Investigation of the capacity of train stations in case of a large-scale emergency evacuation

MAY 15, 2019 | Anna Tscherniewski, Mohcine Chraibi, Lukas Arnold

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Background

- Nature and human made hazards:
  - hurricanes, floods …
  - terroristic attacks, incidents in nuclear power plants …
- Large-scale evacuations carried out with only private / road dependant vehicles:
  - Many people have no access to private vehicles.
  - Not enough bus drivers
  - Limited road capacity
  - Large congestions, lack of fuel, accidents …
- ‘AG Fukushima’ recommends the use of trains for large-scale evacuations.
- Capacity of train stations for large-scale evacuations is unknown.
- Capacity = evacuees[1] / hour

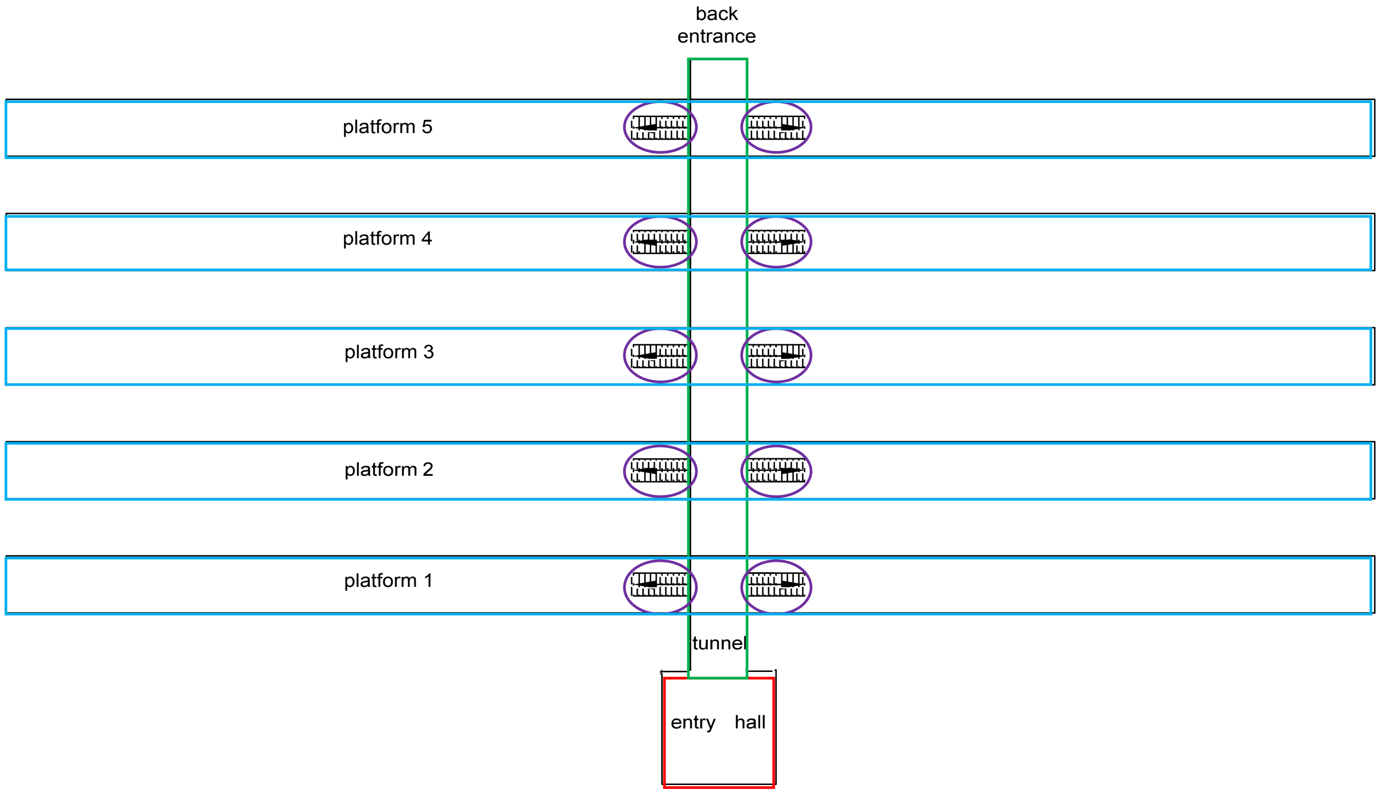
[1] Evacuees = people who leave a threatened area by train

Jülich Pedestrian Simulator - JuPedSim

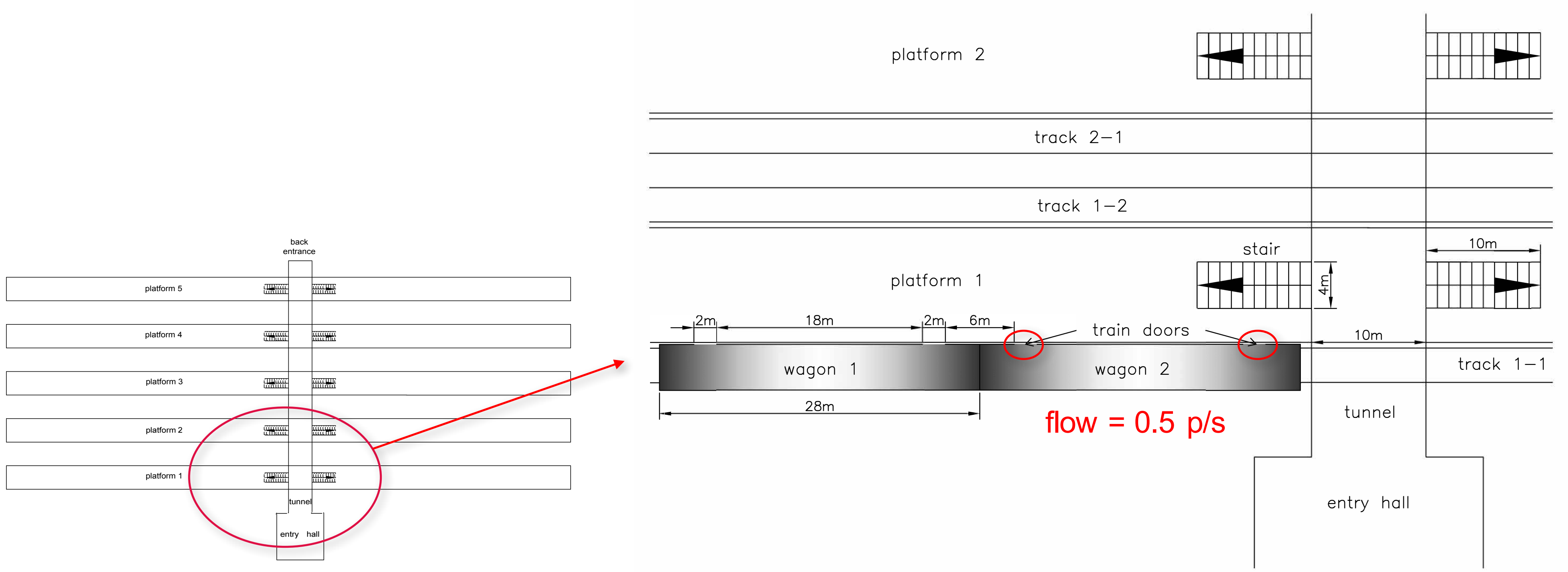
- Developed at the Research Center Jülich
- Free software for pedestrian dynamics
- Before: Only buildings' evacuations
- New: Waiting areas for pedestrian movement in stations in case of a large-scale evacuation
- Pedestrians = agents
  - Individual parameters (shoulder width, velocity …)

- Modified floor field router
- Collision-free-speed model:
  - No overlapping with other agents or walls
  - Self-organisation phenomena like lane formation or clogging

Setup


back
entrance
platform 5
platform 4
platform 3
platform 2
platform 1
tunnel
entry hall

Setup - Detail



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Simulations

- Aim: finding critical bottlenecks and the capacity for the train station
- No daily business – only evacuation trains
- Particularities:
  - Passengers carry a lot of luggage → walking speed decreases, space increases
  - Empty trains and huge number of passengers → increased boarding times
  - Limited capacity/space in the building and on the platforms → inflow restrictions and waiting areas
  - Departure only in specified direction → limited tracks → increased waiting times

- Assumption:
  - Passengers act rational at any time
  - No panic or similar occur
  - Enough trains and train drivers for the evacuation

Simulations

- 5 setups with different operational options:

Setup	Waiting Areas	Train departure interval	Entrances	Specified goals
1a	none	none	2	yes: ½, no: ½
1b	none	5 min	1	yes: ½, no: ½
2a	wt_{hall}: 60 s, $wt_{tunnel:}$ 120 s	5 min	1	all
2b	wt_{hall}: 60 s, $wt_{tunnel:}$ 120 s	10 min	1	all
2c	wt_{hall}: 60 s, $wt_{tunnel:}$ 0 s	10 min	1	all

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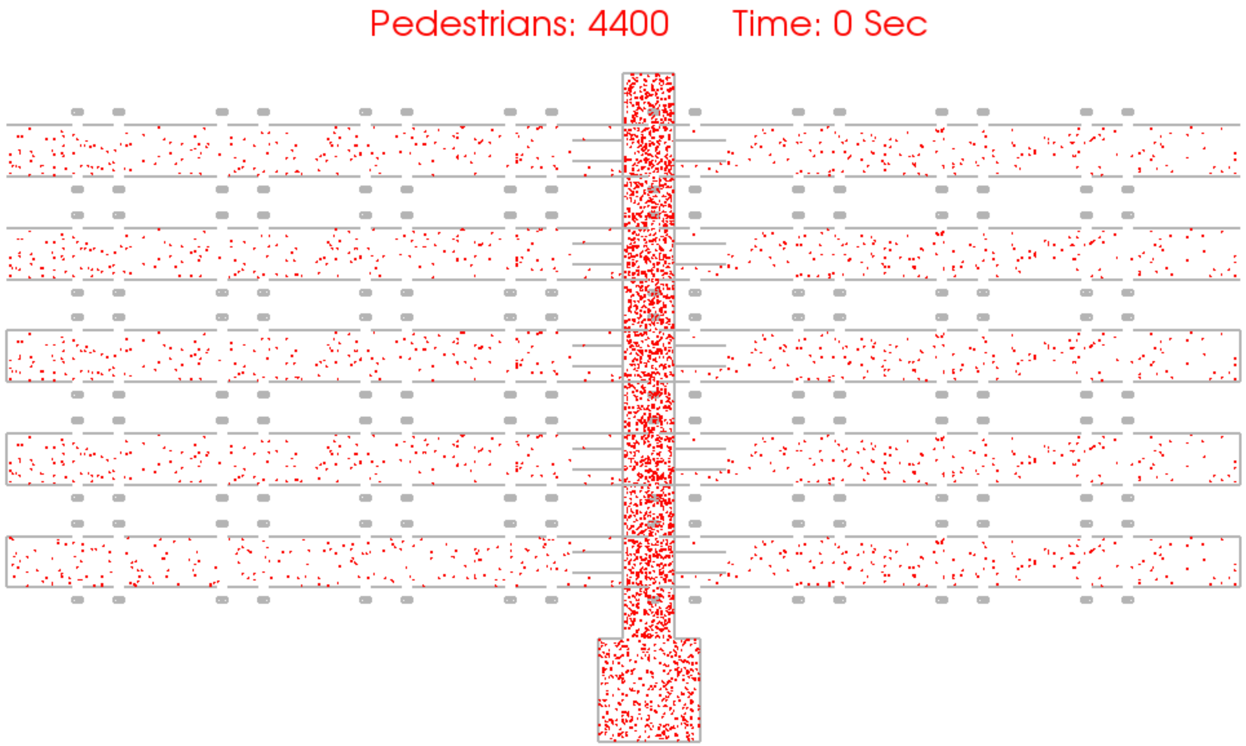
Setup 1a

- No operational options
- 4400 agents:
  - ½ have a defined goal
  - ½ take the first / nearest train
- Random distribution in the station
- Distribution in the tunnel corresponds to the usage of both entrances

- Result:
  - Bidirectional flow
  - Congestion in the middle of the tunnel
    → takes 15 minutes to dissolve



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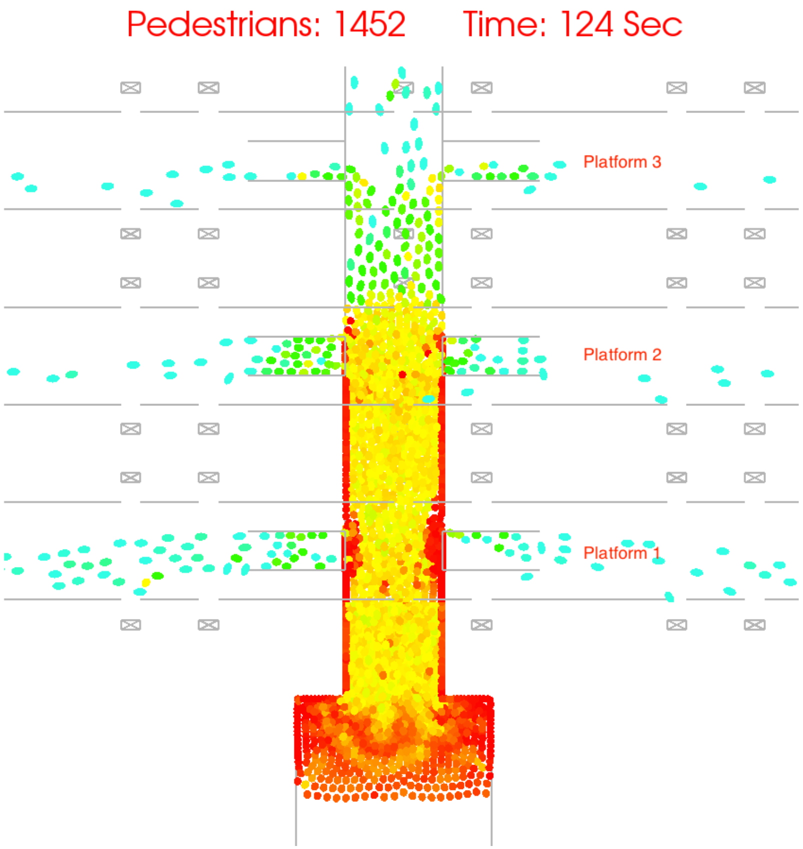
Setup 1b

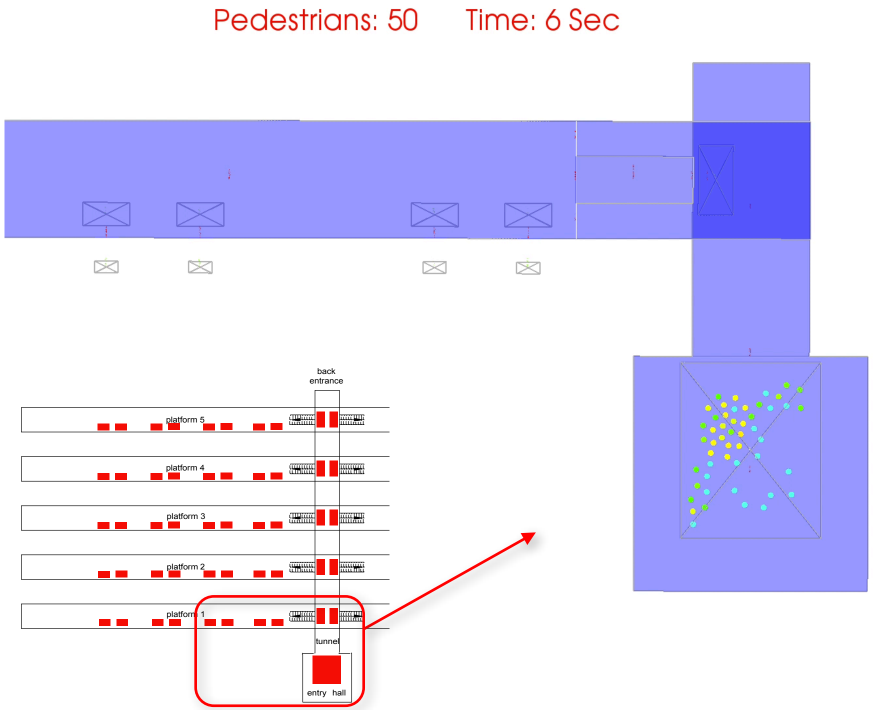
- Back entrance closed
- 3200 agents (640 agents/train)
  - ½ have a defined goal
  - ½ take the first / nearest train
- Random distribution in the station
- More agents in the entrance hall
- Train departure interval of 5 minutes

- Result:
  - Congestion between tunnel entrance and first platforms → takes 4 minutes to dissolve
  - Last boarding after 7 minutes



Setups 2a - c

- Operational options:
  - Waiting areas in the entry hall and the tunnel
    → Barriers to regulate the inflow to the different sections
  - Waiting areas on the platforms
    → Distribution of the agents at the platform edges
- Agents:
  - 1600 agents distributed in the tunnel
  - 1600 agents added with a frequency of 160 agents every 10 seconds
  - 3200 agents added per interval (train arrival) with a frequency of 320 agents every 20 seconds
  - All agents have a defined goal



Setups 2a - c

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Setups 2a and 2b

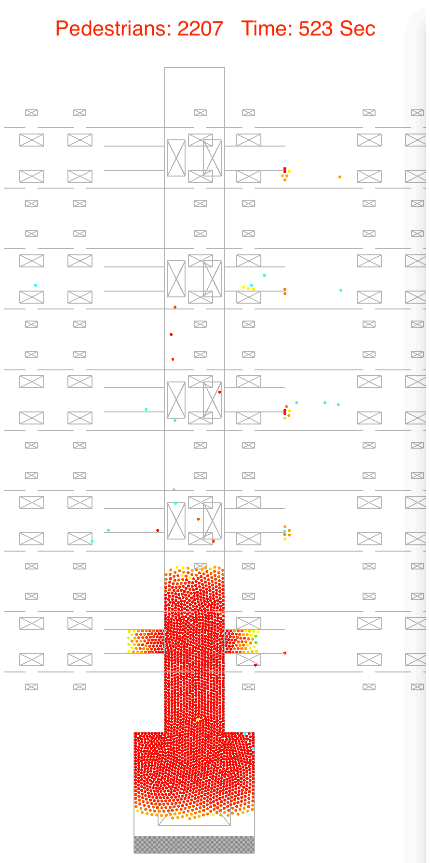
<u>Setups 2a and 2b</u>

- Waiting times:
  - $wt_{hall} = 60$ s
  - $wt_{tunnel} = 120$ s
- Train departure (2a) = 5 minutes
- Train departure (2b) = 10 minutes

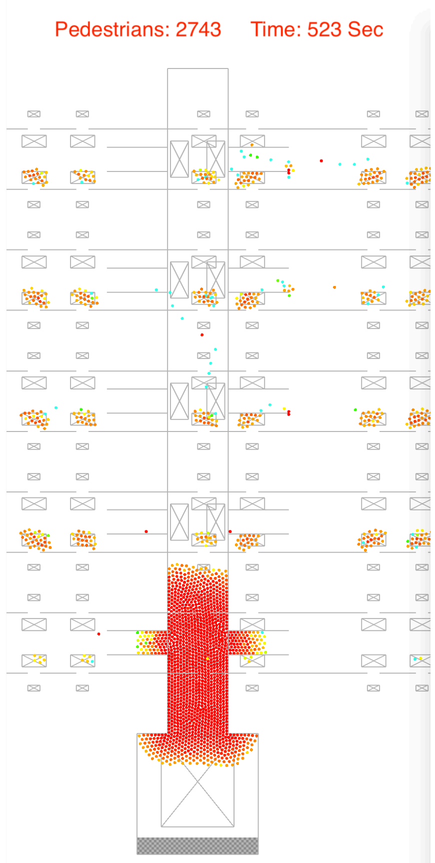
- Result:
  - Congestion between tunnel entrance and first platforms is not dissolved when the next agents were added

    → To high waiting times, to short train departure interval

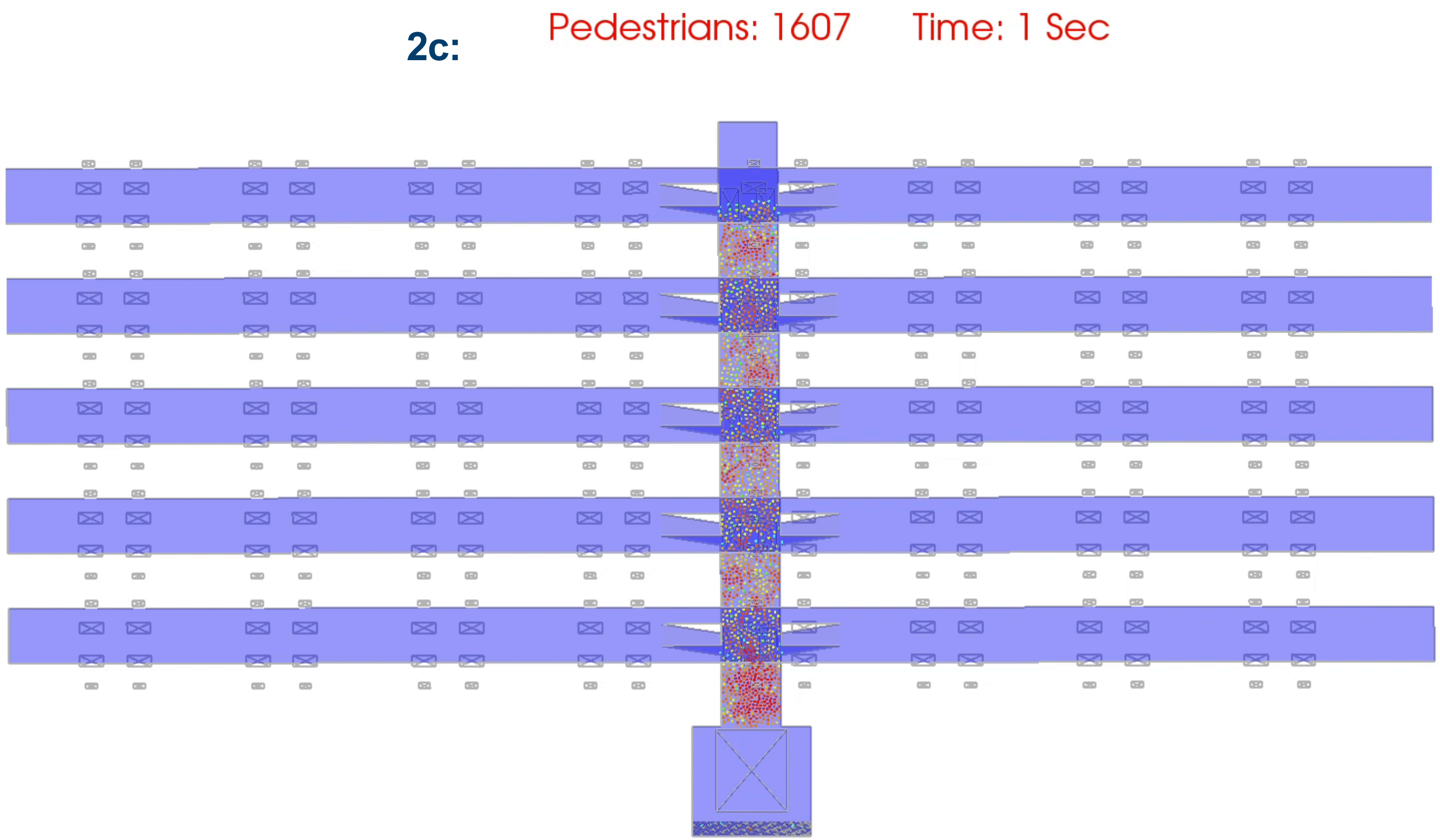
2a:



2b:



Setup 2c



Setup 2c

- Waiting times:
  - wt_{hall} = 60 s
  - wt_{tunnel} = 0 s
- Train departure = 10 minutes

- Result:
  - No congestion
  - Capacity = 19.000 agents/hour

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Conclusion and Outlook

Conclusion:

- Operational options are necessary
- Inflow restrictions in the entrance hall work good
- Barriers (waiting areas) in the tunnel hinder the flow and cause congestion

Outlook:

- Investigation of the influence of luggage and group behaviour like staying together (e.g. families)
- More detailed investigation of operational options like barriers and inflow restriction in and around a station:
  → Cooperation with the federal police: accompany operations like the risk football game (Dortmund-Schalke) two weeks ago or other operations, where a lot of people will use the train station and special barriers and other operational options will be used.
- Detailed modelling of trains

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Questions?

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