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CZECH TECHNICAL UNIVERSITY IN PRAGUE

Challenges In Train Evacuation Modelling Using Pathfinder

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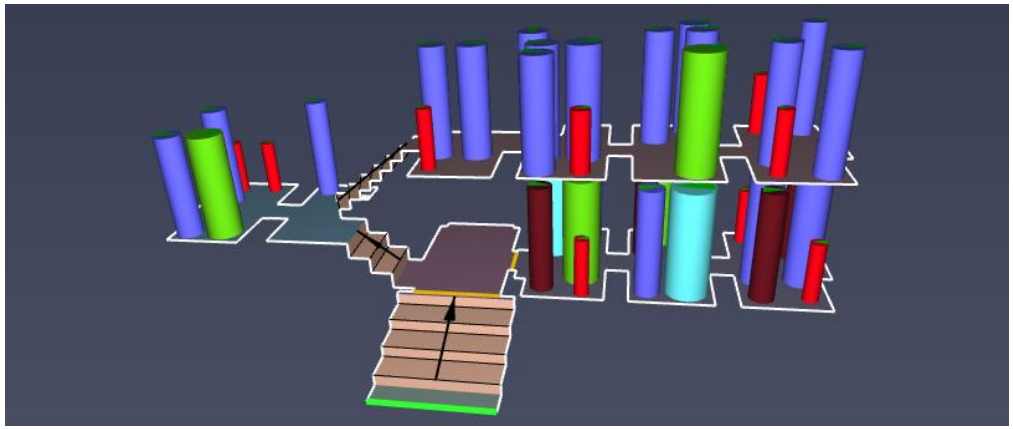
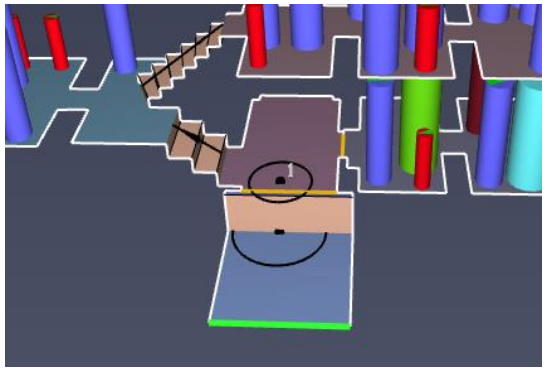
Introduction

Experiment

Pathfinder Model



Encountered challenges



Research Team

Pavel Hrabák
Random processes

Juraj Kmec
Informatics

Hana Najmanová
Fire Safety

Daniel Vašata
Statistical Physics

Full-scale evacuation experiment

H. Najmanová, L. Kuklík, V. Pešková, M. Bukáček, P. Hrabák, and D. Vašata, 'Evacuation trials from a double-deck electric train unit: Experimental data and sensitivity analysis', *Saf. Sci.*, vol. 146, p. 105523, Feb. 2022.

Exit width

0.65 – 1.34 m

Exit type

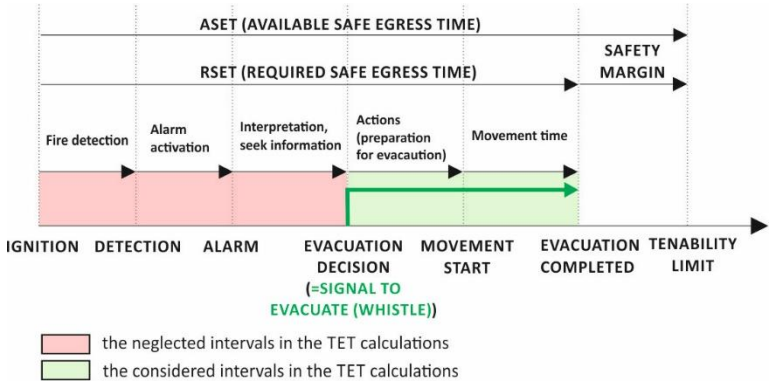
Crowd composition

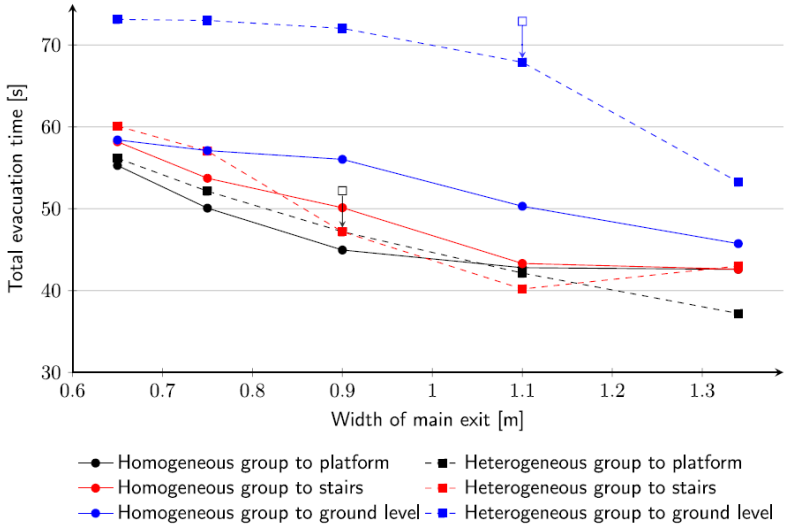
Altogether 30 evacuation scenarios, one trial each.

Total evacuation time investigated

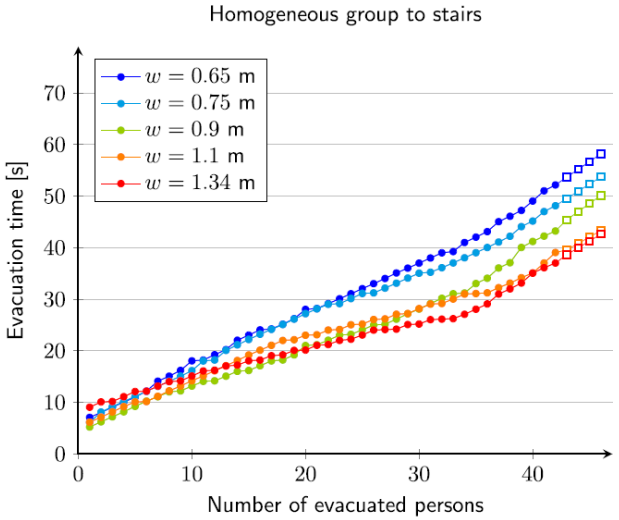
H. Najmanová, L. Kuklík, V. Pešková, M. Bukáček, P. Hrabák, and D. Vašata, 'Evacuation trials from a double-deck electric train unit: Experimental data and sensitivity analysis', *Saf. Sci.*, vol. 146, p. 105523, Feb. 2022.

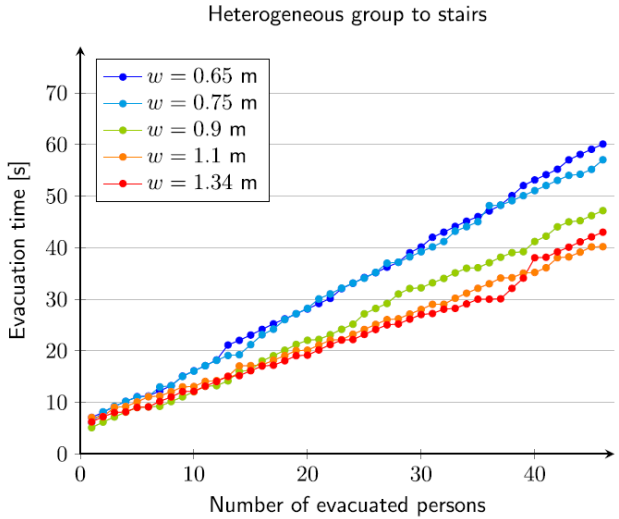
TET





Occupant-evacuation curves

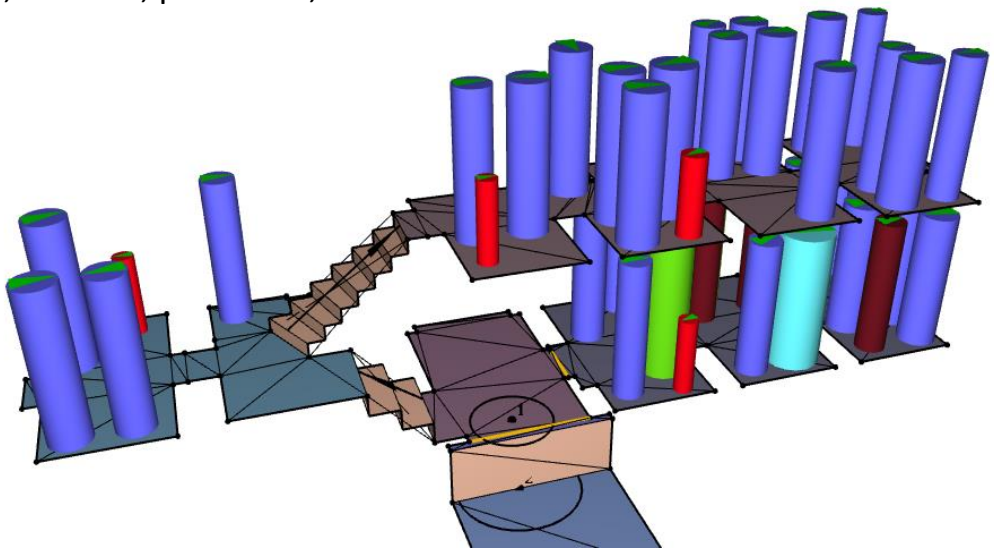




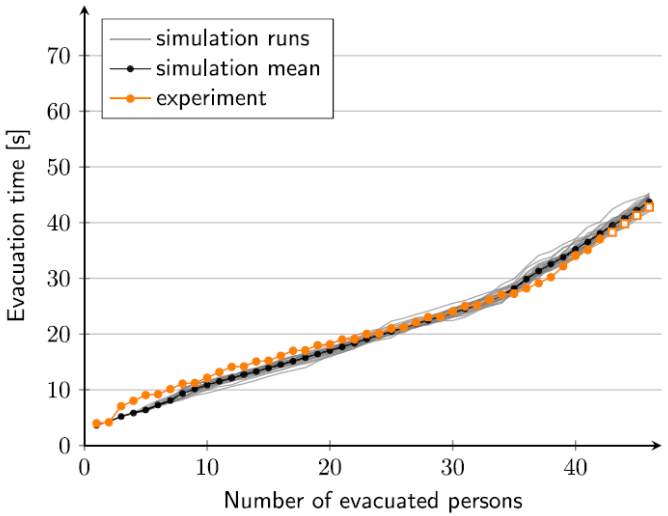
Supported by simulations

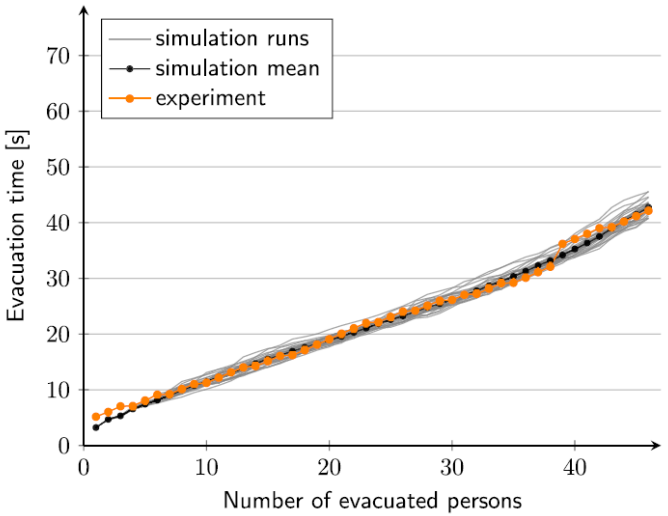
H. Najmanová, L. Kuklík, V. Pešková, M. Bukáček, P. Hrabák, and D. Vašata, ‘Evacuation trials from a double-deck electric train unit: Experimental data and sensitivity analysis’, *Saf. Sci.*, vol. 146, p. 105523, Feb. 2022.

Model in Pathfinder



Validation





Challenges encountered

Cramped interior layout with narrow aisles

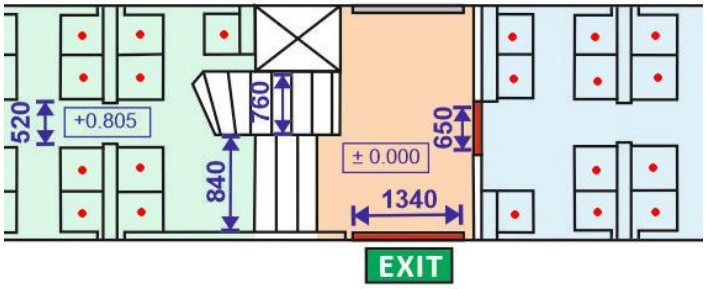
- How to model seats?
- Agent diameter significantly affects the evacuation process.
- Interaction with environment – high local density and speed reduction

Non-standard exit paths

- Navigating 750 mm drop – how to model it?
- Abilities significantly differing among heterogeneous population.

Specifically defined initial positions

- Initial positions defined by seats.
- How to randomize starting agent positions?



Sources of randomness and how to control them?

Variance caused by different seating positions

- Starting position in a rail car partially determines the order, in which passengers are exiting.
- Several initial positions are to be tested.
- Distribution of passengers of various types is important.
- How to capture it without necessity to generate positions manually?

Variance caused by uncertainty in the properties of the passengers

- Identical seats, identical composition of passenger types, yet variance in TET.
- Caused by different realization of parameter distribution.
- Significant influence in a rail-car due to cramped environment.

Variance caused by uncertainty in human behaviour

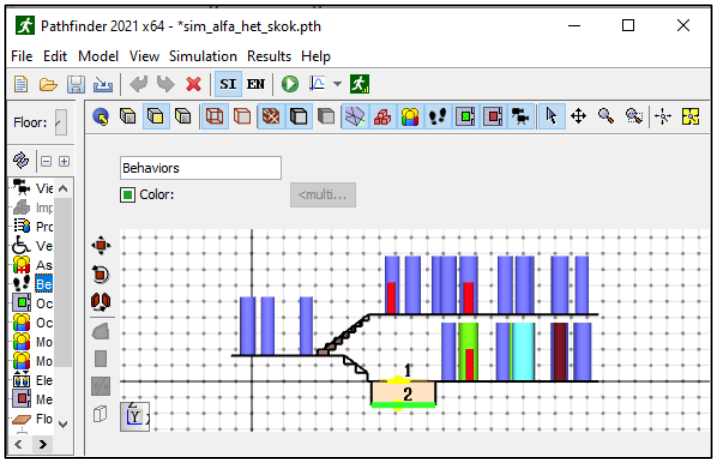
- Identical seats, identical passengers, identical boundary conditions, yet variance in TET.
- Caused by inherent randomness in human behavior.
- How to capture it in Pathfinder?

Technical solution in Pathfinder

Input file sim.txt

```
[version]
8

[param]
show_vis 0

dt_init      0.025
max_time     3600.0
...

[floors]
0: "Floor -3.6 m" -3.6
1: "Floor -0.75 m" -0.75
...

[navmesh]
0: 17 open 64 65 63
1: 17 open 63 65 62
2: 17 open 66 67 68
...

[behaviors]
0: {"name":"Goto Any Exit","script":"tag (last_goal_started); goto
1: {"name":"children","script":"goto point (4.597665821051589, 0.24
2: {"name":"with todler","script":"goto point (4.597665821051589, 0
3: {"name":"seniors","script":"goto point (4.597665821051589, 0.247
4: {"name":"disabilities","script":"goto point (4.597665821051589,

[profiles]
0: {"OccProfile.RESTRICTED_COMPONENTS":0,"OccProfile.DIAMETER":1,"O
1: {"OccProfile.HEIGHT":4,"OccProfile.DIAMETER":3,"OccProfile.COLOR
2: {"OccProfile.DIAMETER":6,"OccProfile.FUNDAMENTAL":0,"OccProfile.
3: {"OccProfile.RESTRICTED_COMPONENTS":2,"OccProfile.DIAMETER":8,"O
4: {"OccProfile.DIAMETER":9,"OccProfile.MIN_SQUEEZE_FACTOR_CONST":0

[functions]
0: {"val":1.0,"type":"const"}
1: {"x":[0.0,0.5,0.541,0.638,0.748,1.8],"y":[1.0,0.8785714285714287
...

[distributions]
0: {"min":"0.67 m\/s","max":"1.56 m\/s","mean":"0.94 m\/s","type":"
1: {"min":"38.0 cm","max":"58.0 cm","mean":"45.7 cm","type":"stdNor
2: {"val":"1.32 m\/s","type":"cc"}
...

[occupants]
0:
1:
2:
...
```

Pathfinder GUI



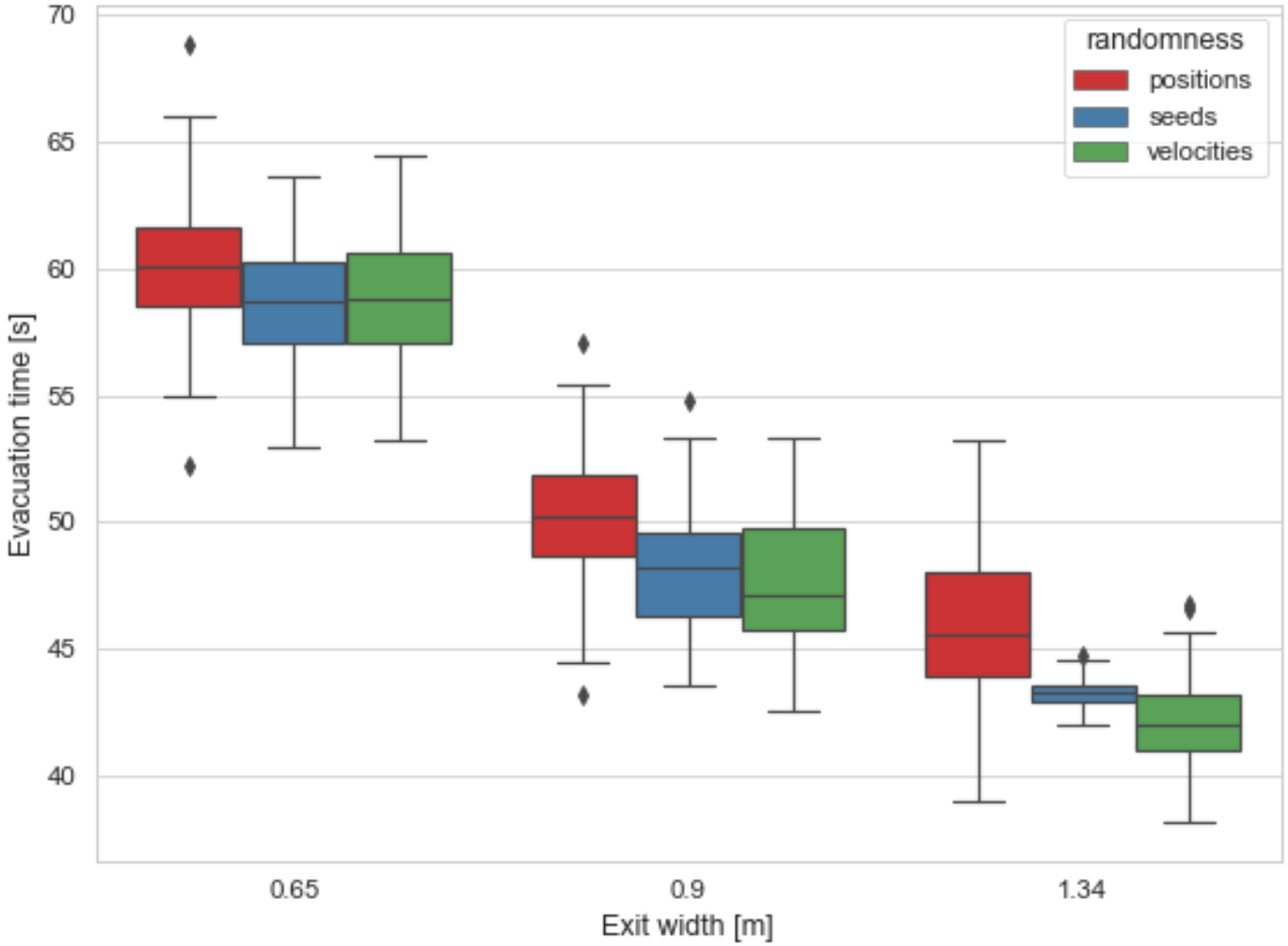
Python occupant generator

- Random seat
- Random parameters
- Inherent randomness

```
NewOcc:{
 "loc":"10.3 0.3 2.085",
 "OccProfile.MAXVEL":"0.9634",
 "rseed":5068836496919502848,
 "OccProfile.PRIORITY_LEVEL":"0.0923"
}
```

Influence of sourcess of randomness

100 simulations per source of randomness



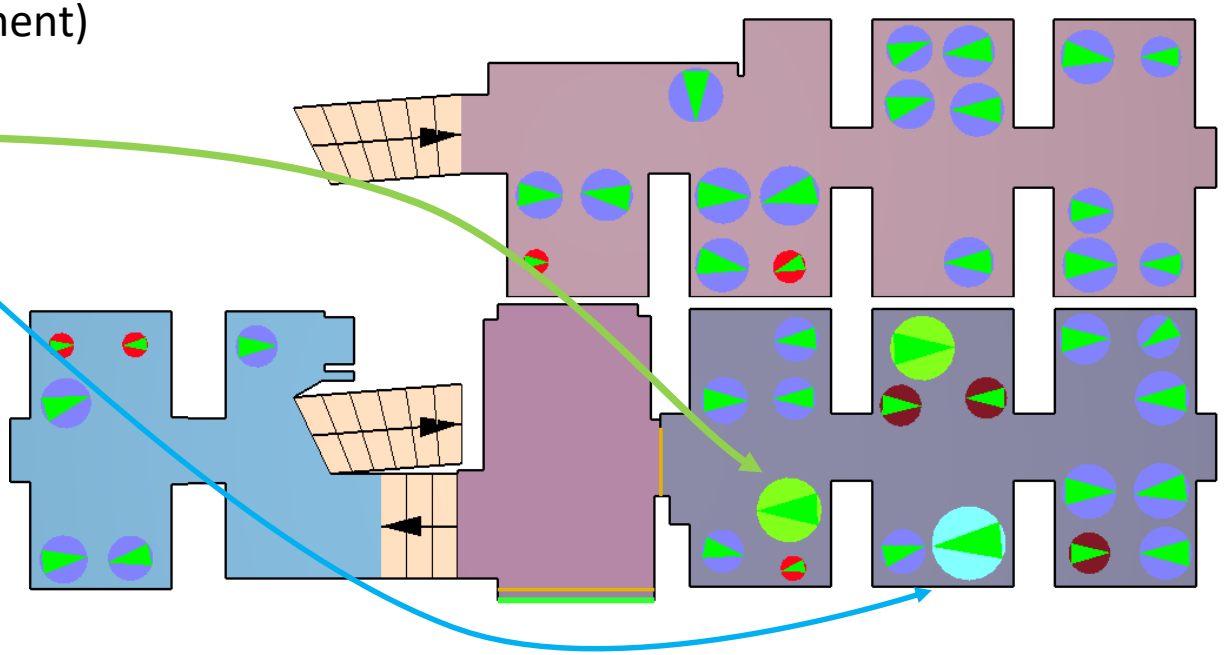
Cramped interior layout

Modelling seats

- Most realistic simulation – ommiting the seats, modelling seat backs as impenetrable obstacle or wall
- Seat positions defining potential starting positions of agents

Agent diameter plays important role

- Heterogeneity captured by speed, diameter, and ability to overcome the jump
- Diameter associated with shoulder width (measured before experiment)
- For agent types
  „Carrying todler“,
  „With disabilities“
  necessary to adjust **sqeeze factor** and reduction due to **narrow geometries**

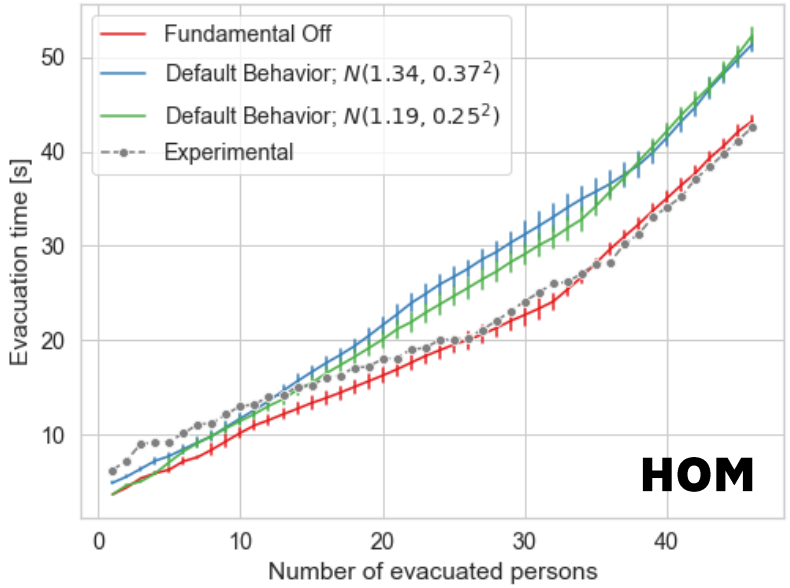


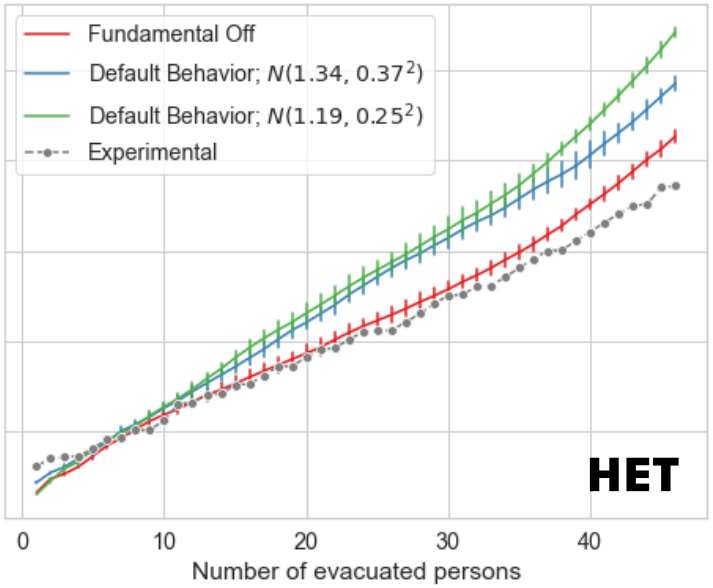
SFPE curve for desired speed

Applying SFPE speed-density relation overestimates TET

- For design mean speed 1.19 m/s
- But even for free space mean speed 1.34 m/s
- Unrestricted movement speed of HOM passengers walking in a line in the aisle measured during experiment - 0.94 m/s
- Applied as desired speed for agent type „Without limitations“ SFPE relation turned OFF.

Comparing approaches for width 1.34 m and platfom exit type





Non-standard exit path – jump

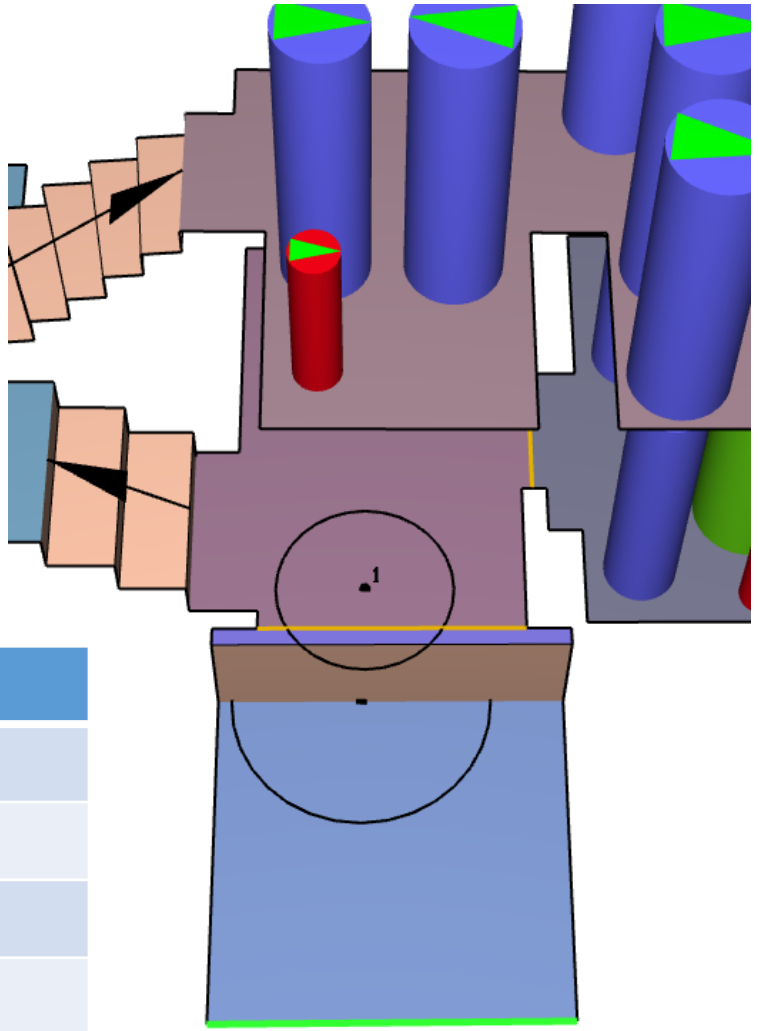
No problem for passengers without movement limitations

Hesitation and balance delay differing for passengers with limitations

How did we solve it?

Behavior according to agent type

- goto point 1 [before jump];
- wait [hesitation delay];
- goto point 2 [behind jump];
- wait [balance delay];
- goto exit any



Delays measured in experiment

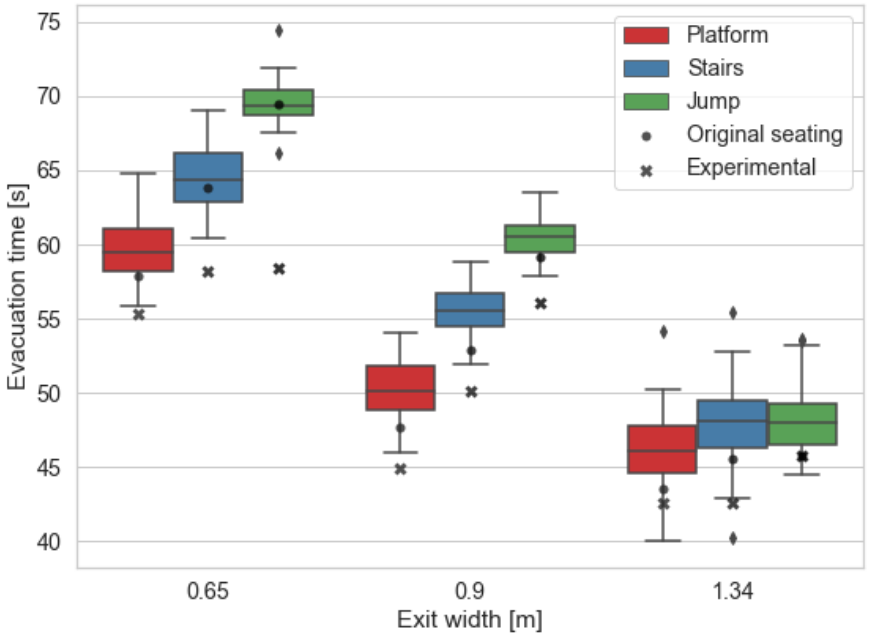
Type	Hesitation	Balance
Children	2.5 s	0.5 s
Carrying todler	1.5 s	0.5 s
Seniors	2.0	1.0 s
With disabilities	1.5	0.75 s

Influence of seating positions

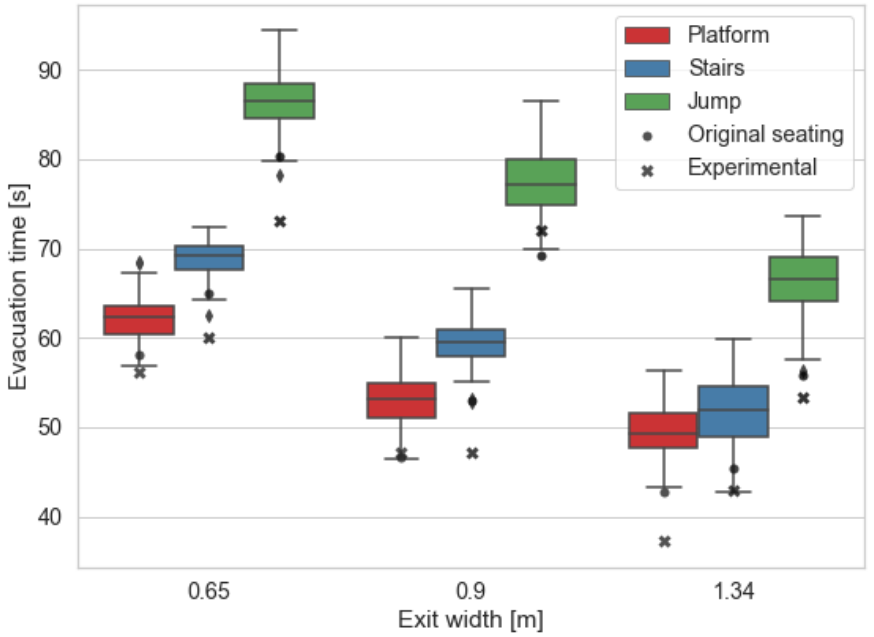
Random generation of initial agent positions

- All potential seating positions stored in CSV file
- Initial positions generated randomly from the file
- Original (experimental) seating configuration leads to significantly shorter evacuation

Homogeneous group



Heterogeneous group

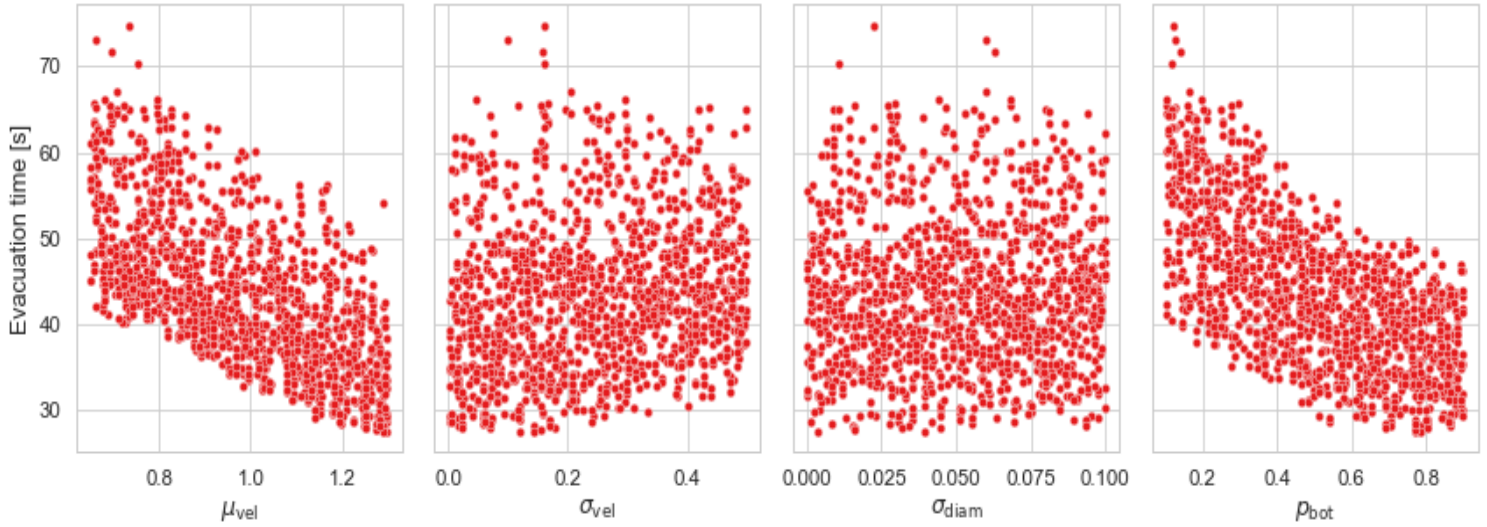


Global sensitivity analysis

Sobol sensitivity indices (by means of SALib)

	μ_{vel}		σ_{vel}		σ_{diam}		p_{low}	
	S_1	S_T	S_1	S_T	S_1	S_T	S_1	S_T
0.65m	**0.793**	**0.955**	**0.078**	**0.130**	**0.044**	**0.099**	**0.090**	**0.155**
0.90m	**0.535**	**0.615**	**0.013**	**0.123**	**-0.001**	**0.083**	**0.270**	**0.396**
1.34m	**0.437**	**0.528**	**0.042**	**0.117**	**0.001**	**0.045**	**0.476**	**0.583**

Scatter-plots of TETs for width 1.34 m



Conclusions and future work

Challenges in train evacuation in Pathfinder

- Identified
- Issue described, some solutions suggested

Automatic generation of different realisations

- Achieved using external Python script running simulation via command line
- Enables to control three sources of randomness

Analyses

- SFPE curve overestimates TET – some research on velocity-density relation in cramped interior would be beneficial
- Seating positions significantly affects TET (with similar importance as exit width) – some research on seating preferences needed

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Thank you for your attention