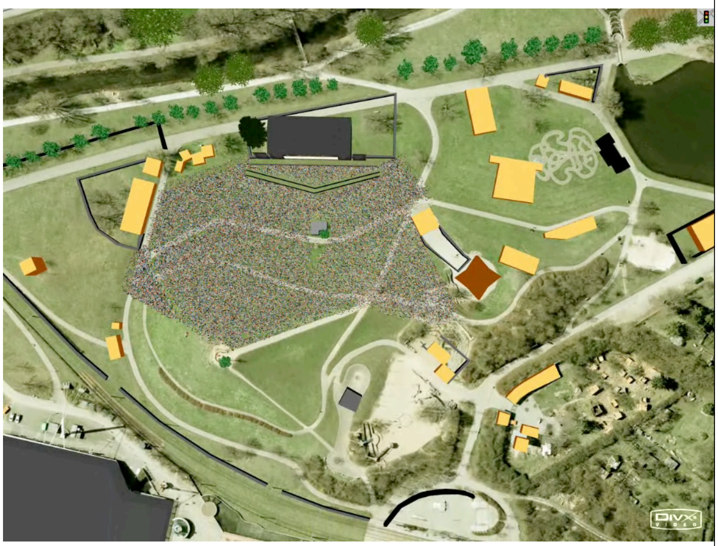
Emergent Pedestrian Flow Behavior

Symposium “Vluchten bij Brand”

25/10/10, Prof. dr. S.P. Hoogendoorn

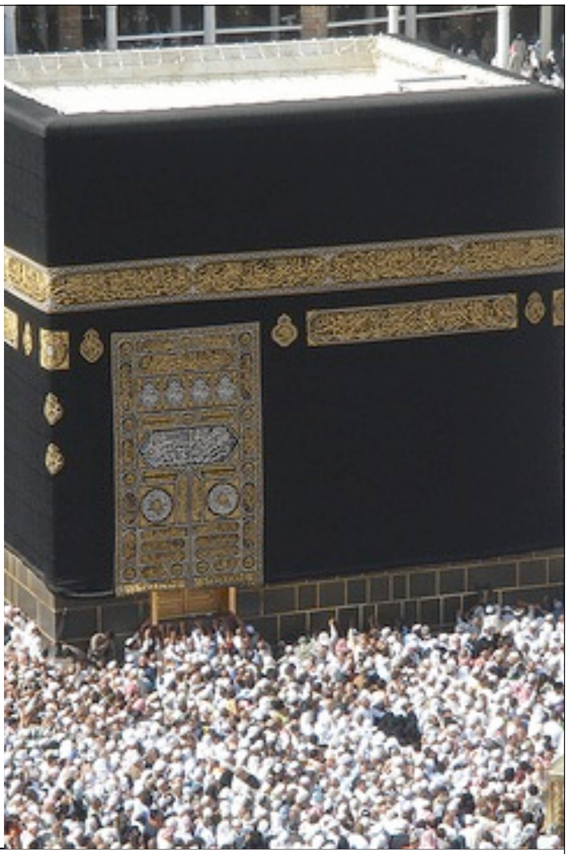
Traffic Engineering Perspective

- Assess operations of transfer stations, buildings, public areas in terms of efficiency, comfort and safety under a variety of conditions
- Need for theory and models that reproduce or predict main flow characteristics



Talk contribution

- Show recent findings regarding main flow characteristics:
  - Capacity and key factors
  - Flow states and fundamental diagram
  - Network fundamental diagram
- Present underlying mechanisms
- Discuss resulting model requirements



Back-of-envelope calculations...

- Consider a room with n pedestrians
- Exit of the room has capacity C
- Average free walking time to exit = T_0

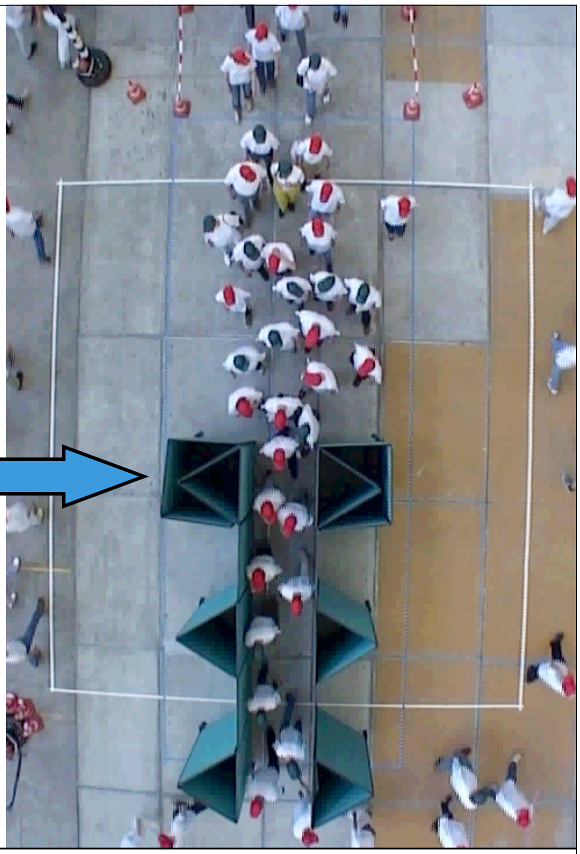
- Average evacuation time (excluding free walking time):

$$T_{evac} \approx T_0 + \frac{n}{C}$$

- How large is the capacity?
- What are its determining factors?

Measuring capacity

- Questions raised about capacity values in building regulations
- Door capacity = 135 P/min/m
- Value for corridors (1 m) = 73 P/min/m
- Dedicated experiments TU Delft shows:
  - Reference values
  - Influence of flow composition, effect door, stress, etc.



Example experiments…

- Variety of experiments with different groups, under different conditions (opening width, ambient condition, presence of door)

Capacity determining factors

- For each scenario, opening capacity was determined
- Impact factors determined using Multivariate Linear Regression

$$C = 2.69 + 1.06 \cdot P_C - 0.21 \cdot P_E - 2.13 \cdot P_D$$
$$-0.01 \cdot \text{Stress} - 0.12 \cdot \text{Width} - 0.18 \cdot \text{Door} + 0.09 \cdot \text{Light}$$

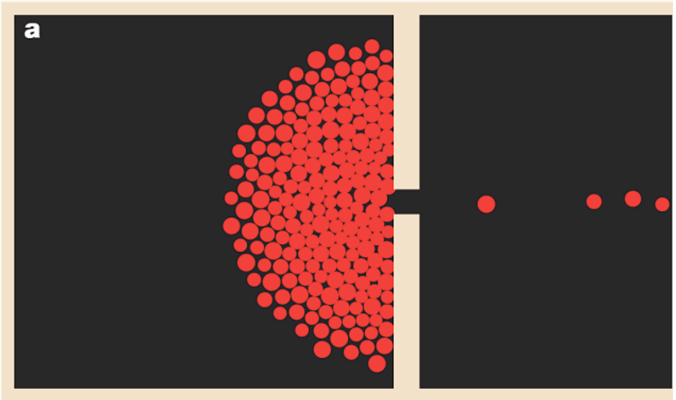
- Strong impact of flow composition
- Some influence of presence of door, width of door, and ambient conditions
- Minor inflow of stress level (?!?)

Faster is slower effect

- Impact of haste / time pressure has severe impacts on capacity

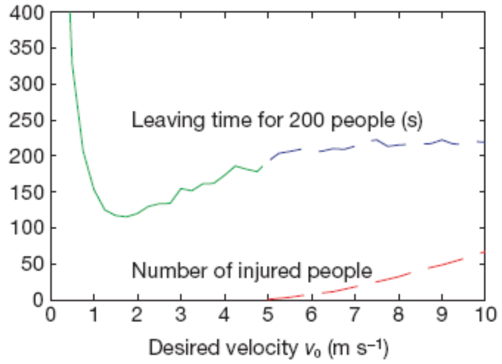
Desired speed and escape features

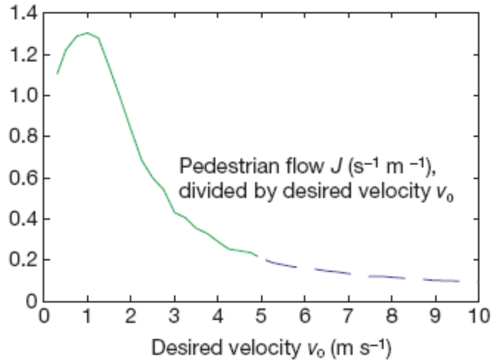
- Example shows impact of 'desired speed' expressing haste (anxiety to get out of the room)



Desired speed and escape features

- Increasing desired speed leads to increase of time needed to leave and decrease in capacity





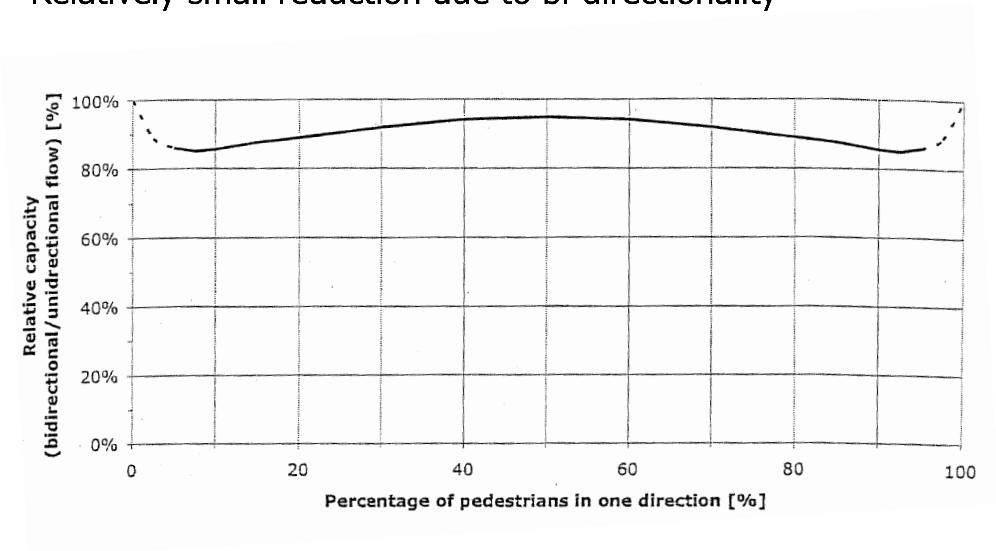
DIY pedestrian experiment

The 'Frans Bauer' effect...

- Capacity is strongly influence by behavior...

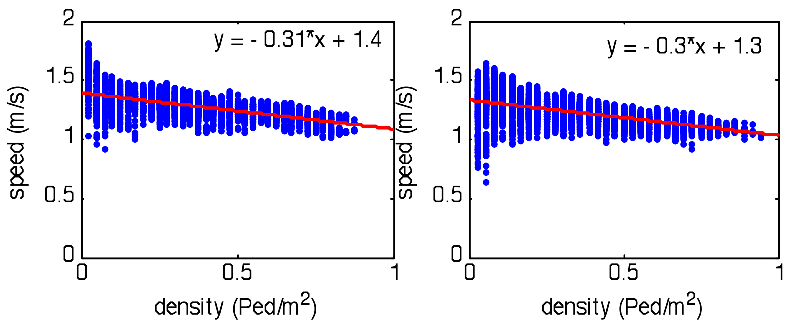
Capacity of bi-directional flows

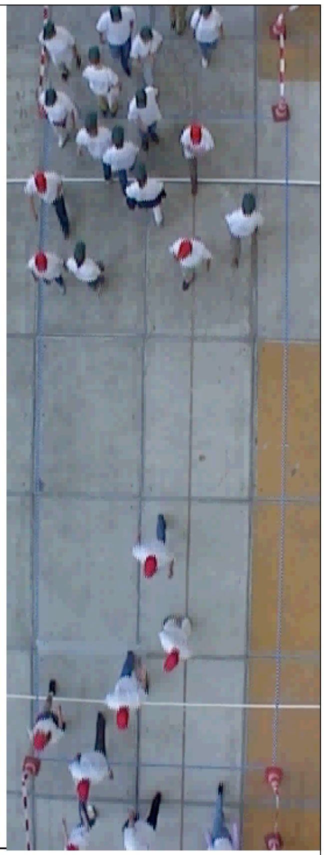
- Relatively small reduction due to bi-directionality



Self-organization

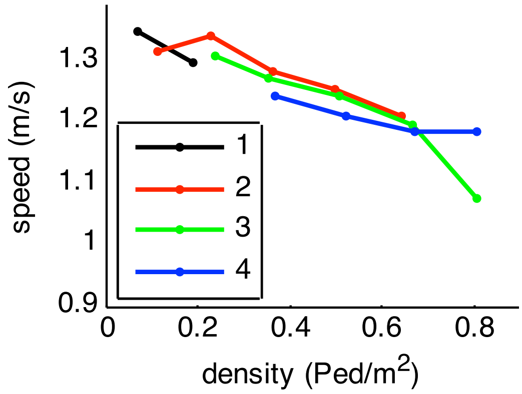
- Efficiency is caused by self-organization of lanes
- Difference between bi-directional flow and uni-directional flow is very small
- Fundamental diagrams for both flow types

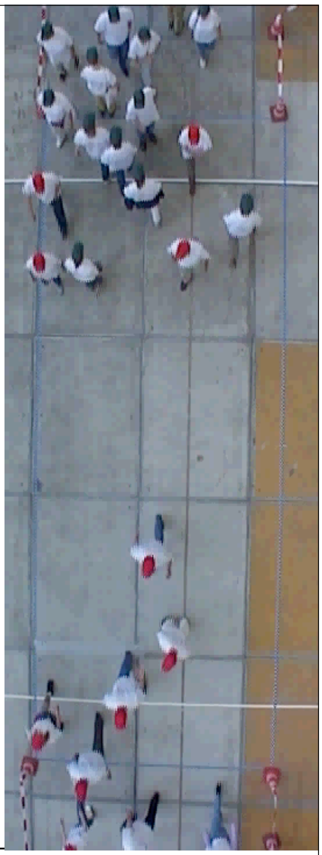




Self-organization

- Efficiency is caused by self-organization of lanes
- Self-organization has chaos-like properties
- Number of lanes has small impact on efficiency





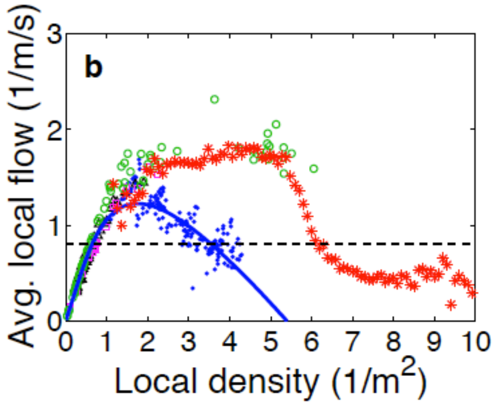
Self-organization

- Efficiency is caused by self-organization of lanes

- But for very high densities, lane formation process breaks down and grid-lock / congestion occurs (phase transition)

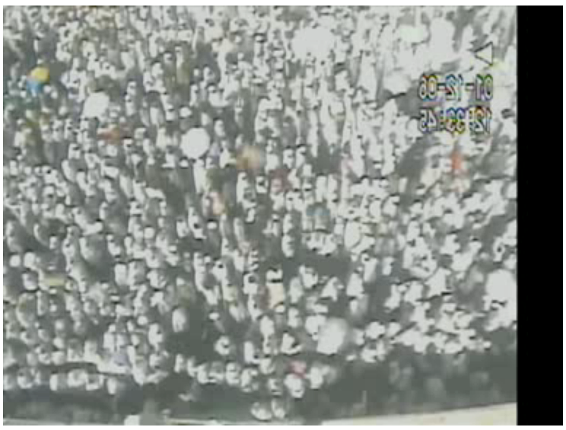
Stop-go waves and turbulence

- Discovery of new traffic states in high-density flows



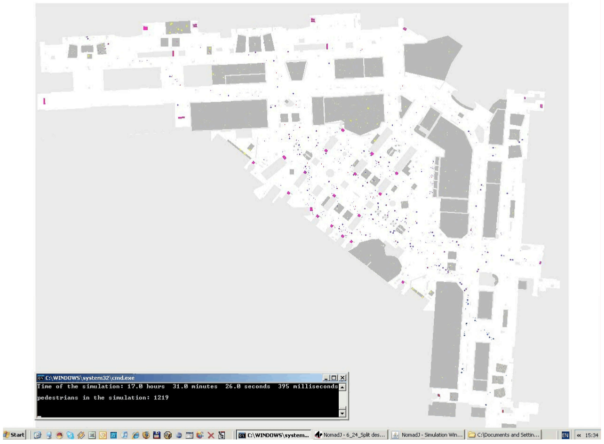
Stop-go waves and turbulence

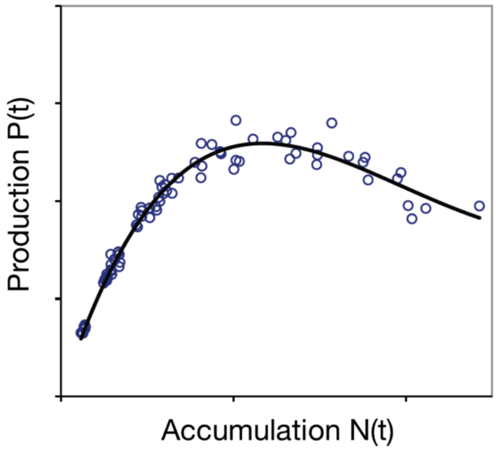
- Discovery of new traffic states in high-density flows
- Not only in Mecca (dance parade in Duisburg)



Network Fundamental Diagram

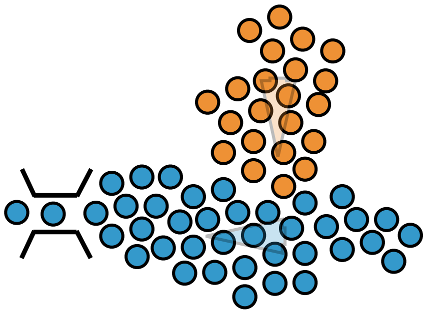
- Relation between production P and accumulation N



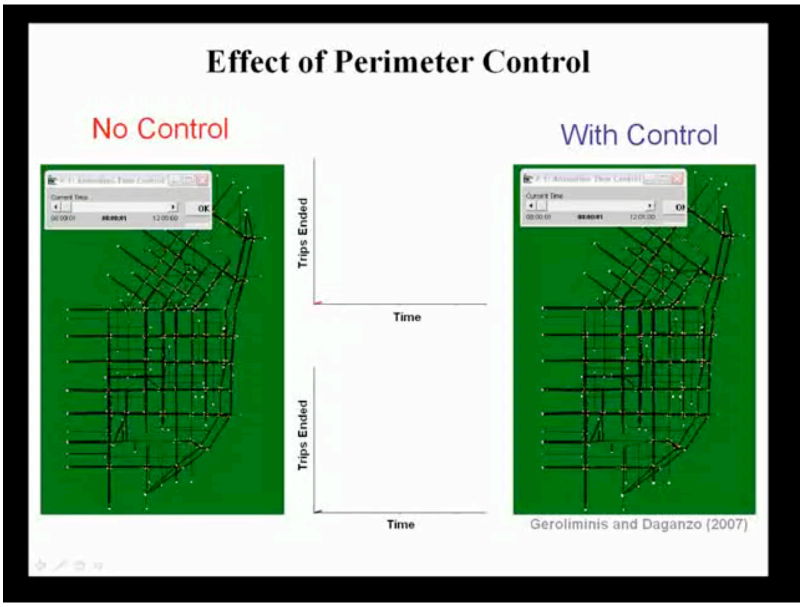


Traffic & crowd management

- Some implications for crowd (and traffic) planning & management:
  - Need to keep accumulation below critical accumulation e.g. using perimeter control
  - Avoid intersecting flows as much as possible, in particular in high-density areas
  - Reduce self-blockage effect (internal bottlenecks) e.g. by buffering traffic upstream of intersections



Implications for crowd management



Implications for modeling

- Applicability of models determined by extent in which fundamental flow characteristics can be replicated or predicted

Static	Dynamic
Capacity incl. influencing factors	Self-organization
Fundamental diagram	Phase-transitions, start-stop waves, turbulence
Network fundamental diagram	Capacity drop, spill-back and blockage

Discussion

- Many models (social-forces, NOMAD) are able to describe key flow characteristics sufficiently
- Models are not able to describe walker behavior at the microscopic level

- Implications for applicability of these models?