Capacity of train stations in case of a large-scale emergency evacuation

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Background

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- Nature and human made hazards:
  - Hurricanes, floods, wild fires …
  - 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

www.hs-rottenburg.net

- After the nuclear power plant disaster of Fukushima the 'AG Fukushima' was found (Germany)
- 'AG Fukushima' recommends the use of trains for large-scale evacuations.
- Capacity of train stations for large-scale evacuations is unknown.

Studies

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- KapaKrit = Optimising the capacity of train stations in case of large-scale emergency events

  - Identification of critical bottlenecks
  - Operational options to increase the capacity
  - Finding the maximum capacity
  - Capacity = evacuees* / hour

- Field studies at the main station of Dortmund (NRW, Germany)
- Simulations with JuPedSim

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* Evacuees = people who leave a threatened area by train

Field Studies

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- Field studies at the main station of Dortmund (NRW, Germany)
  - Entry times for different train types
  - Pedestrian movements inside the station
  - Pedestrian movement and waiting behaviour at the platforms
  - Influence of luggage

- Cooperation with the federal police
  - Accompany special events like the risk football game Dortmund vs. Schalke (April 2019) or other events where a lot of people are using the train station
  - Special barriers and other operational options are used to restrict the inflow or guide the people to the station

Jülich Pedestrian Simulator - JuPedSim

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- Developed at the Research Center Jülich
- Free software* for pedestrian dynamics

- 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

* github.com/JuPedSim

Simulations

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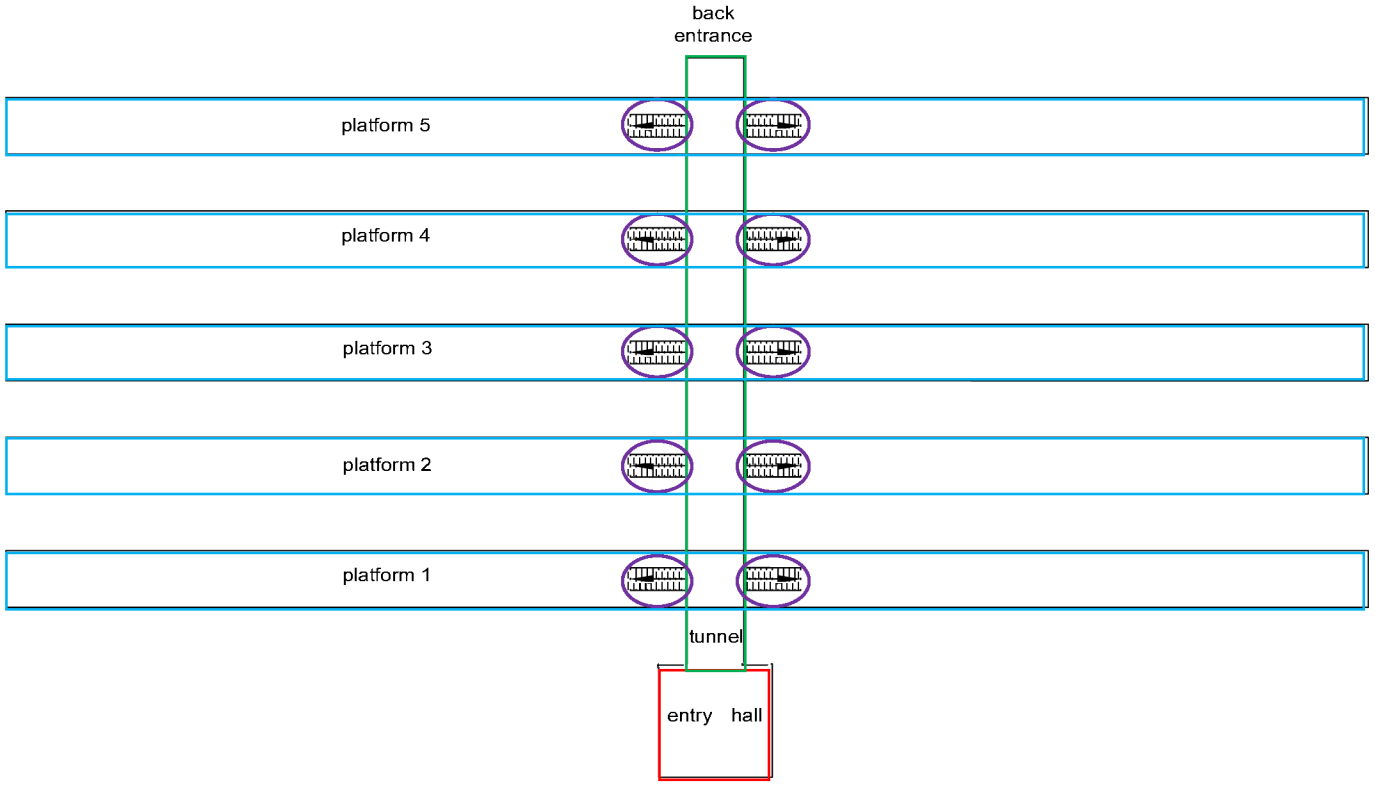
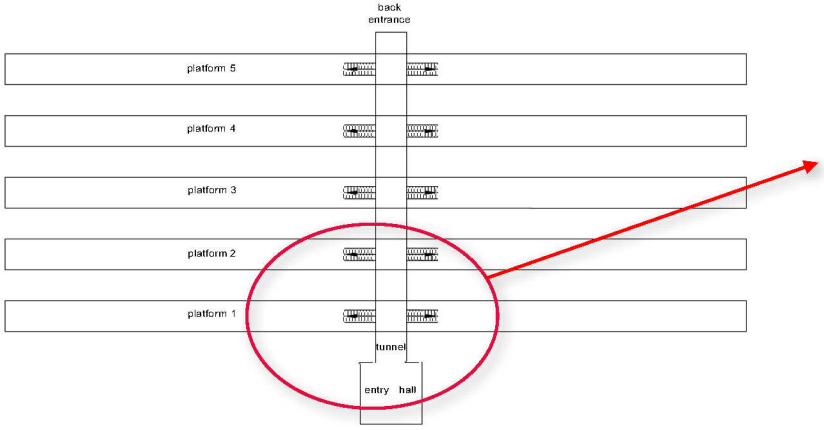
- No daily business – only evacuation trains
- Particularities:
  - Passengers carry a lot of luggage → walking speed decreases, space increases
  - Empty trains and huge number of passengers → increased boarding and dwell times
  - Limited capacity/space in the building and on the platforms → inflow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

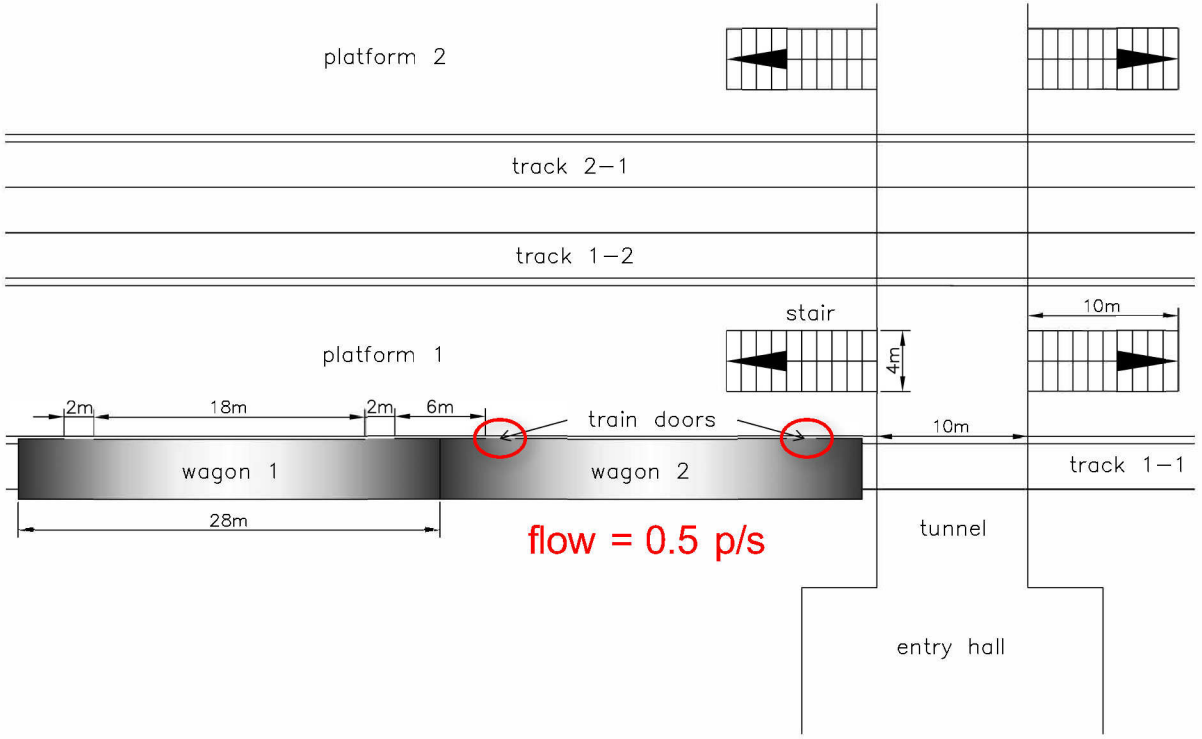
- Assumption:
  - Passengers act rational at any time
  - No panic or similar occur
  - Enough trains and train drivers for the evacuation

Setup


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

Setup - Detail

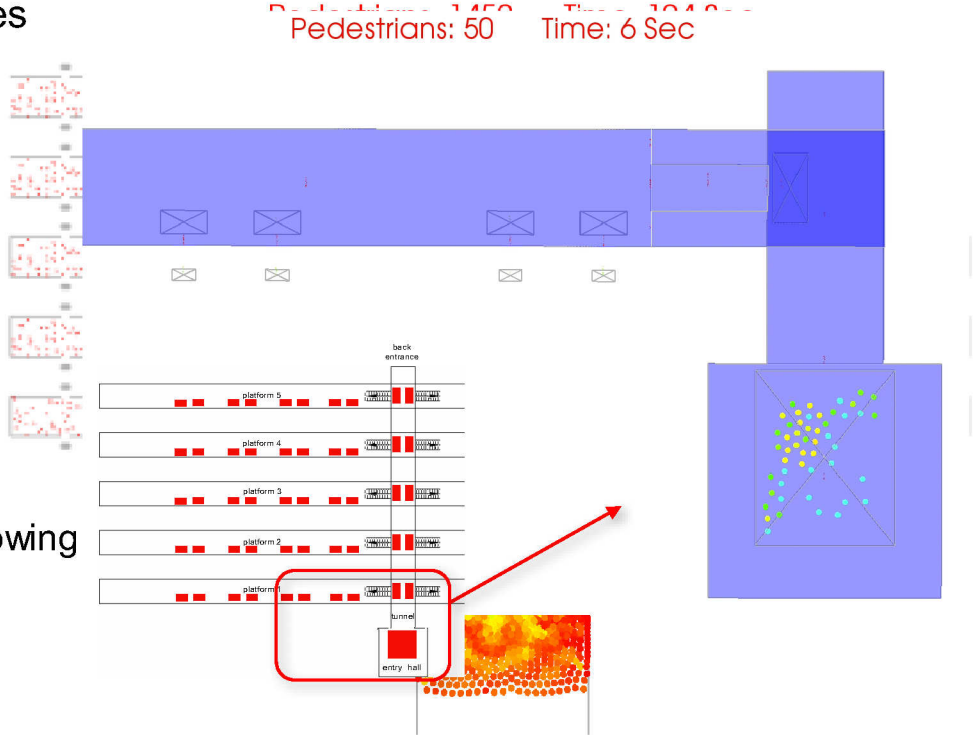




First Studies

Critical bottlenecks

- One train at each of the five platforms every 5 – 10 minutes
- 3200 agents → 640 agents/train
- Three setup variations:
  1. Usage of both entrances
  2. Only main entrance
  3. Main entrance and waiting areas
- Bottlenecks:
  1. Bidirectional flow → huge congestion inside the tunnel
  2. Congestion at the first platform accesses → blockage of following agents
  3. Congestion at transition between entrance hall and tunnel
- Capacity = 19000 agents / hour



Actual studies

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- Three different train types:

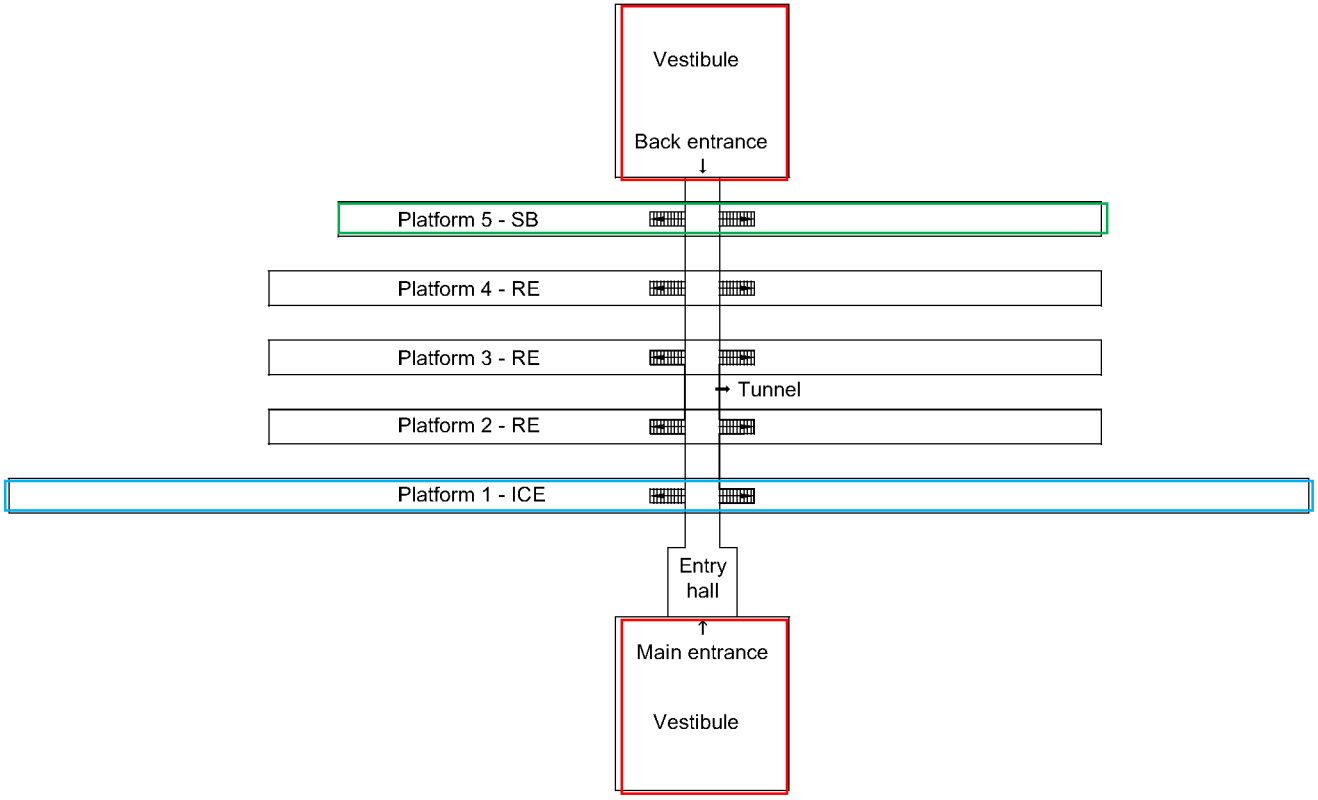
Train type	Capacity [agents]	Length [m] $door_1$ - $door_n$	Door width [m]	Agents / door	Door flow [s^{-1}]
ICE (**Inter**city **E**xpress)	1170	372.9	0.9	45	0.45
RE (**R**egional **E**xpress)	1350	236.2	1.9	75	0.95
SB (City Express)	1440	195.2	1.3	40	1.10

- Different time schedules for each platform:
  - How long does it take to refill the singe platforms? → Train arrival time
  - How long does it take to fill the trains? → Dwell time

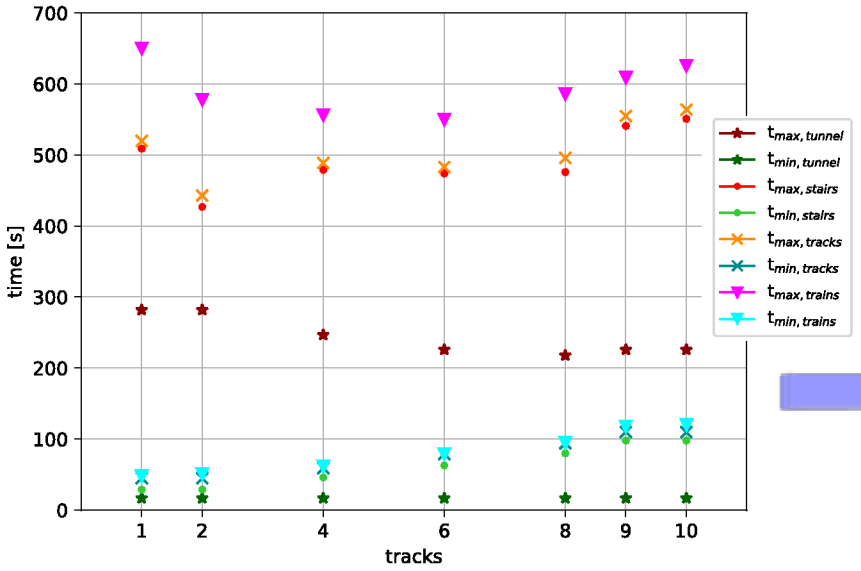
  } Departure time

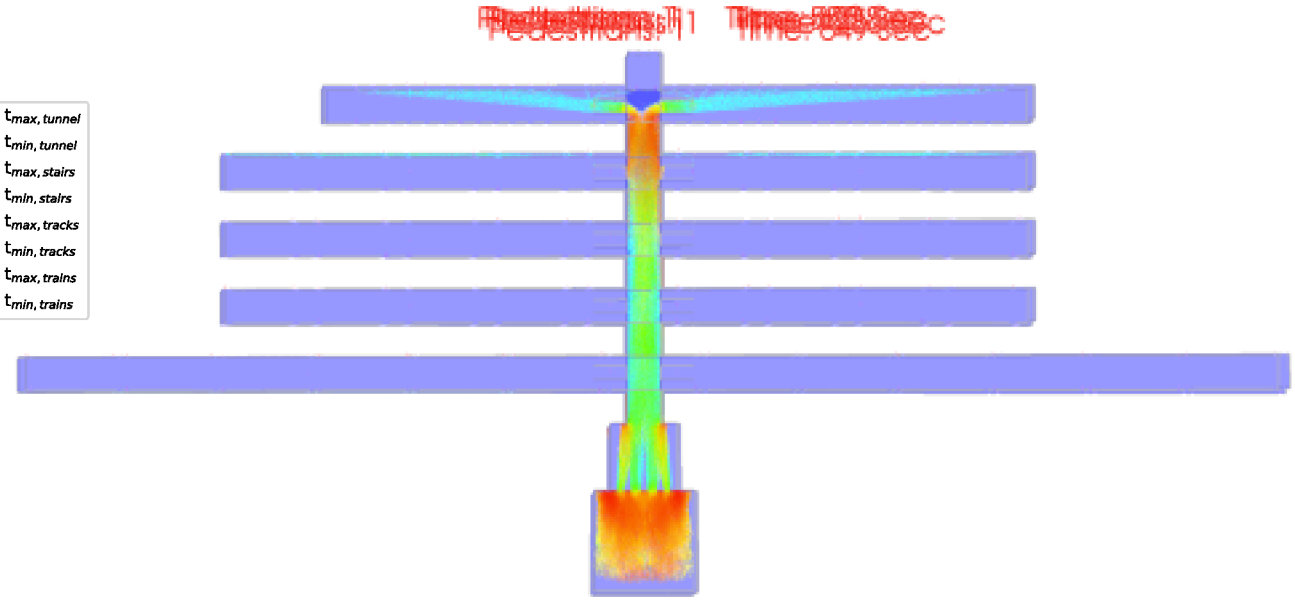
  - When do the last agents enter the tunnel and the staircases? → Inflow restriction to avoid congestion

Adapted Setup



Transition times





- Track 1 & 2: Short distance to the platform → congestion in front of the stairs influences the flow inside the entrance hall
- Track 4 & 6 : Mean distance to the platform → only a small influence on the flow inside the entrance hall
- Track 8 – 10: Longer distance to the platform → no tailback to the entrance hall

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- Minimum and maZimum times of the transition between tunnel and staircases
  - Qirst agents k 2 minutes
  - Difference between first to last agents f .d minutes Ttrack hUe h minutes Ttrack 1U
- Train arriving interval Wg minutes
- Usage of both entrances Tmain: platform 1l 2, back: platform bl d, both: platform aU
- Dwell time Wa minutes

6latFor7 2C		6latFor7 2J		6latFor7 2K		6latFor7 2L		6latFor7 2M	
Track 1	Track 2	Track a	Track b	Track d	Track f	Track g	Track h	Track 9	Track 10
21[		1a		g main			g		1b
	ad		2h		21 back	2h		ad	
df		b9		b2 main			b2		b9

211d0 V/h

[Time in minutes

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Conclusion:

- ! Xperational options like inflow restrictions are necessary
- ! A good time schedule can increase the capacity

Xutlook:

- ! Yvestigation of the influence of luggage and group behaviour like staying together Te.g. familiesU
- ! More detailed investigation of operational options like barriers and inflow restriction in and around a station to increase the train departures per hour
- ! Detailed modelling of trains

OuestionsP

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