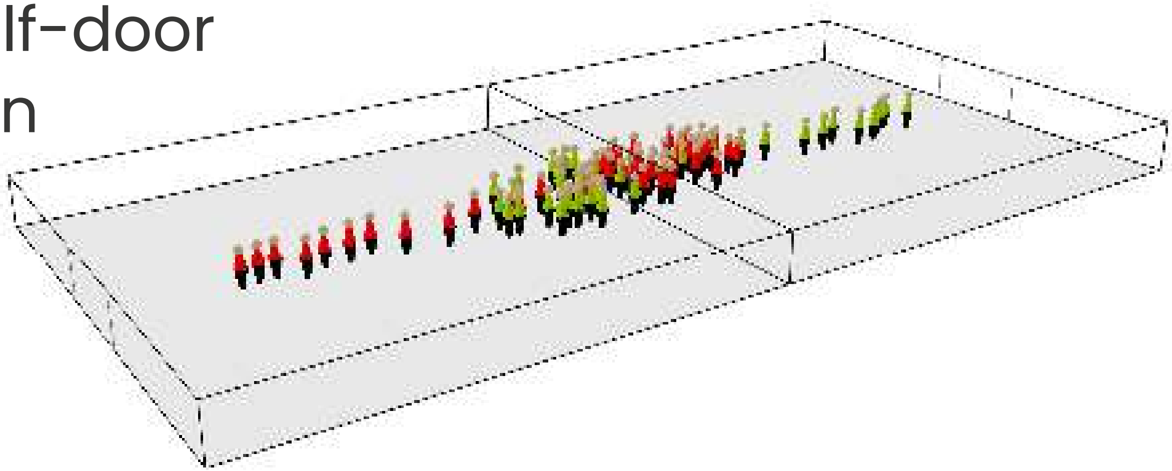


Pathfinder SFPE mode

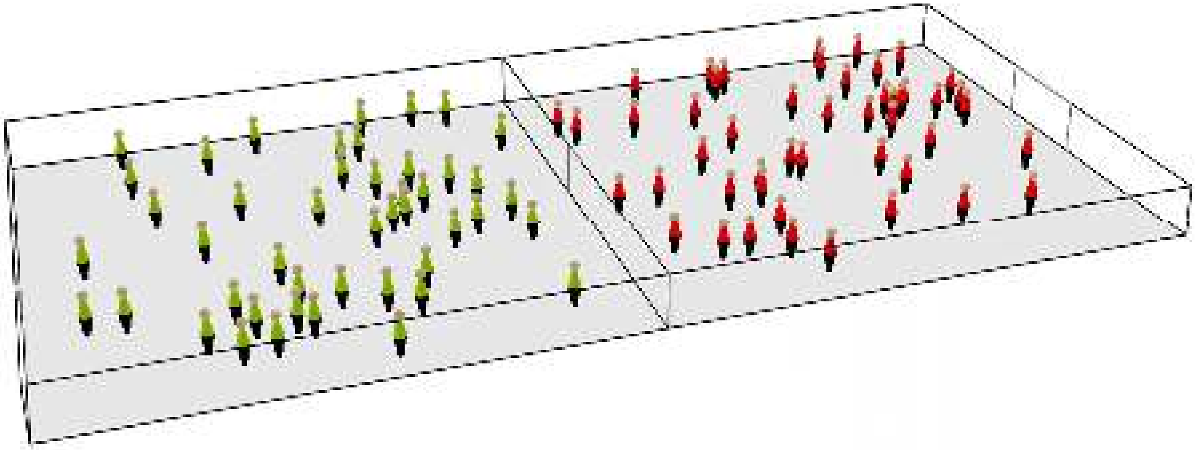


Evacuationz

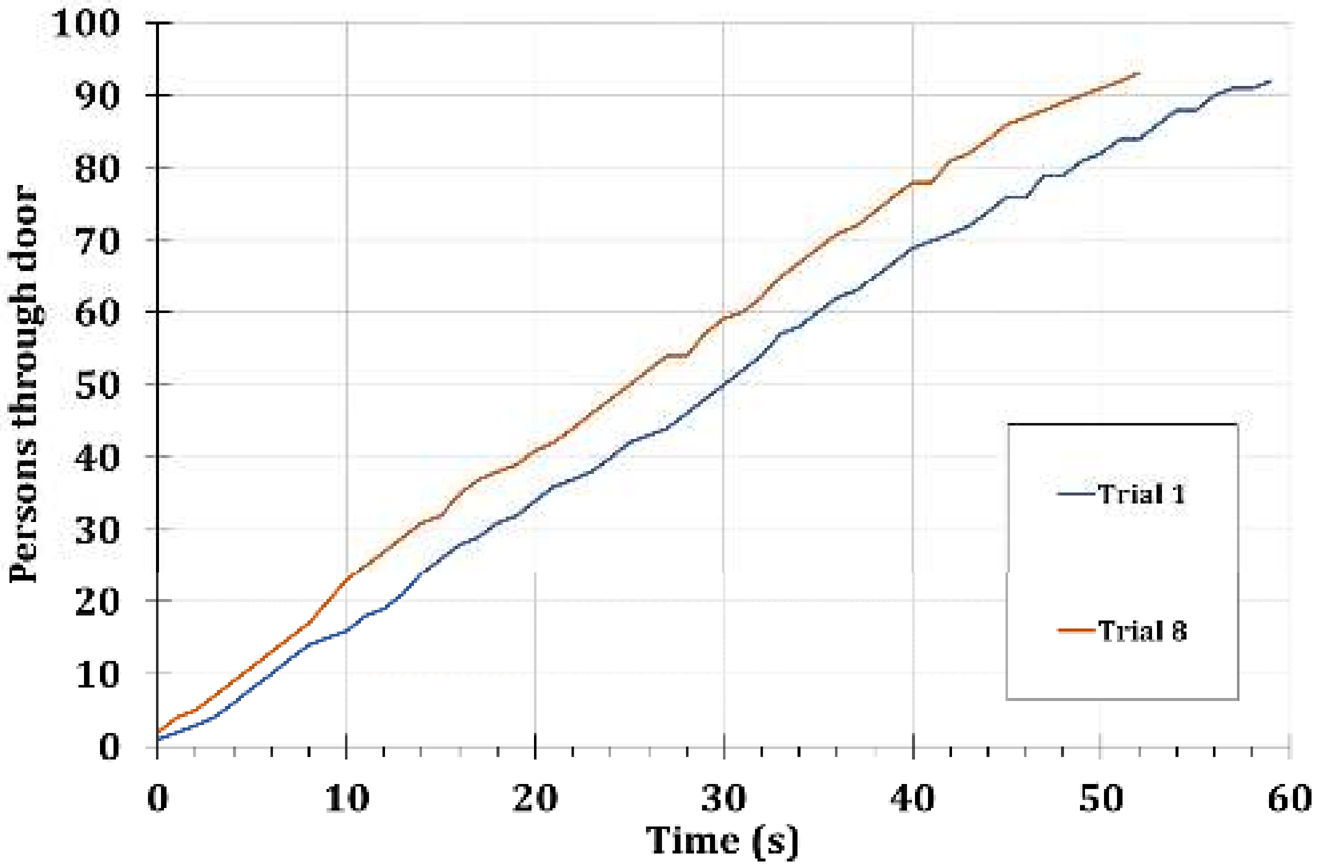
- Evauationz adopts the same principles as the SFPE mode in Pathfinder, imposing a flow limit and velocity through doors as a function of density. Again, agents can interpenetrate
- Adopts an equivalent half-door opening effective width in counterflow situations



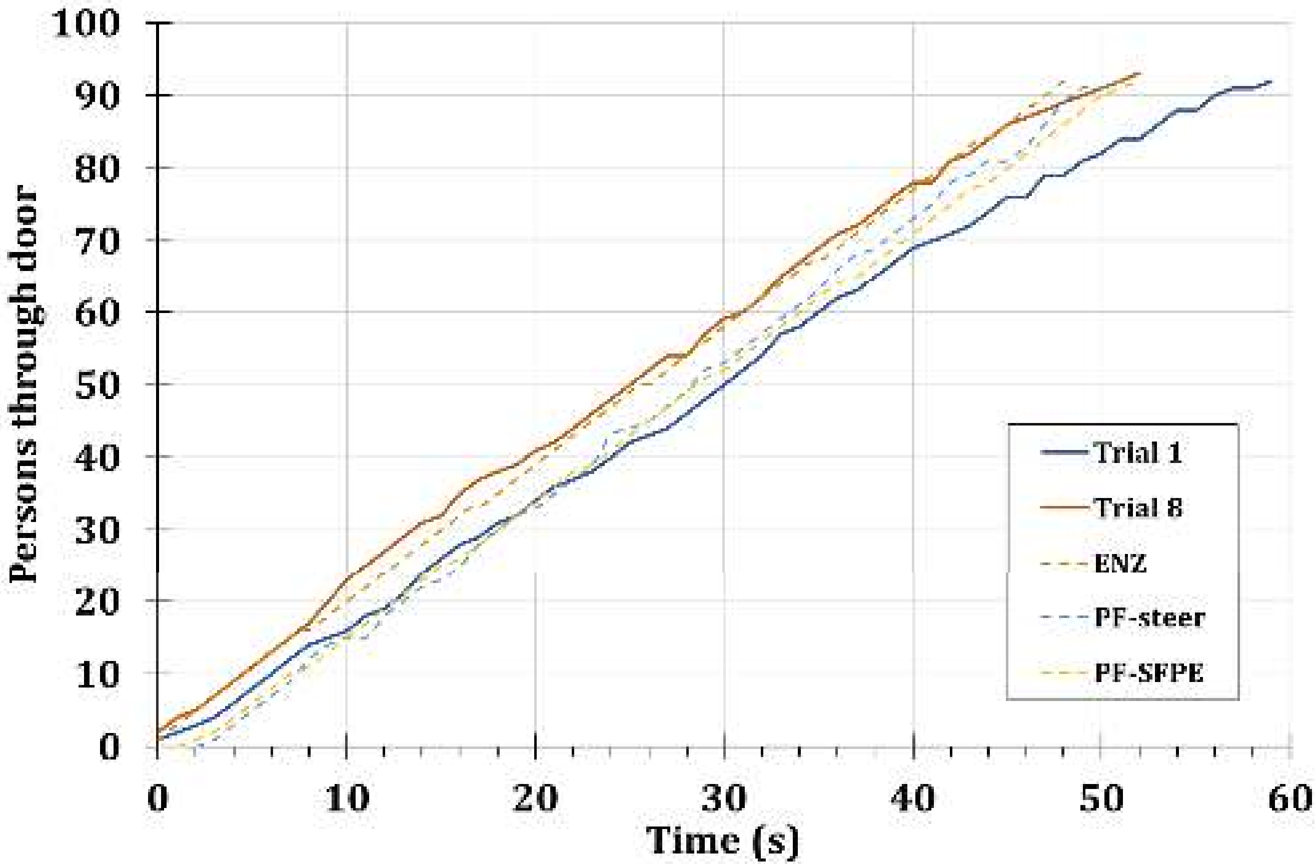
Evacuationz



Results - unidirectional



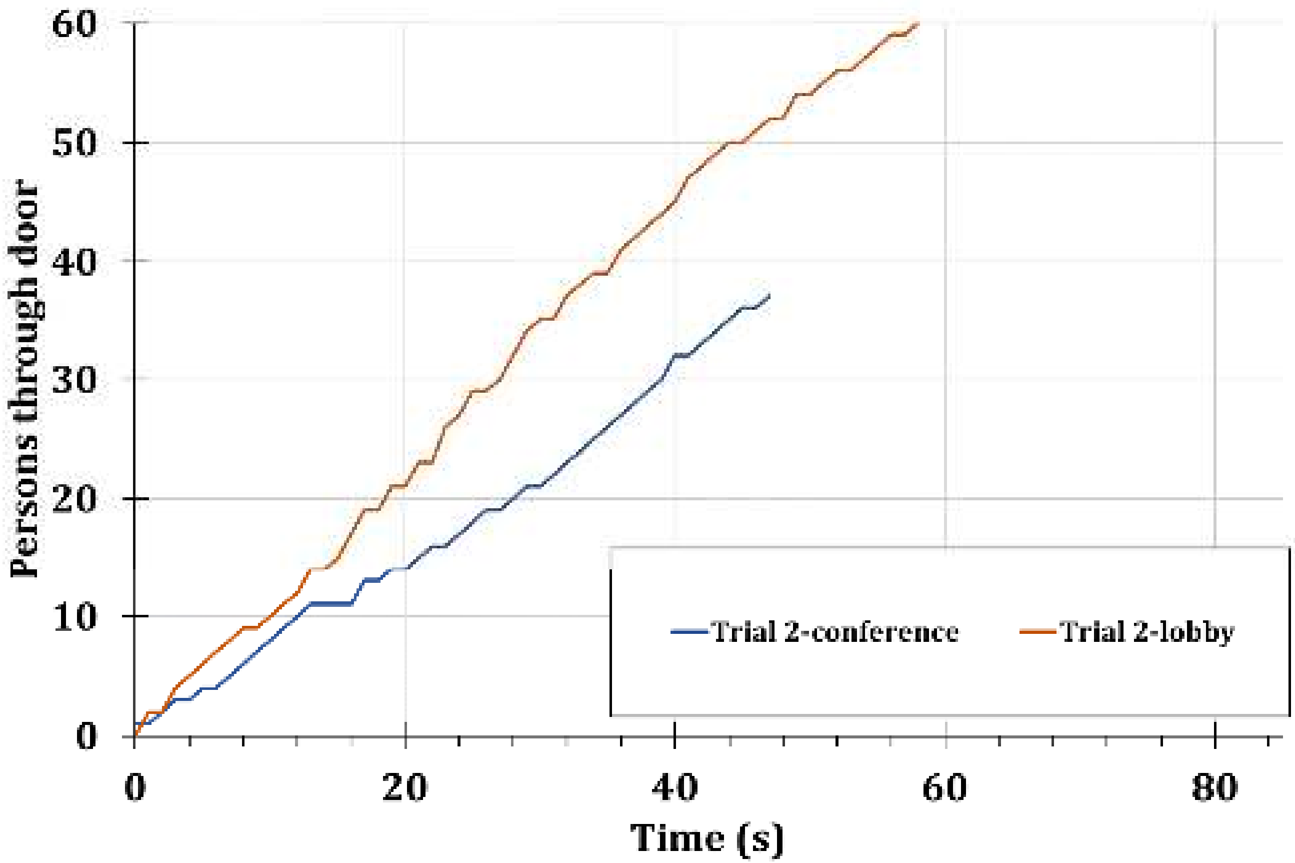
Results - unidirectional



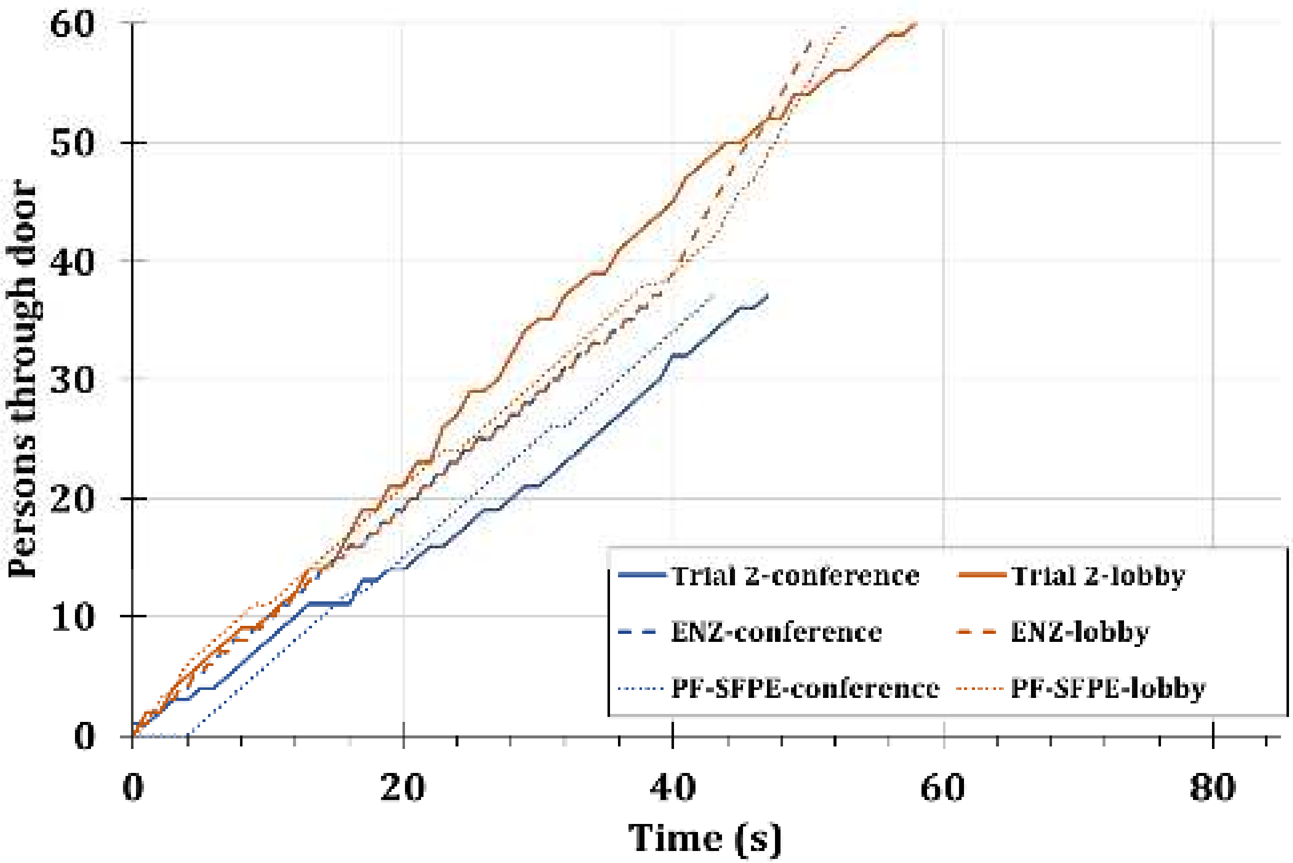
Results

- Trial 1 = 1.56 pers/s
- Trial 8 = 1.79 pers/s
- Hydraulic model = 1.85 pers/s
- Pathfinder (steering) = 1.80 pers/s
- Pathfinder (SFPE) = 1.77 pers/s
- Evacuationz = 1.92 pers/s

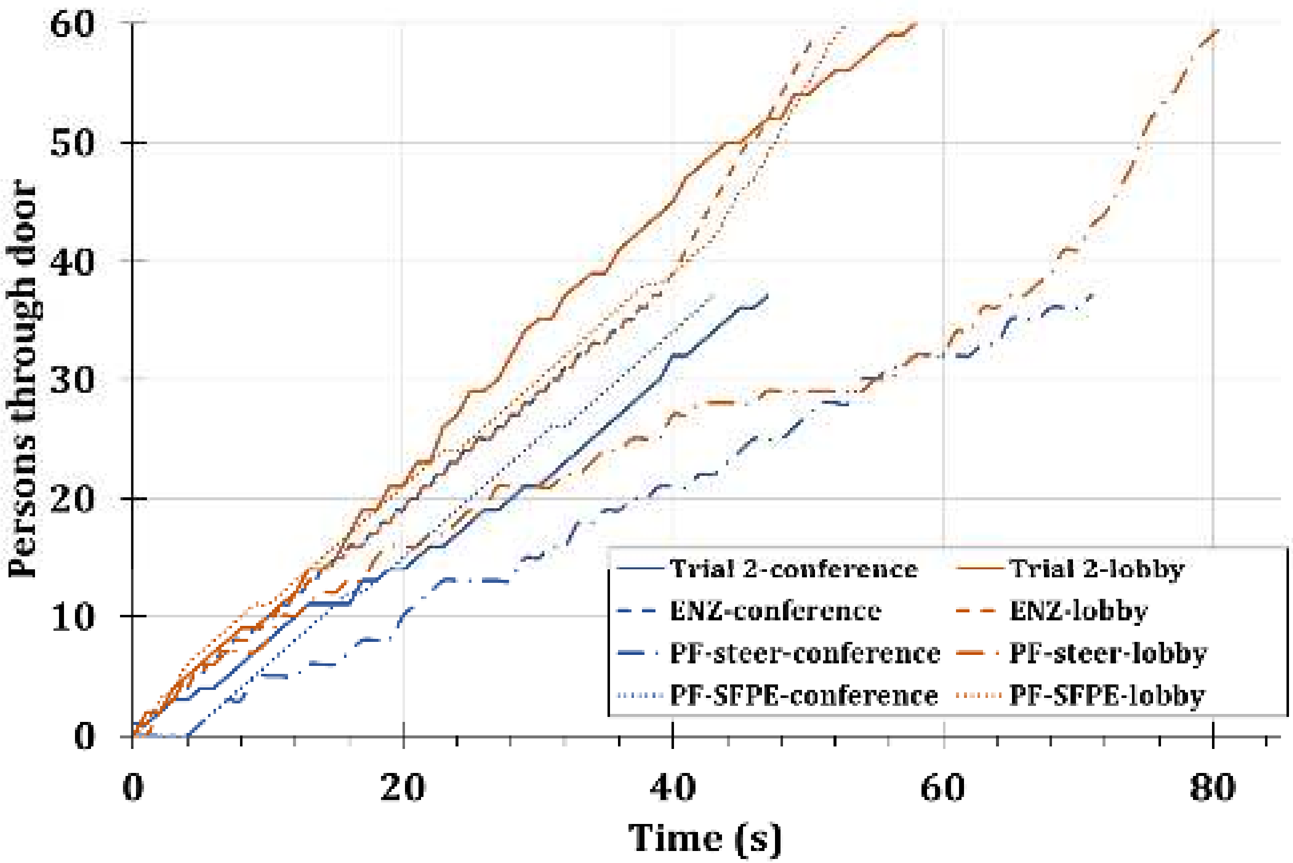
Results – random group counterflow



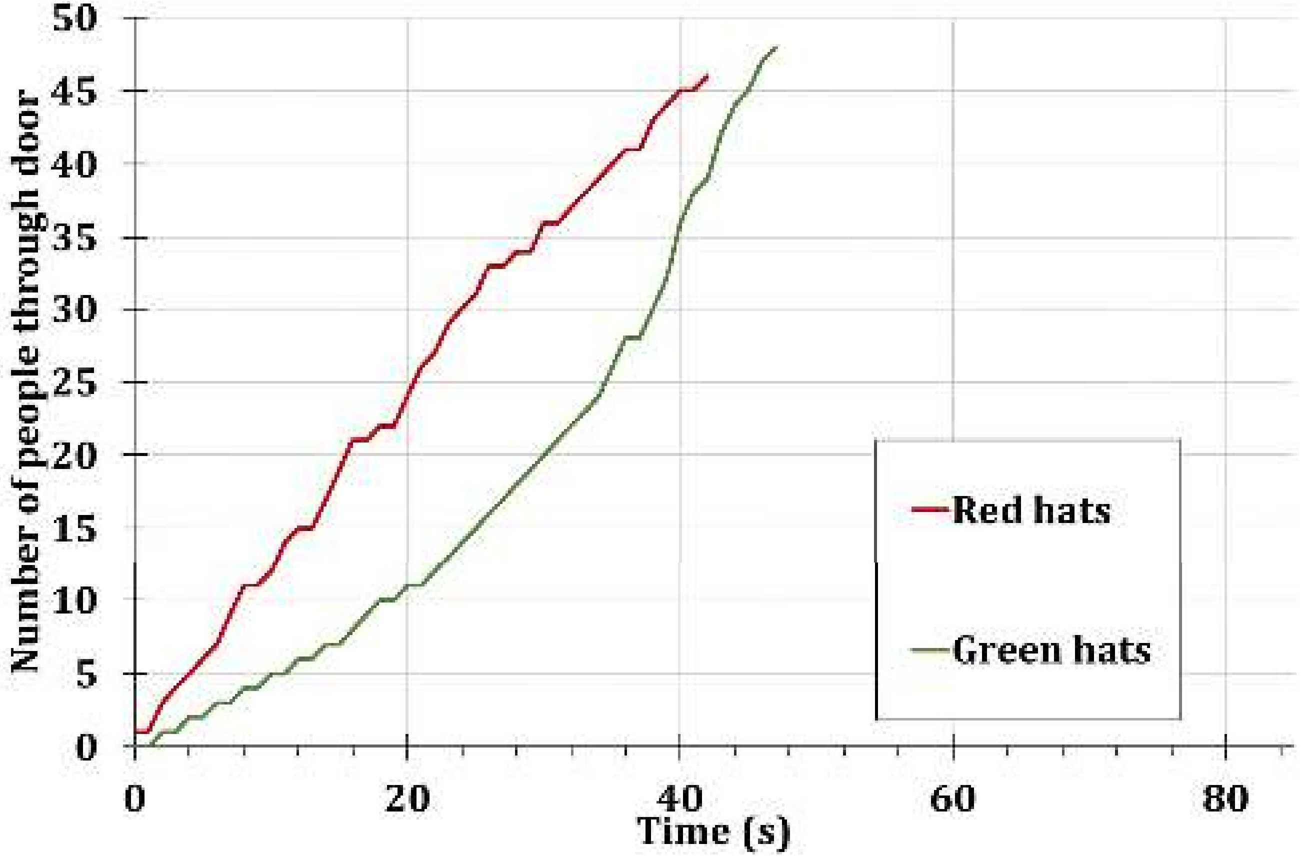
Results – random group counterflow



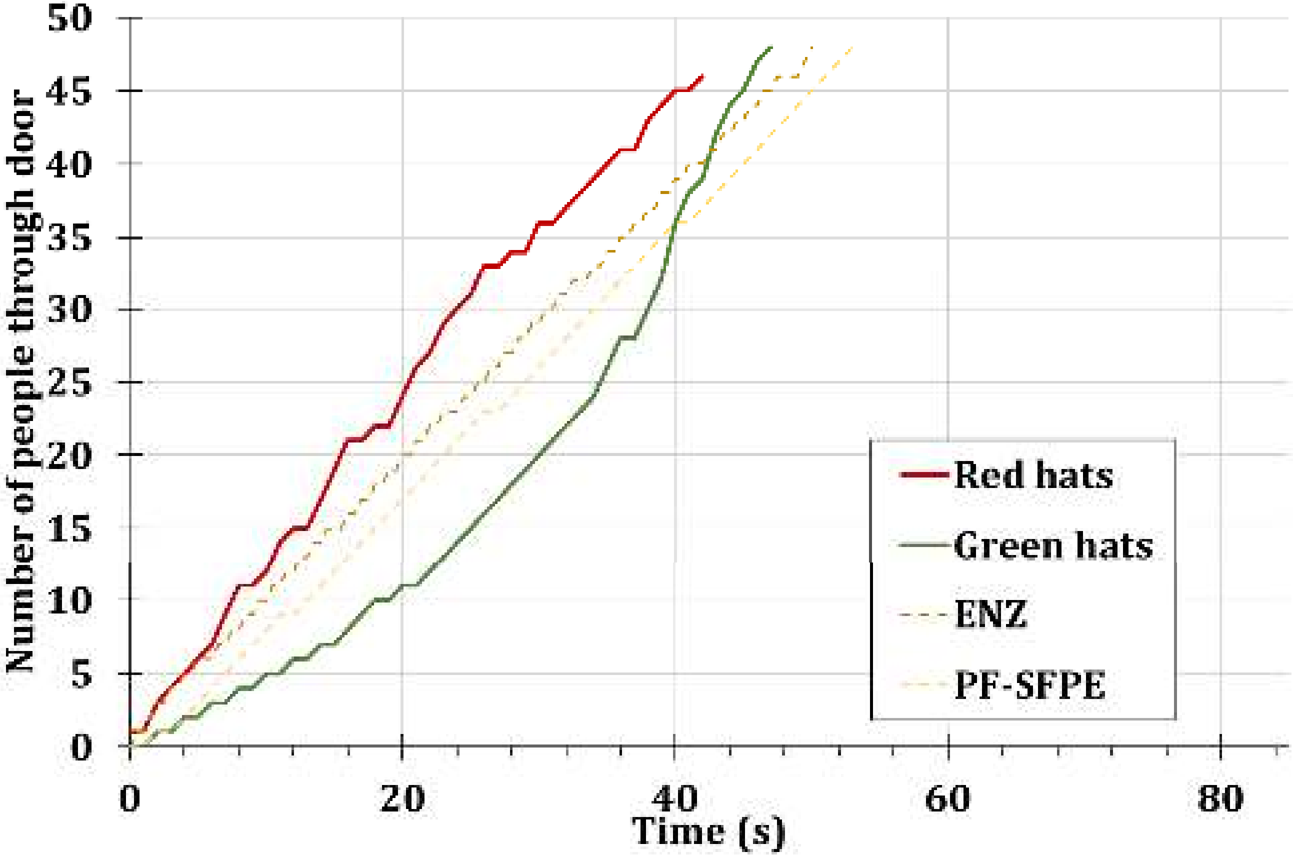
Results – random group counterflow



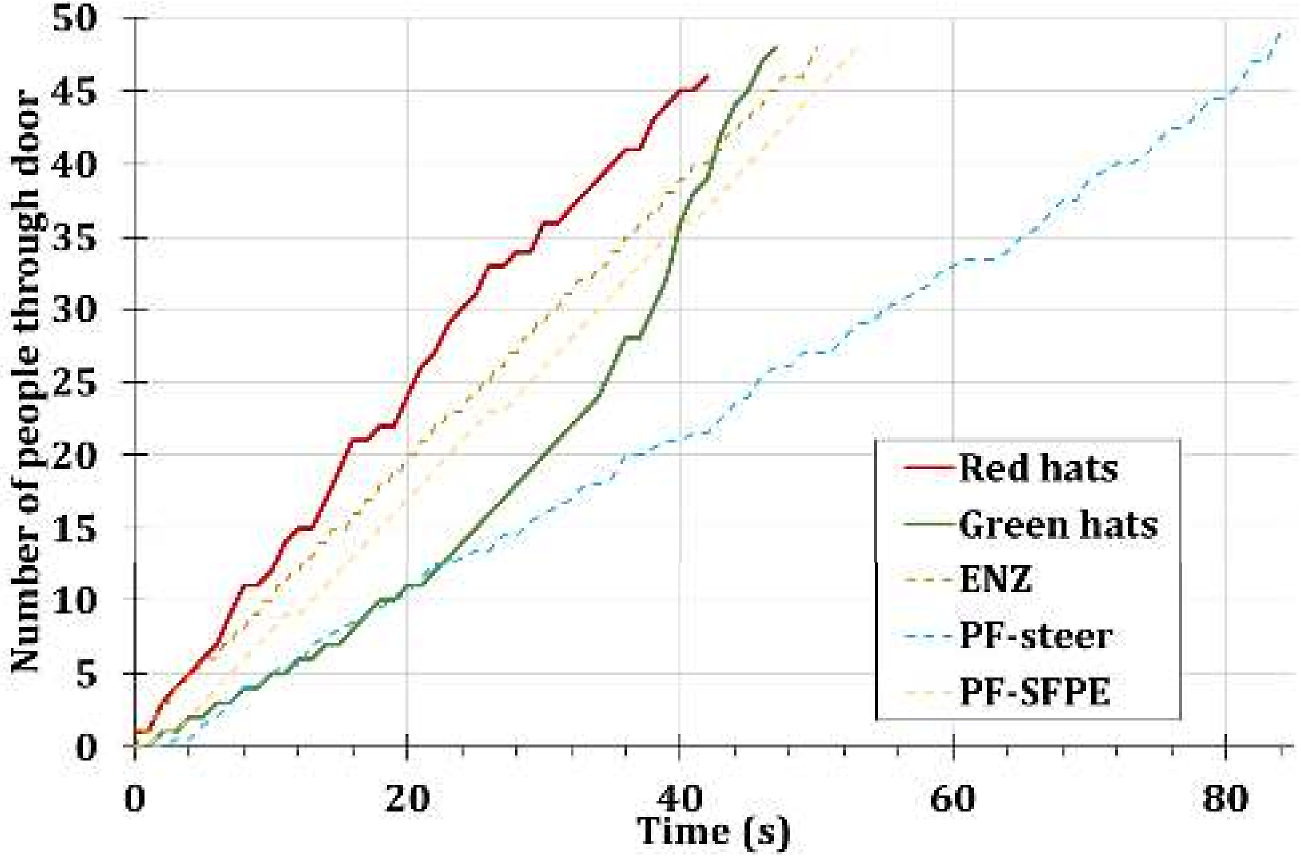
Results – in-group counterflow



Results – in-group counterflow



Results – in-group counterflow



Results

- Random trial average = 0.96 pers/s
- In-group trial average = 1.05 pers/s
- Hydraulic model = 0.92 pers/s
- Pathfinder (steering) = 0.57 pers/s
- Pathfinder (SFPE) = 0.90 pers/s
- Evacuationz = 0.96 pers/s

Results

- Random trial average = 0.96 pers/s
- In-group trial average = 1.05 pers/s
- Hydraulic model = 0.92 pers/s
- **Pathfinder (steering) = 0.57 pers/s**
- Pathfinder (SFPE) = 0.90 pers/s
- Evacuationz = 0.96 pers/s

Discussion – Pathfinder steering mode

- Consideration has been given to select variables that may affect the counterflow rate in steering mode:
  - The ability of agents to reduce their diameter to resolve congestion
  - The agents’ personal space factor

Conclusions

- A representative effective width for counterflow
  - Trial results suggest that counterflow rates through doorways are around 13-20% greater than assuming a half effective width
- Agent interaction that works in unidirectional flow can introduce challenges in counterflow
  - The steering mode in Pathfinder underpredicts the counterflow rate
- The group mentality dynamic
  - The flow is shown to increase when in-group psychological behaviour is introduced

Thanks for listening

Any questions?

Matt Arnott
OFR Consultants
Matthew.arnott@ofrconsultants.com