Evacuation of Ships and Buildings based on a CA model

www.traffgo-ht.com

„Bilderbuch Duisburg“

Bilderbuch Duisburg.avi

Topics

1. Model Characteristics
2. Calibration: Experiments and Observations
3. Alternative Methods: „Hand calculations"
4. Validation: Exercises, Reports, Field Studies
5. Technical Aspects: CAD etc.
6. Assessment based on simulation results
7. Limits (in principle, time, memory)

TraffGo

TraffGo HT, Background

- *Physics of Transport and Traffic,* Universität Duisburg-Essen
- Started in 2001
- Support from „Pfau“ (now: „Exist“)

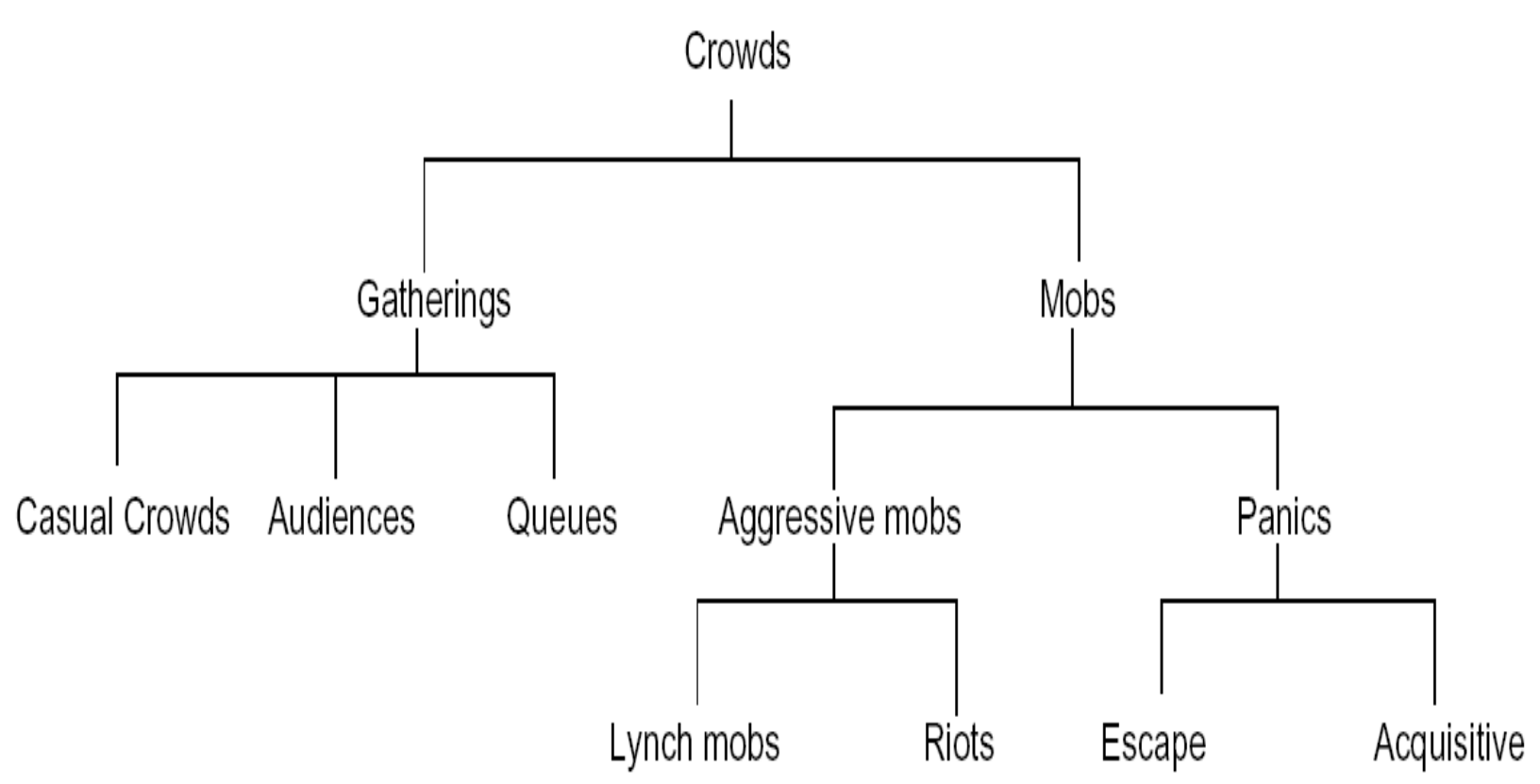
„Since I‘m a member of the Green Party and not catholic, this is the most attractive position available.“

TraffGo HT, References

- Cooperation Germanischer Lloyd AG
- Maritime Industry (FSG, Meyer, Kvaerner)
- Built Industry (Stadiums, WYD, Hajj)
- Guideline (www.rimea.de) – open project
- www.ped-net.org
- PED 2008 (www.ped2008.com)
- „Last-mile evacuation“

Data

Introduction – Groups

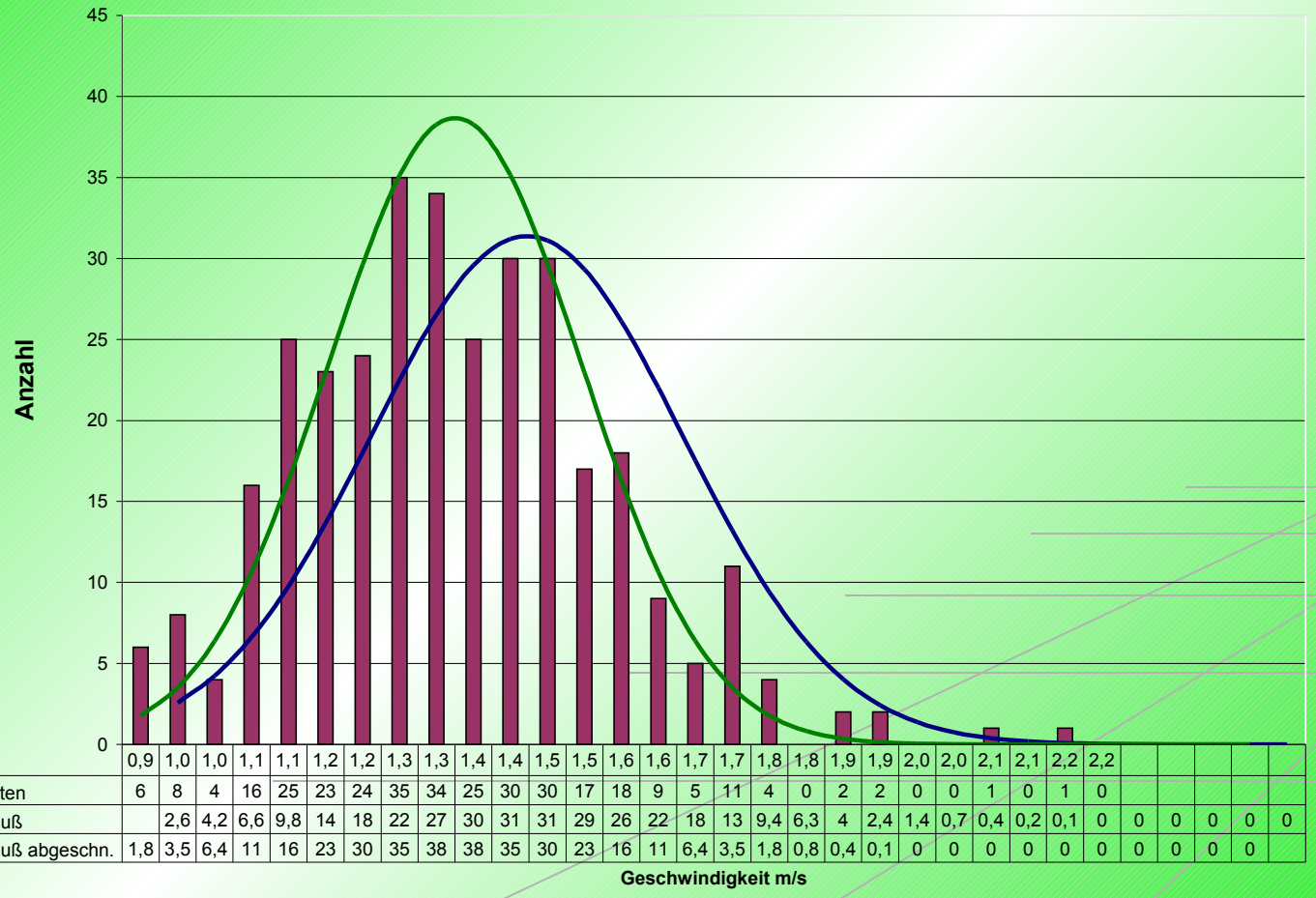


Panic is a controversial concept.

Influence of Group Size

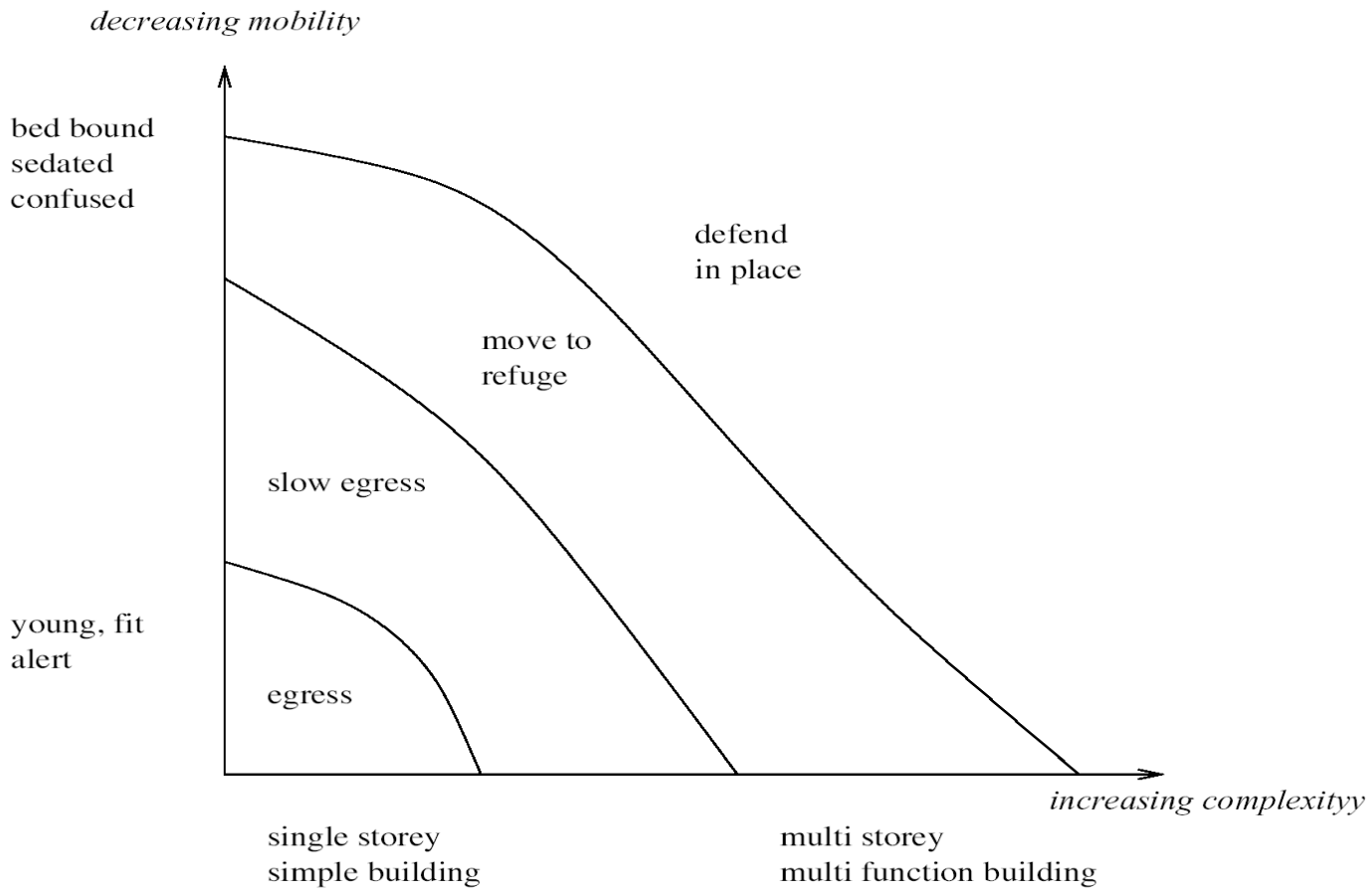
Group Size	Number	Speed
1	95	1,38
2	149	1,28
3	59	1,24
4	17	1,24
5	10	1,22
6	2	1,10
sum	332	1,30

Distribution of Walking Speeds

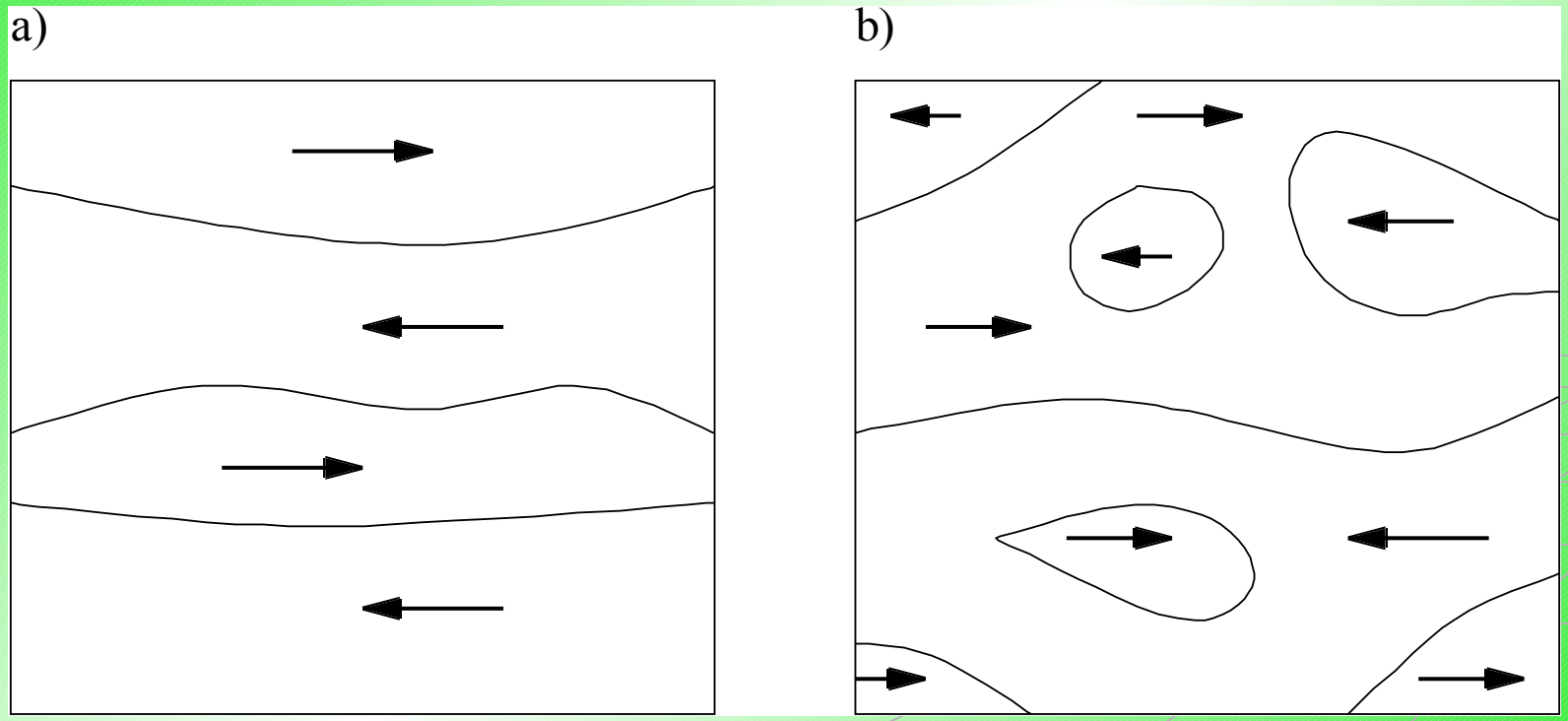


	0,9	1,0	1,0	1,1	1,1	1,2	1,2	1,3	1,3	1,4	1,4	1,5	1,5	1,6	1,6	1,7	1,7	1,8	1,8	1,9	1,9	2,0	2,0	2,1	2,1	2,2	2,2					
Daten	6	8	4	16	25	23	24	35	34	25	30	30	17	18	9	5	11	4	0	2	2	0	0	1	0	1	0					
Gauß		2,6	4,2	6,6	9,8	14	18	22	27	30	31	31	29	26	22	18	13	9,4	6,3	4	2,4	1,4	0,7	0,4	0,2	0,1	0	0	0	0	0	0
Gauß abgeschn.	1,8	3,5	6,4	11	16	23	30	35	38	38	35	30	23	16	11	6,4	3,5	1,8	0,8	0,4	0,1	0	0	0	0	0	0	0	0	0	0	

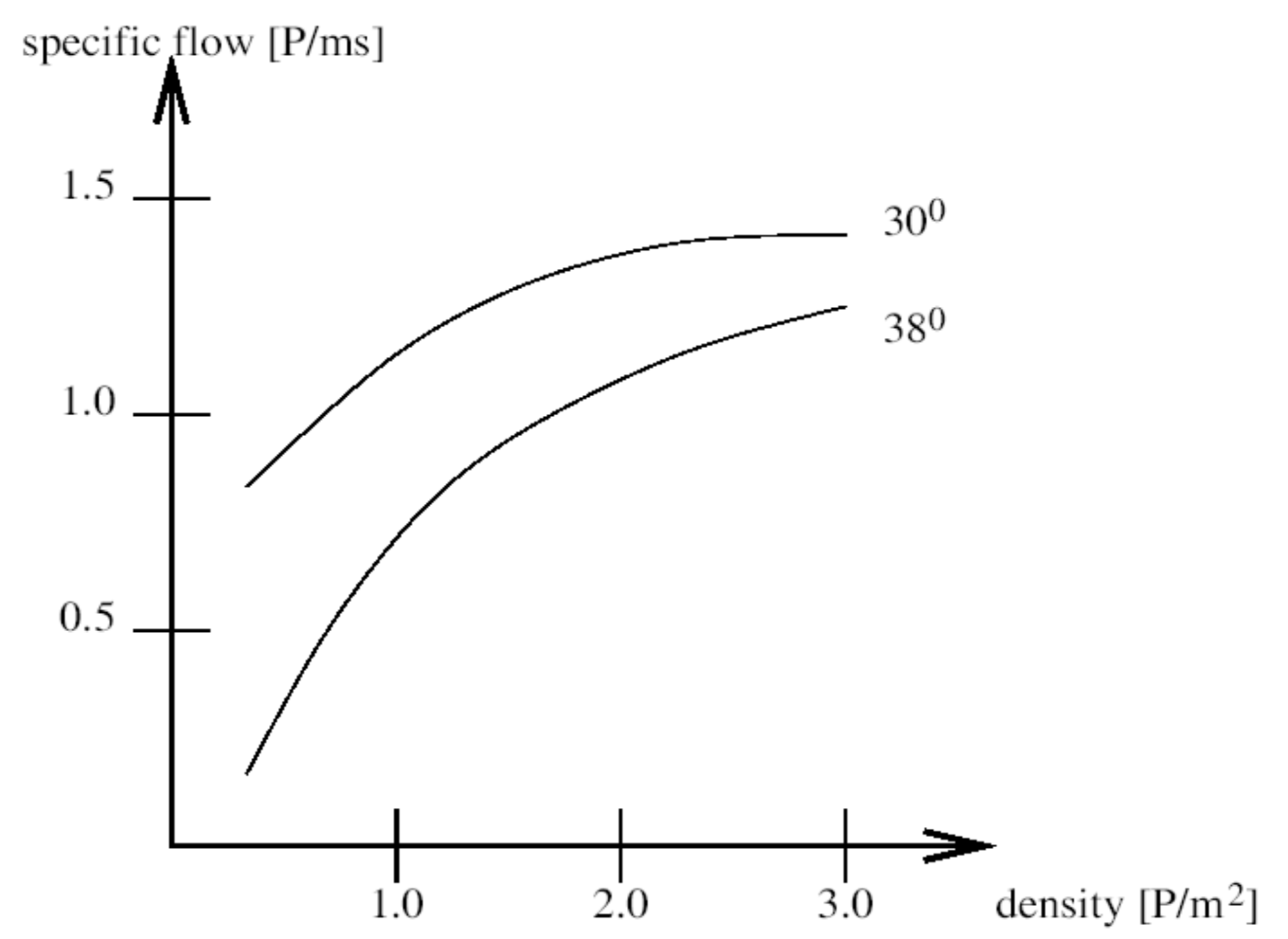
Individual Strategies



Formation of Lanes



Movement on Stairs

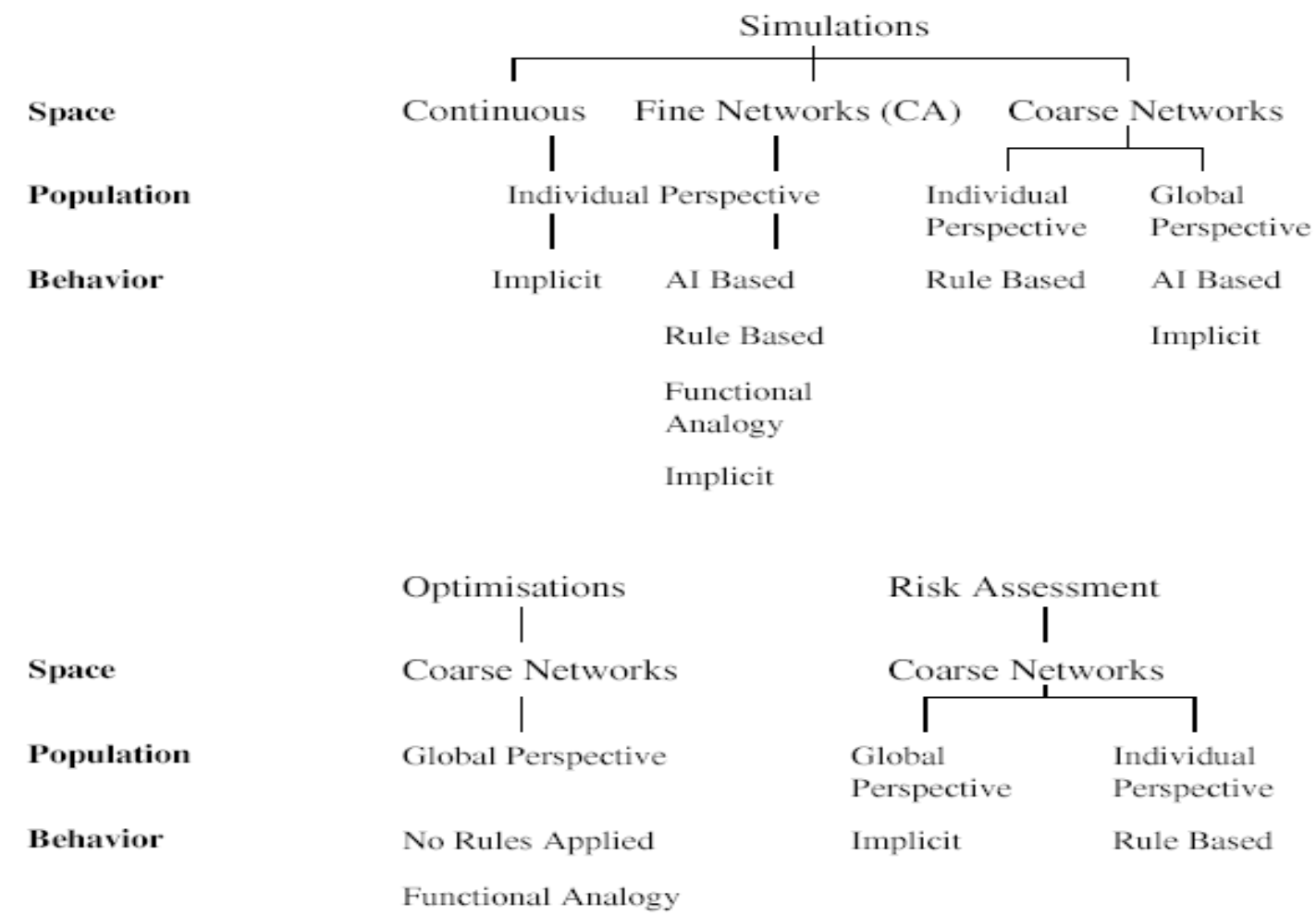


Film Evakuierungsübung FL

Evaküb ung FSG.avi

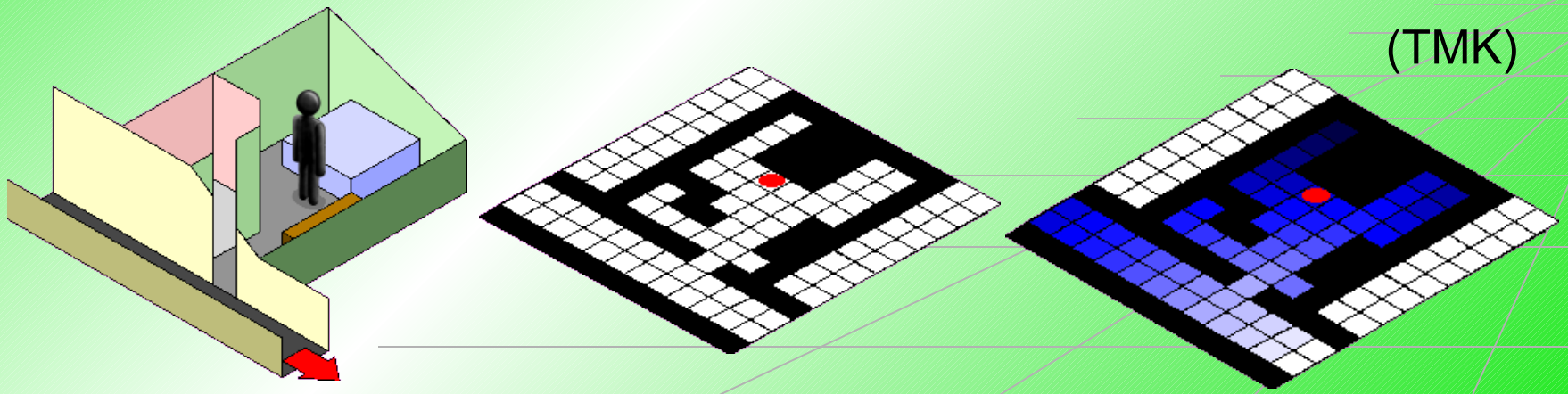
Models

Classes of Models

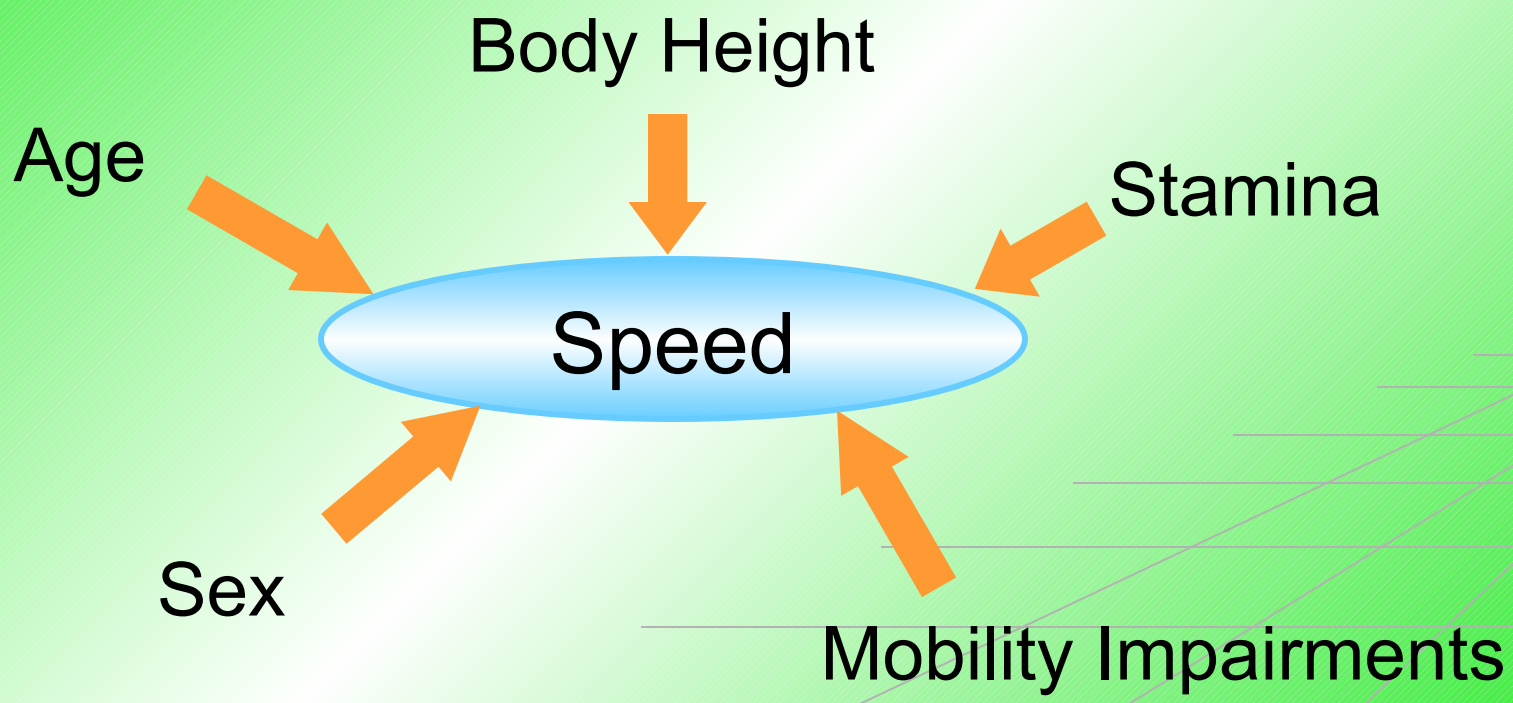


Model

- Cells 40cm x 40cm
- Cells are accessible or walls
- At most one person per cell



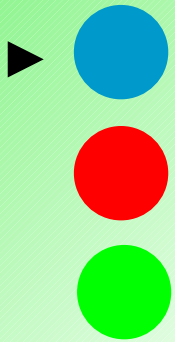
Simulation, Influences

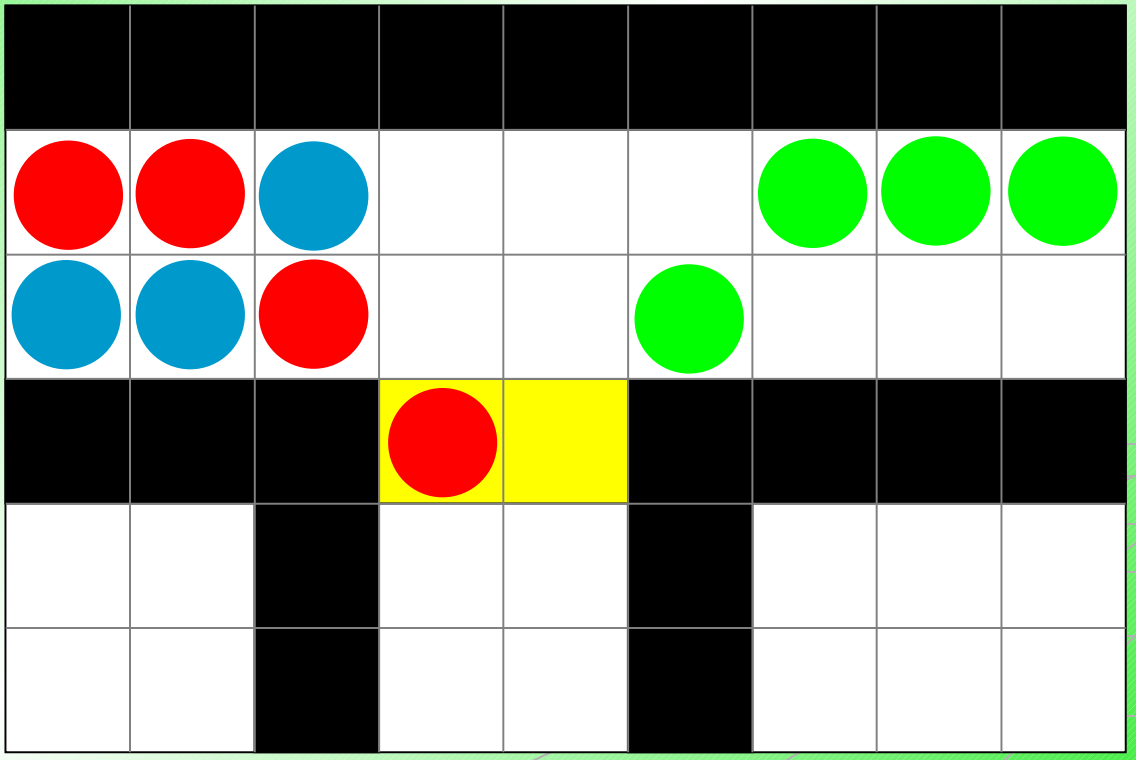


Movement Algorithm

$\Delta t = 1s$

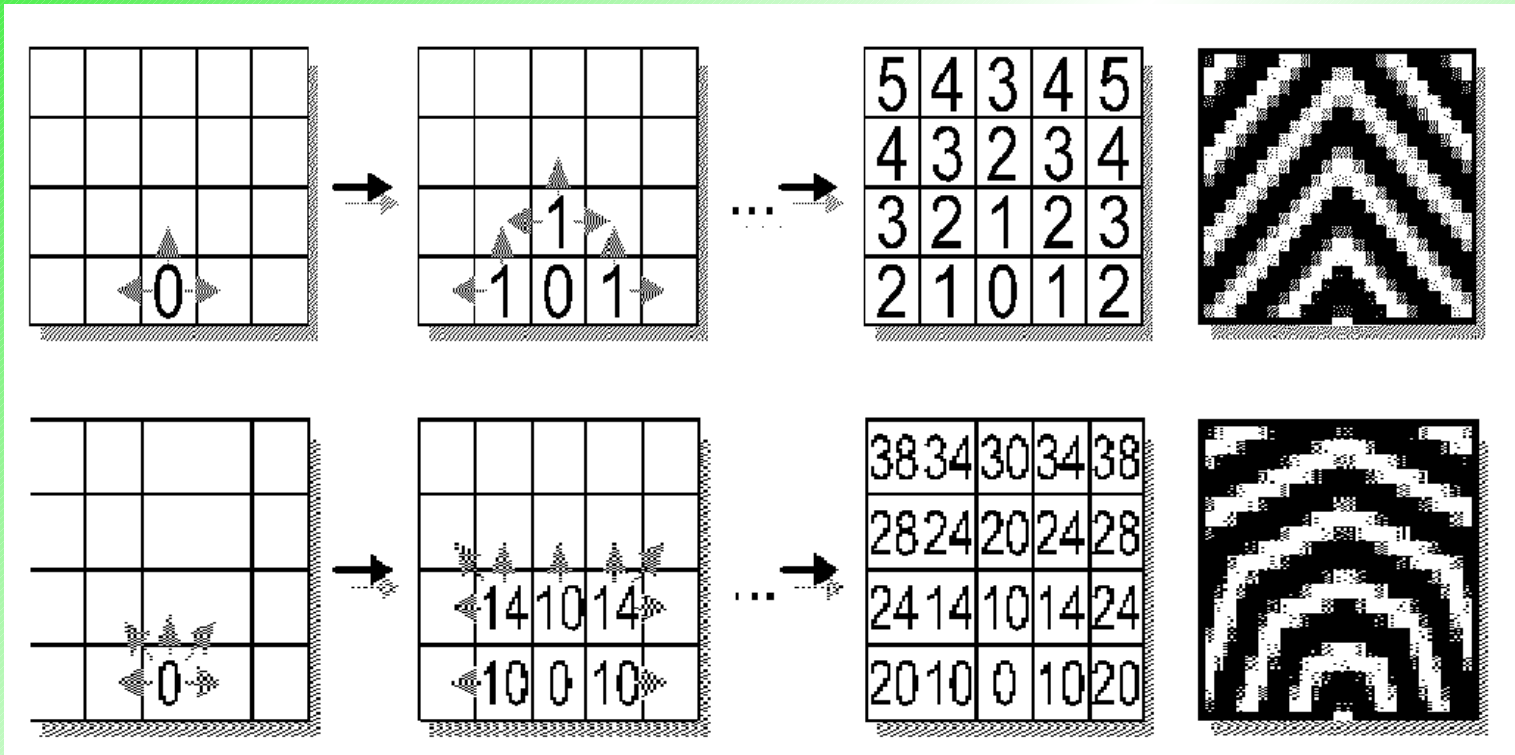
Conflict solution:





$v_{free} = 3$ $v_{free} = 2$ $v_{free} = 3$

Potential Spread



Transition probabilities

Transition probabilities:

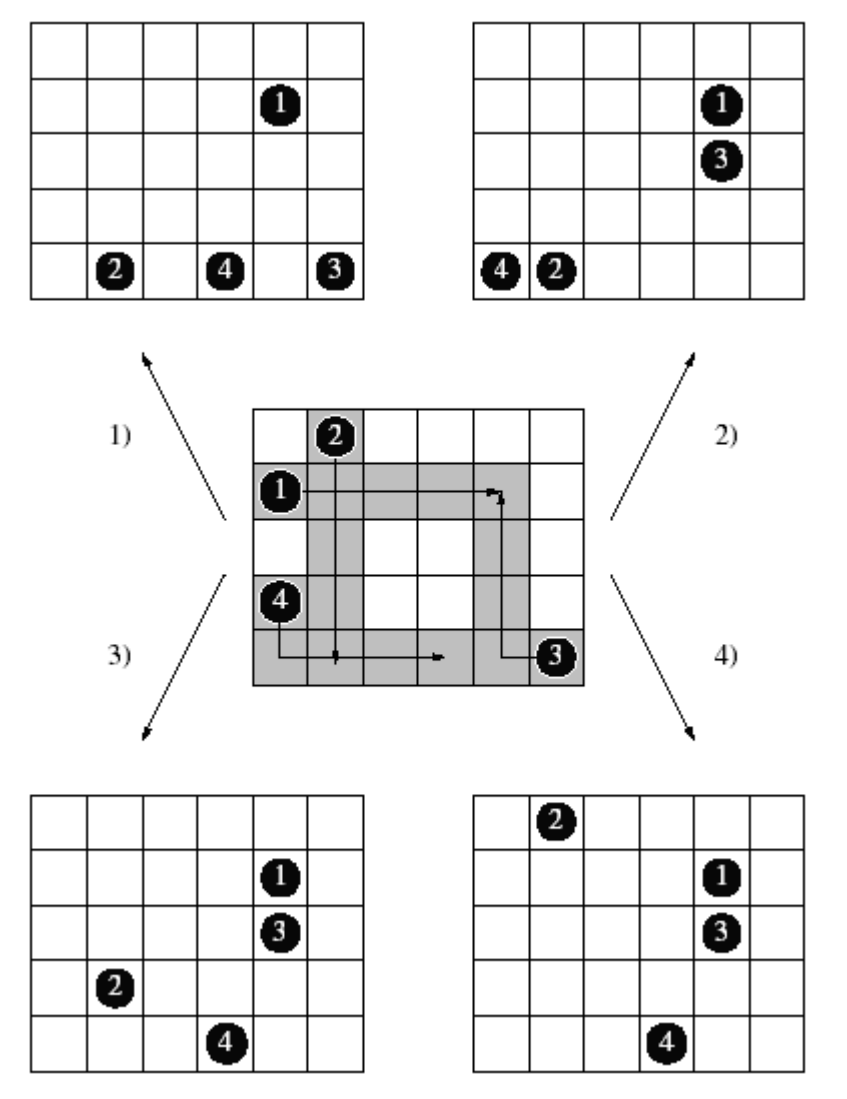
$$p_i = e^{-\frac{(P_i - P_0) + S}{S}}$$

Inertia:

$$p_{i,\,\text{current direction}} \rightarrow p_{i,\,\text{current direction}} \cdot \Theta$$

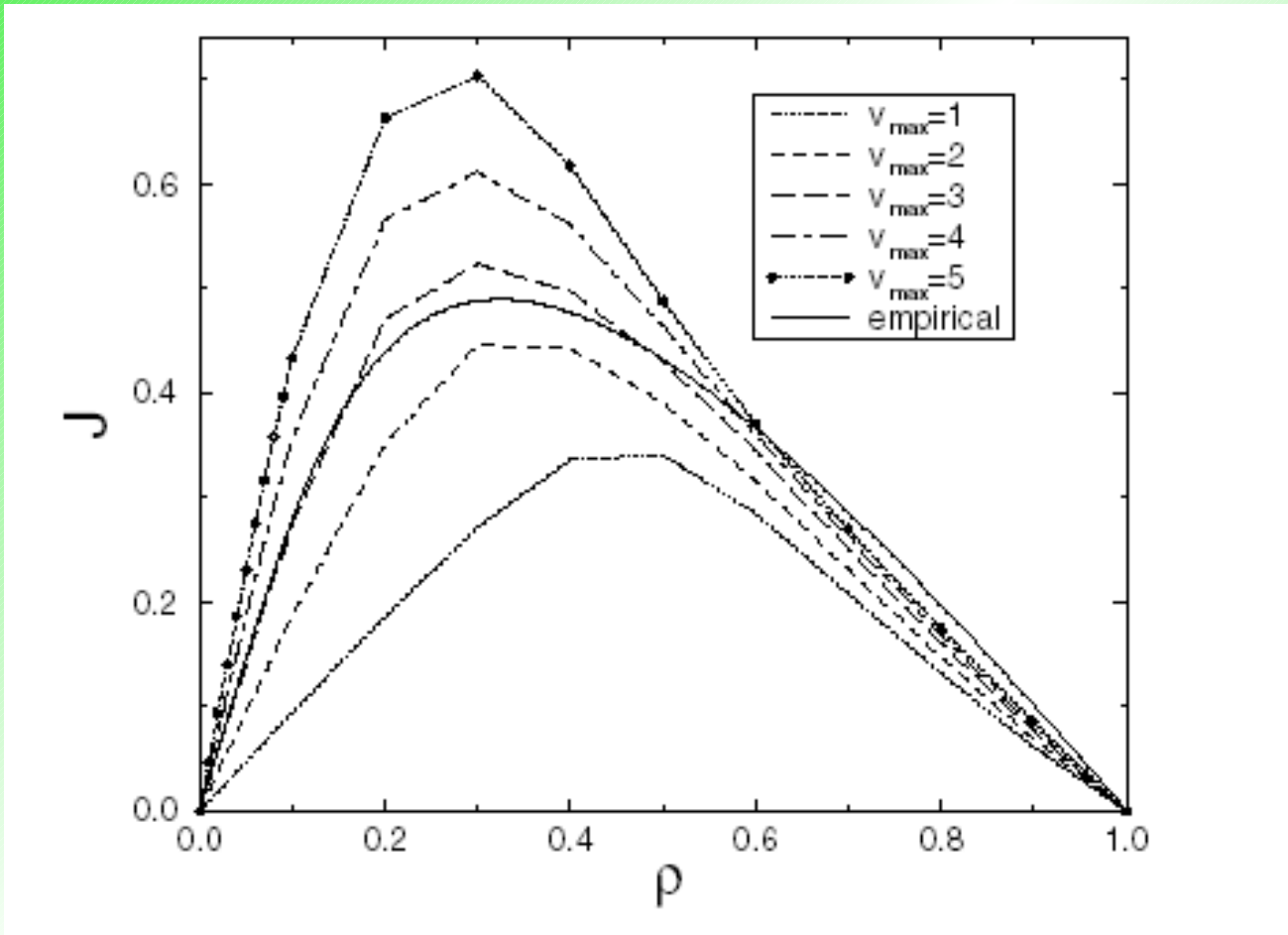
Update Strategies

1. Hop or stopp
2. Move as far as possible
3. Sub-steps
4. No crossing paths

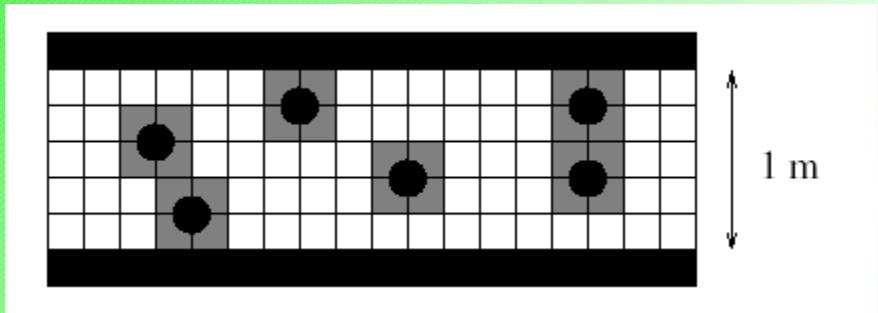


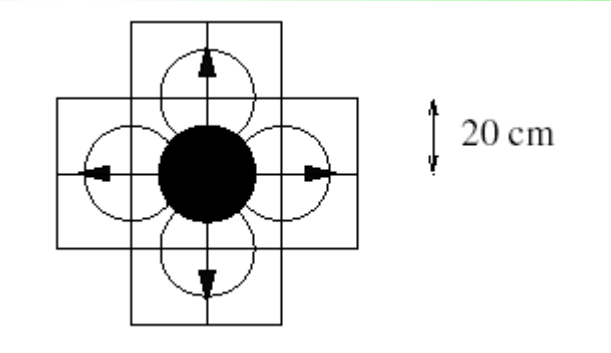
Kirchner et. al., J. Stat. Mech.: Theor. Exp. (2004) P10011

Strategy 3 – Sub-Steps

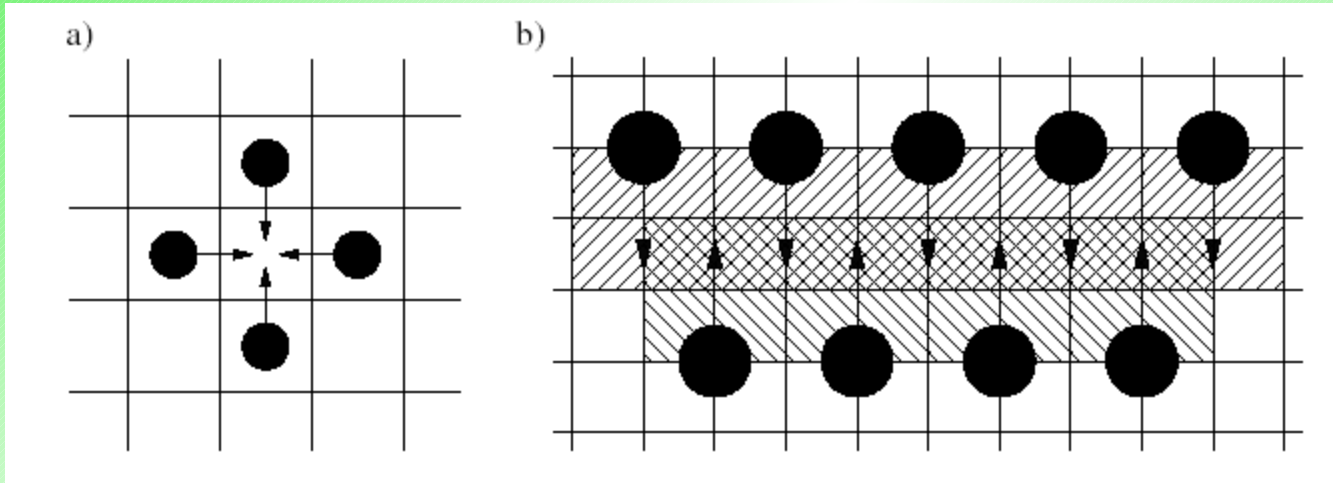


Discretization

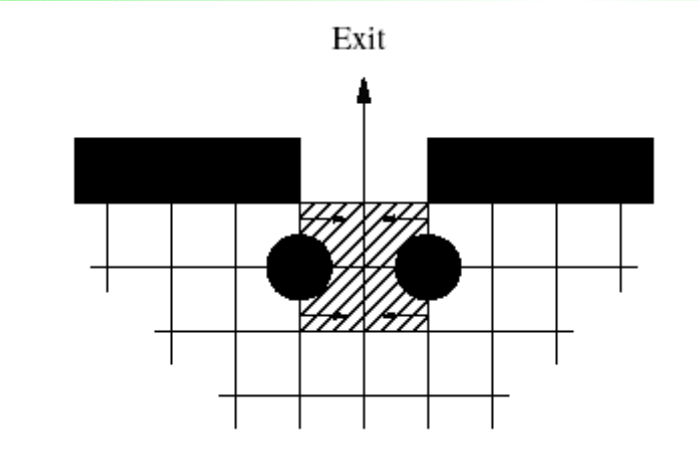




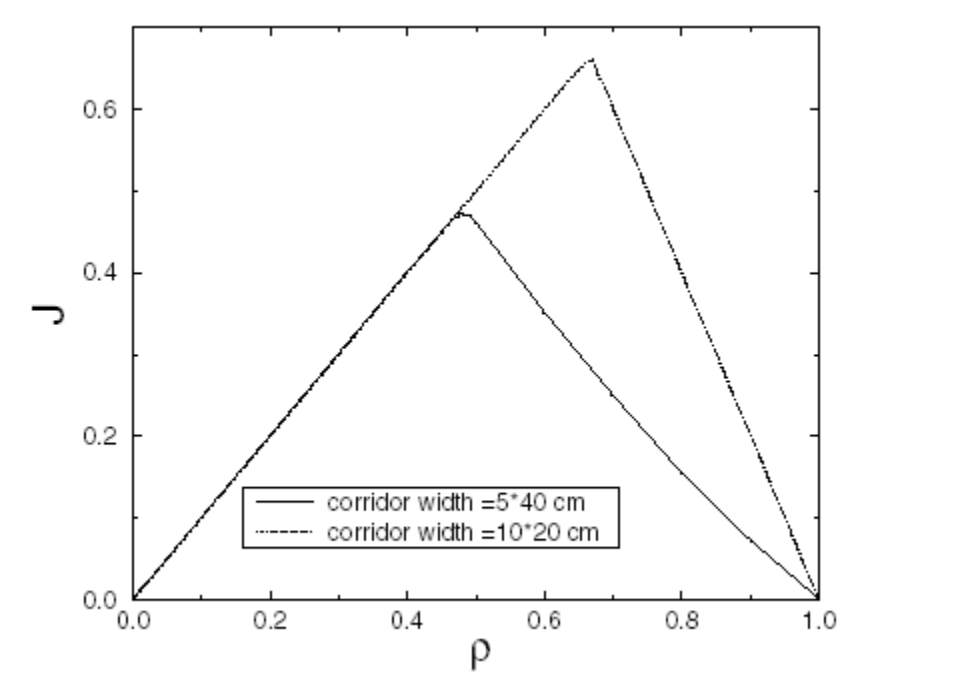
Non-local Conflicts



Clogging at the Exit



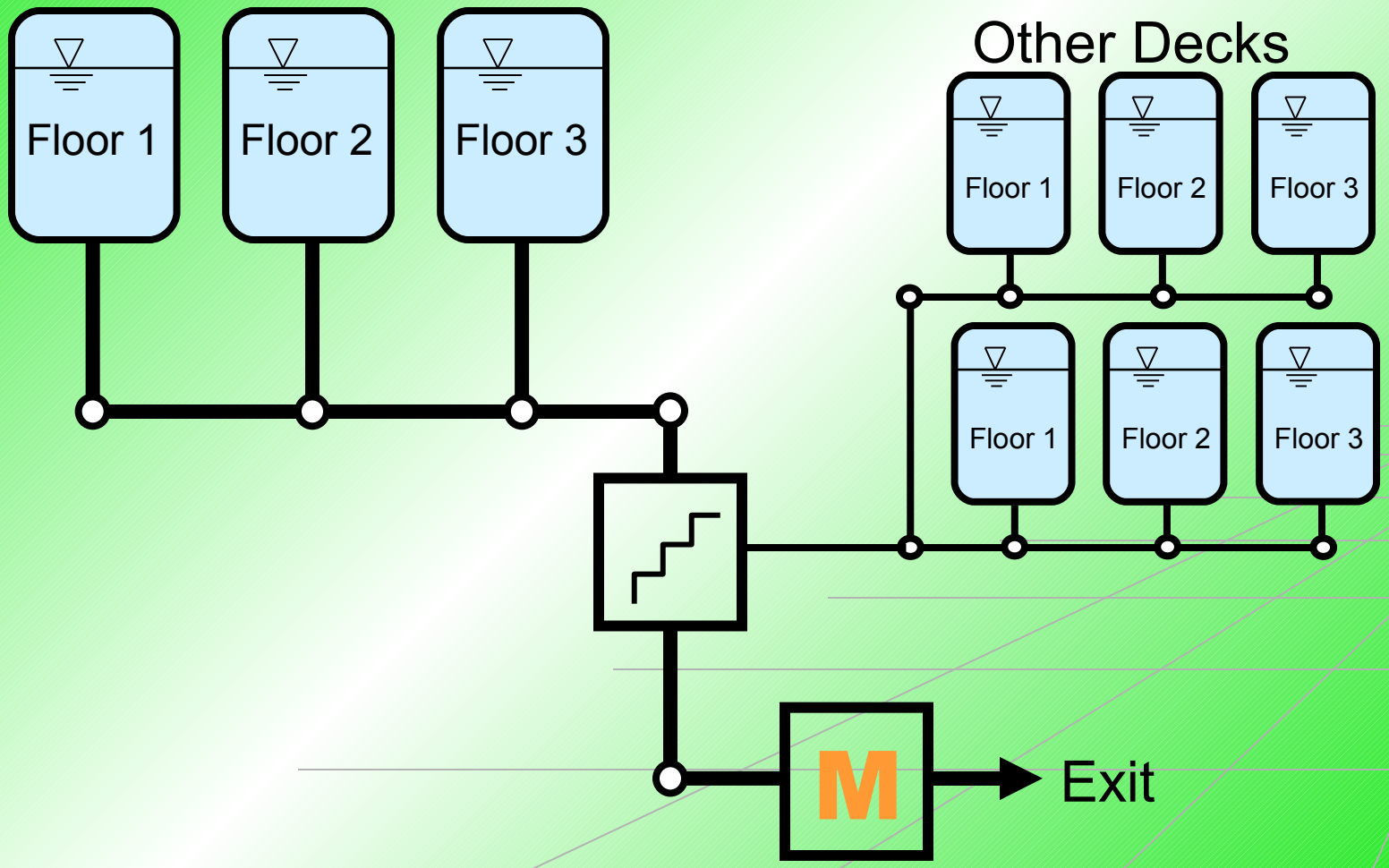
Higher Flow for a=20cm



Flow Models, Assumptions

- Flow = f(Density)
- No overtaking
- Identical Persons
- Unhindered Movement
- Safety or Correction Factors

Flow Models, Basics



Flow Model, Example

Predtetschenski/Milinski

- Calculaton of initial density in sqm/sqm
- Take flow value from list
- Calculate flow time → t_{Flow}
- Calculate walking time → t_{Walk}
- Total time: $t_{Total} = t_{Flow} + t_{Walk}$

Flow Models, Assumptions

- Flow = f(Density)
- No overtaking
- Identical Persons
- Unhindered Movement
- Safety or Correction Factors

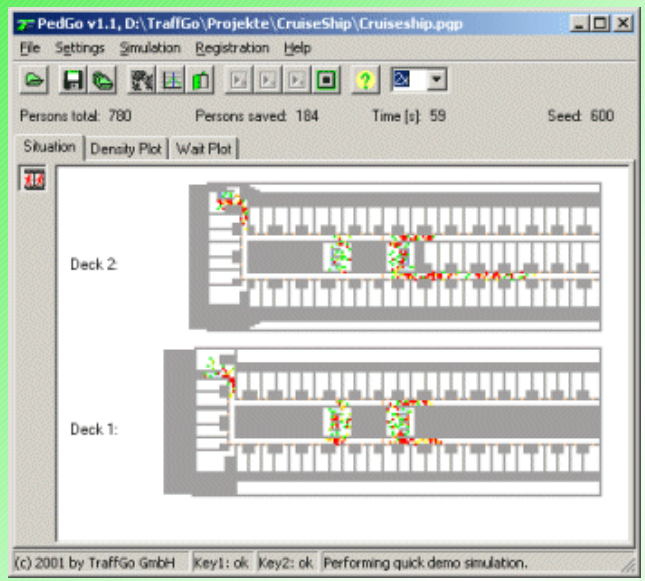
PedGo

Film RTL Supertrend

RTL Future Trend

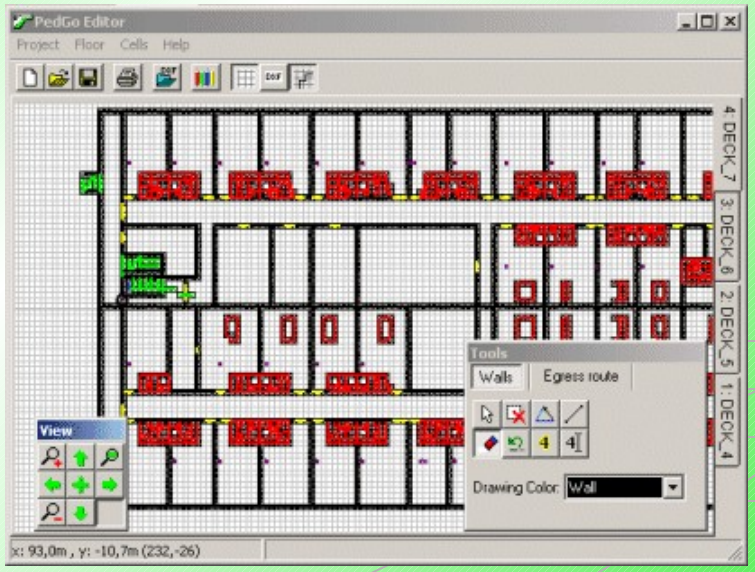
Software Package

PedGo



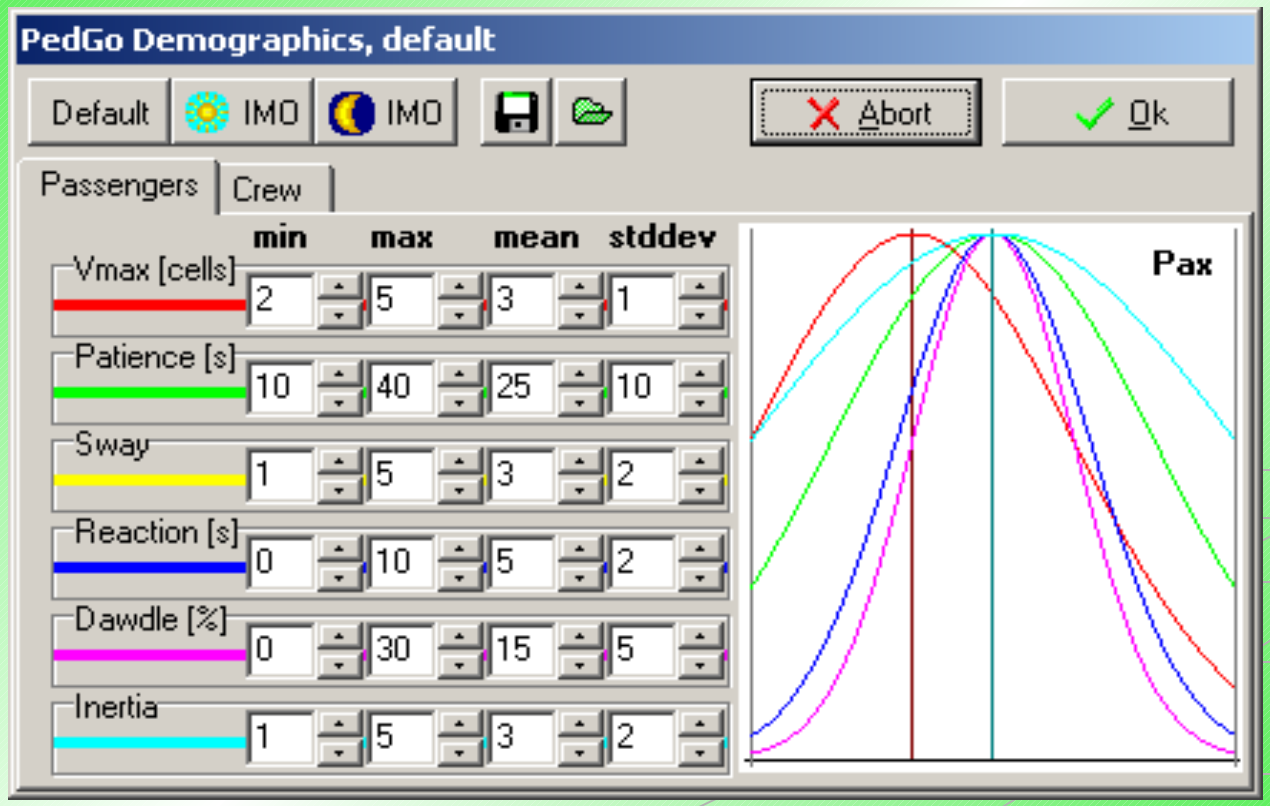
- Simulation
- Analysis

PedGo Editor



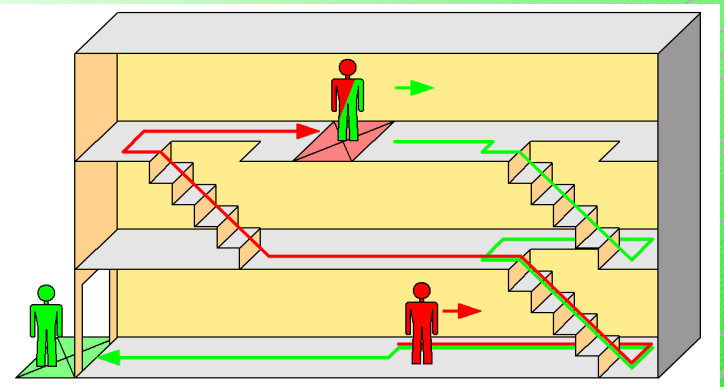
- Import DXF-Files
- Model scenario

Personal Parameters

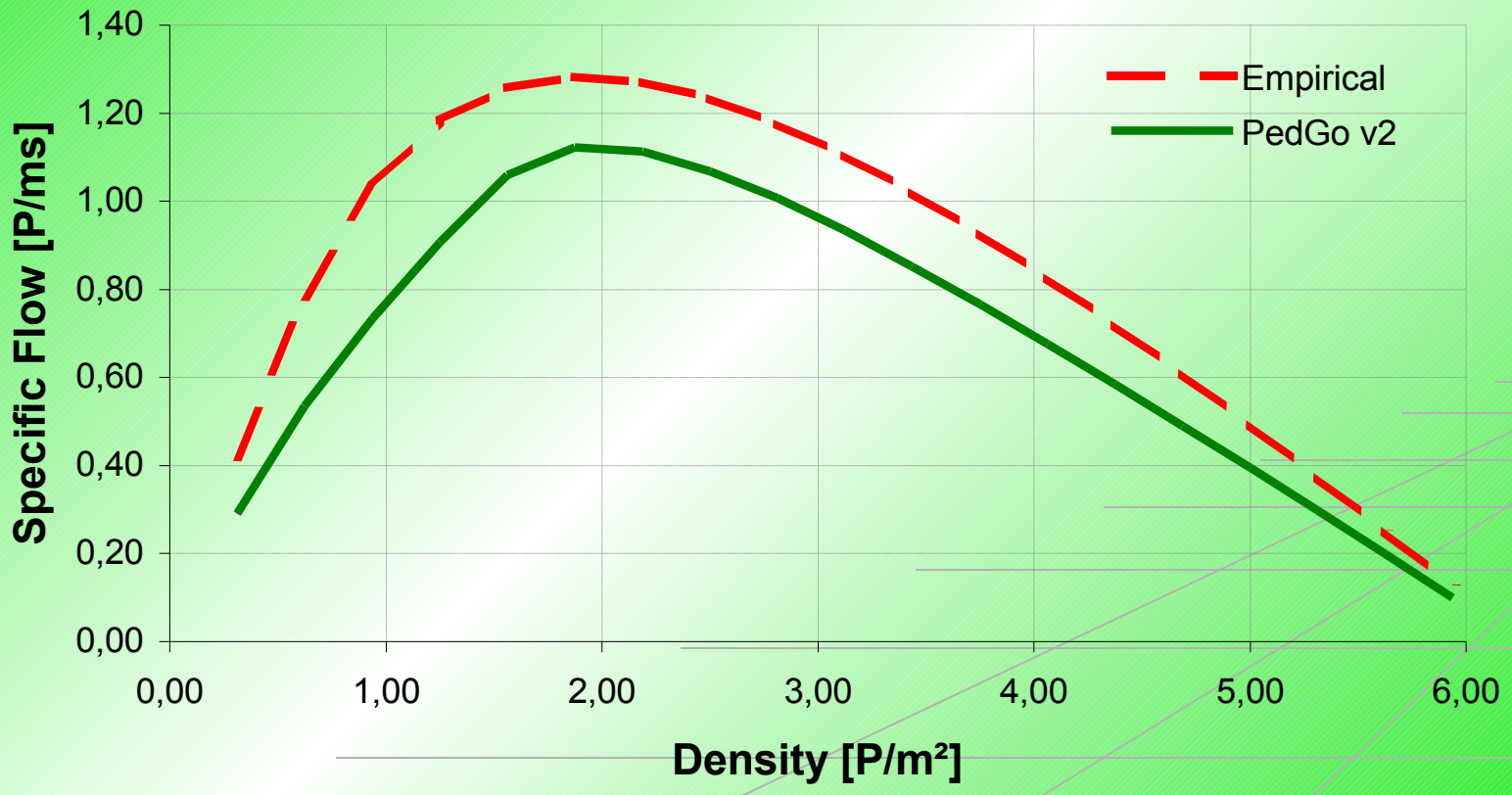


Routes

- Define different routes for different groups
- Crew and passenger routes



Flow-Density-Relation



Simulation, Results

- Statistical Distribution of Total Times
- Interaction of Persons
- Different Behavior
- High Calculation Speed
- Variation of Scenarios (Sensitivity Analysis)
- Fast Implementation of Geometrical Changes

Simulation, Results

Density plots (integrated over time):

Red Areas: congestion (ρ > 3.5 /sqm, 0.1 T)

Yellow Areas: medium congestion (0.01 T)

Green Areas: little congestion (1 second)

Animations/Screenshots:

Red dots: people standing

Yellow dots: medium speed

Green dots: free walking speed (v_{max})

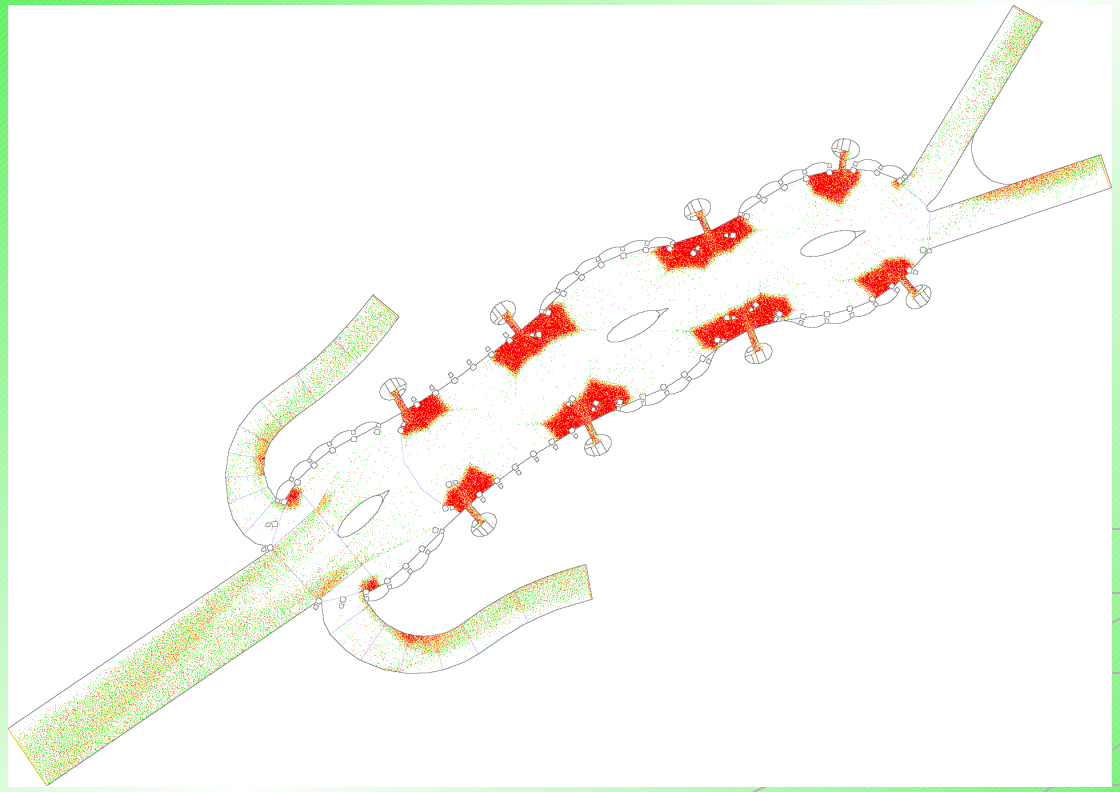
New Jamarat Bridge

Film Mekka

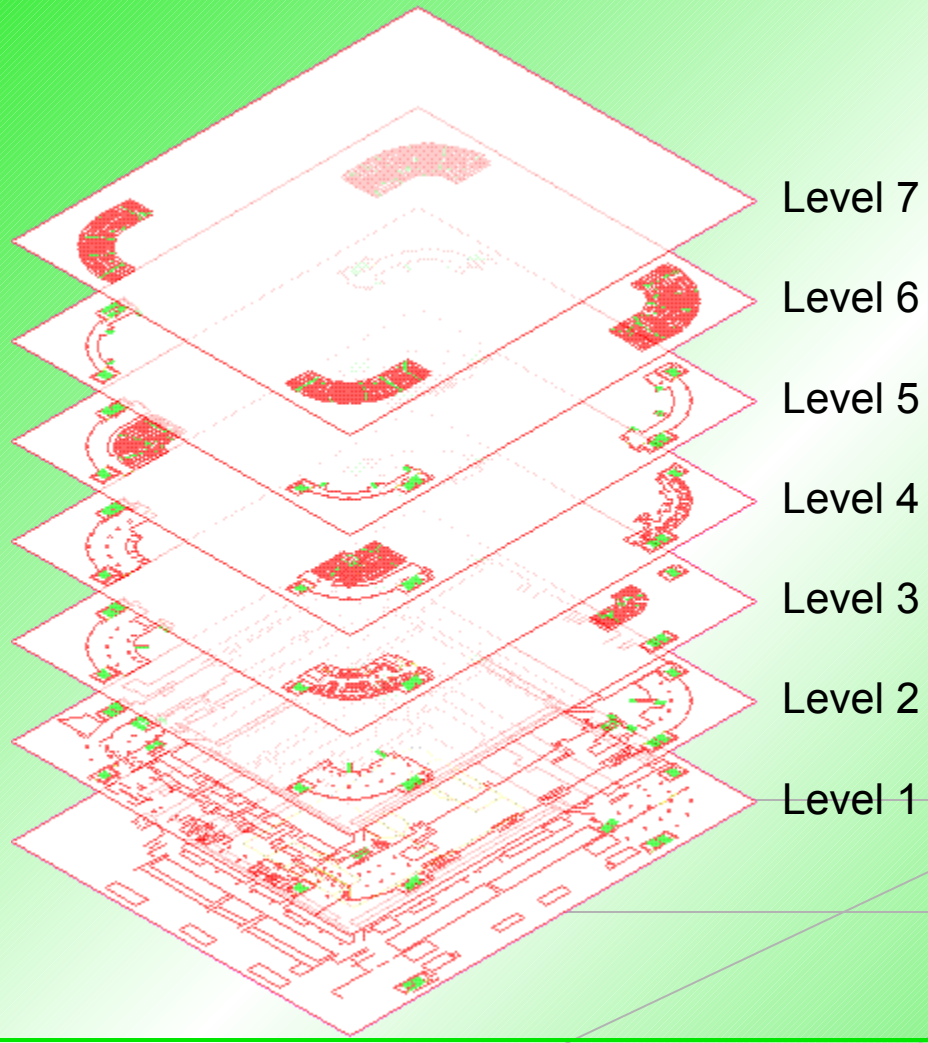
National Geographic.wmf

Simulation Jamarat Bridge

Assessment of the new design with respect to evacuation via side-towers.



Westfalenstadion Dortmund



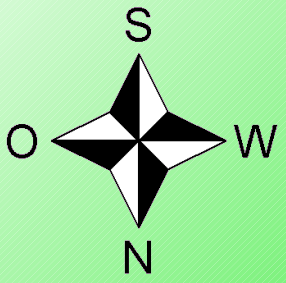
rot: Walls
Barriers

grün: Stairs

Egress

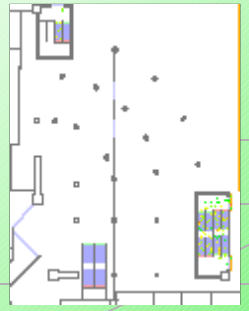
Exits

Level 1



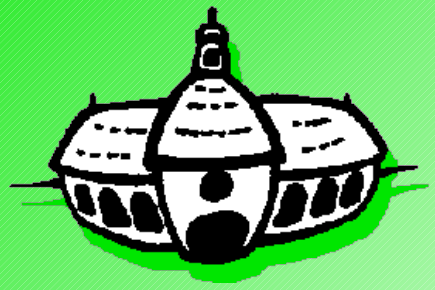
Congestion on the stairway → no congestion at the exits.

Level 2



Techniques

Steps

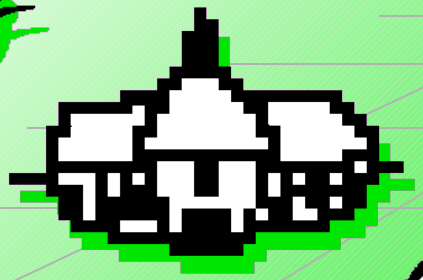


Pruning

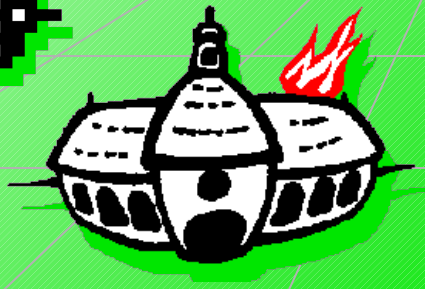
Coloring

Modeling

Scenarios

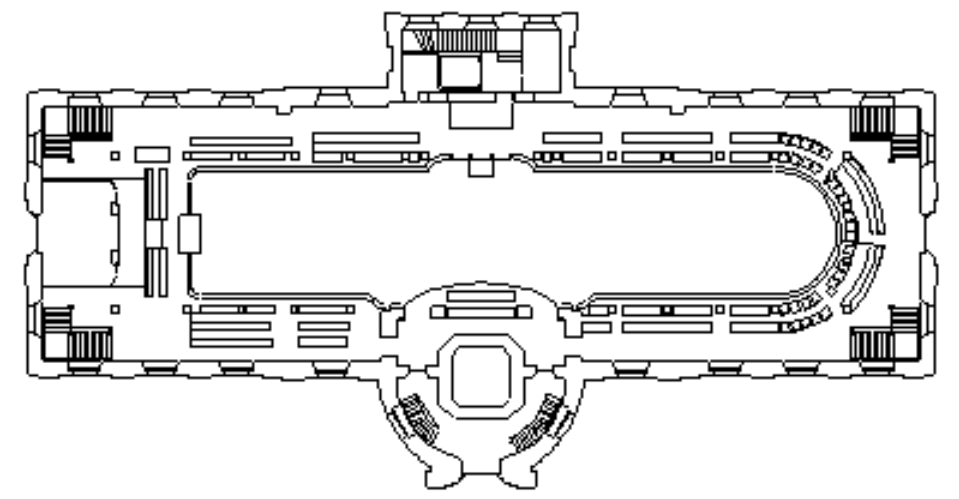


Simulation



Evaluation

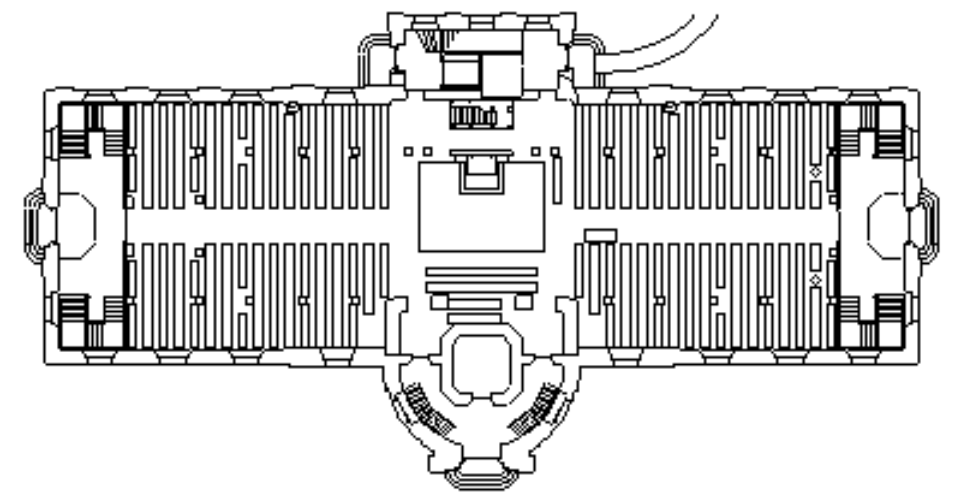
St Evakuus, Floor-plan



Gallery

226 Persons

(202: seats, 24: choir)



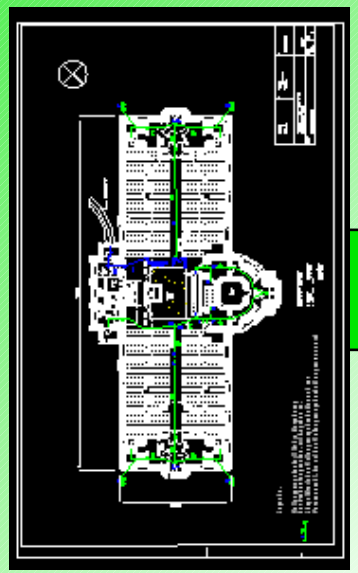
Ground floor (exit)

793 Persons

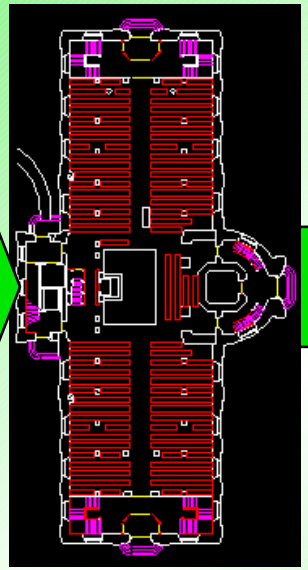
(788: seats,
5: wheelchairs)

Work-flow

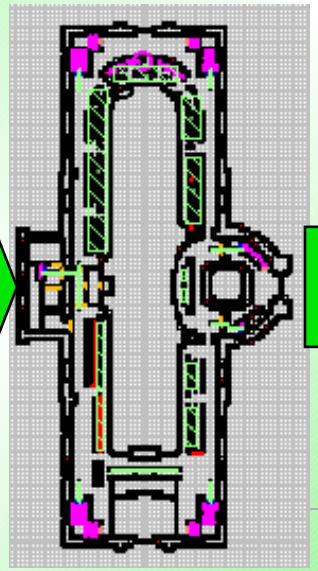
CAD-drawing



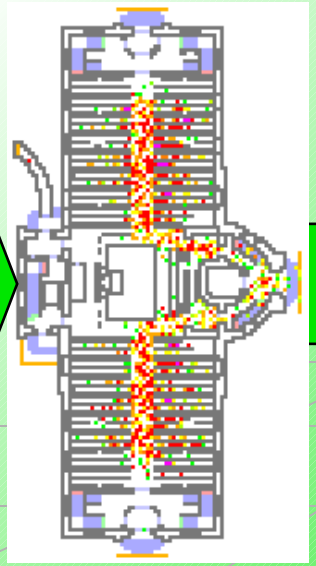
Preprocessed CAD



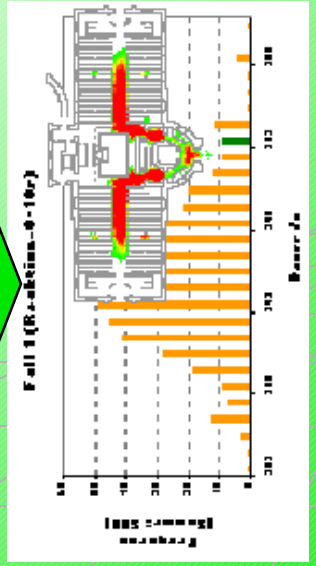
Grid-based Floor-plan



Simulation



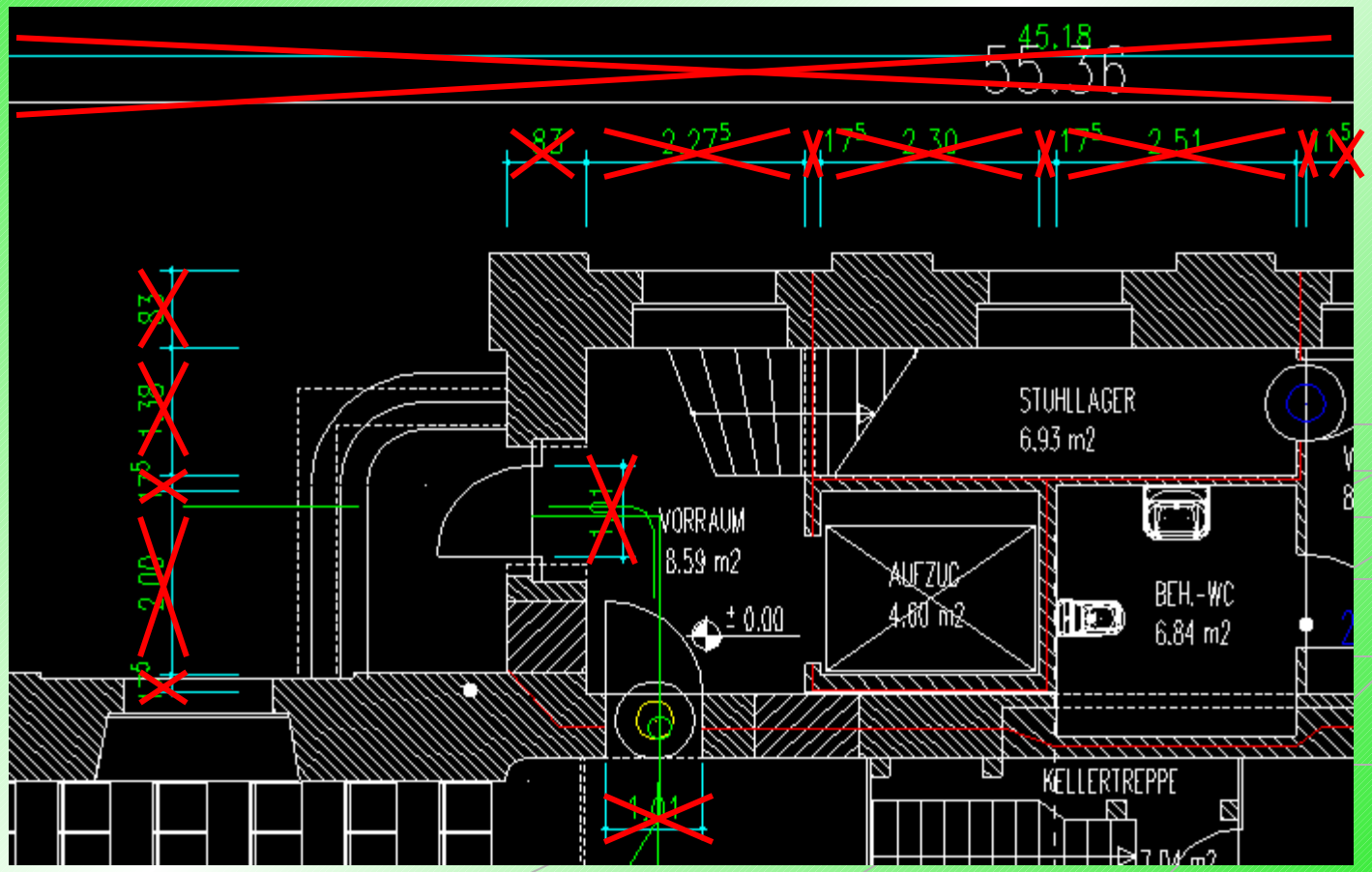
Evaluation



Preprocessing
Pruning

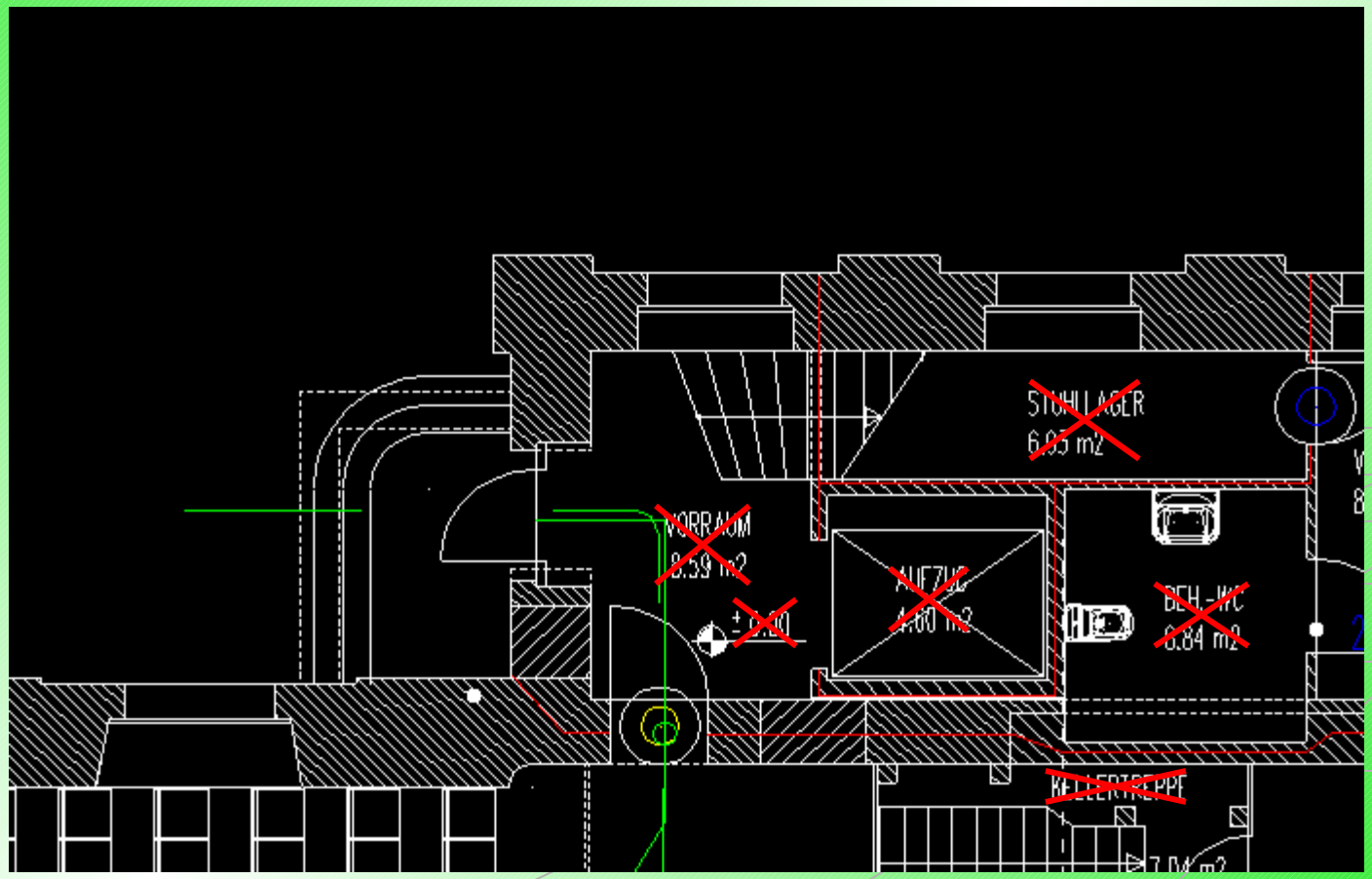
Preprocessing, Pruning

Remove numbers and dimension lines



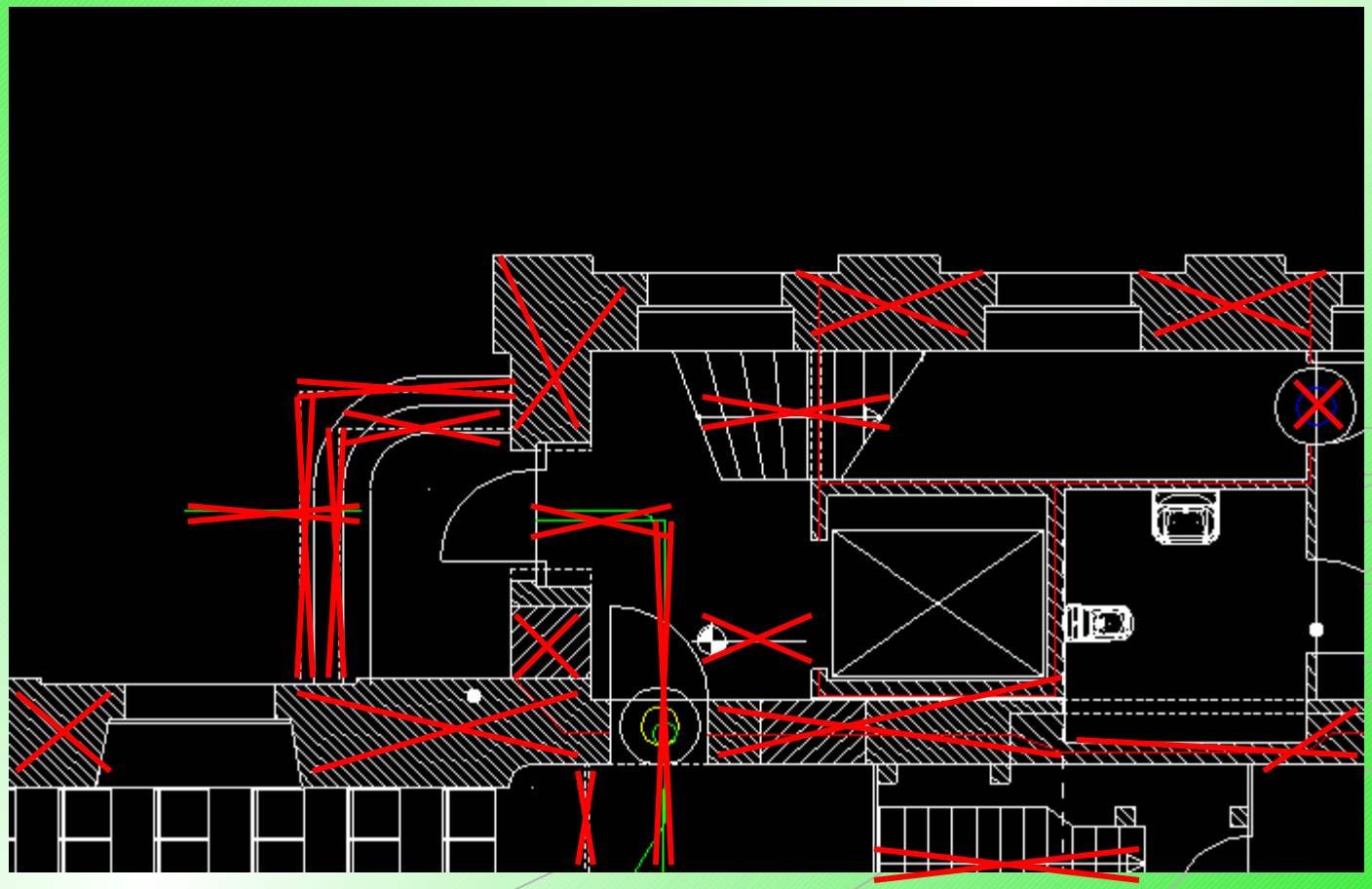
Preprocessing, Pruning

Remove text



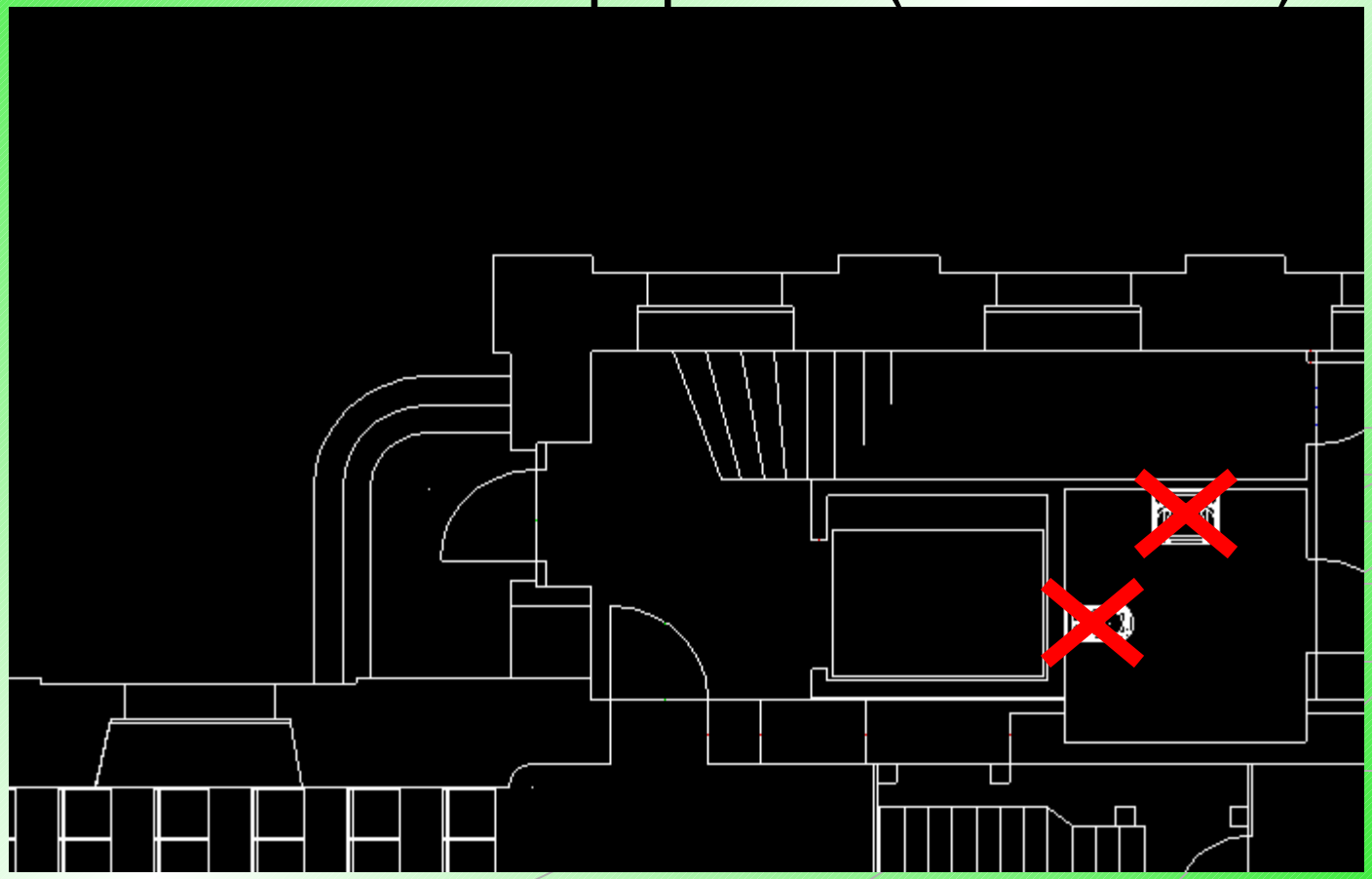
Preprocessing, Pruning

Remove hatches and similar lines



Preprocessing, Pruning

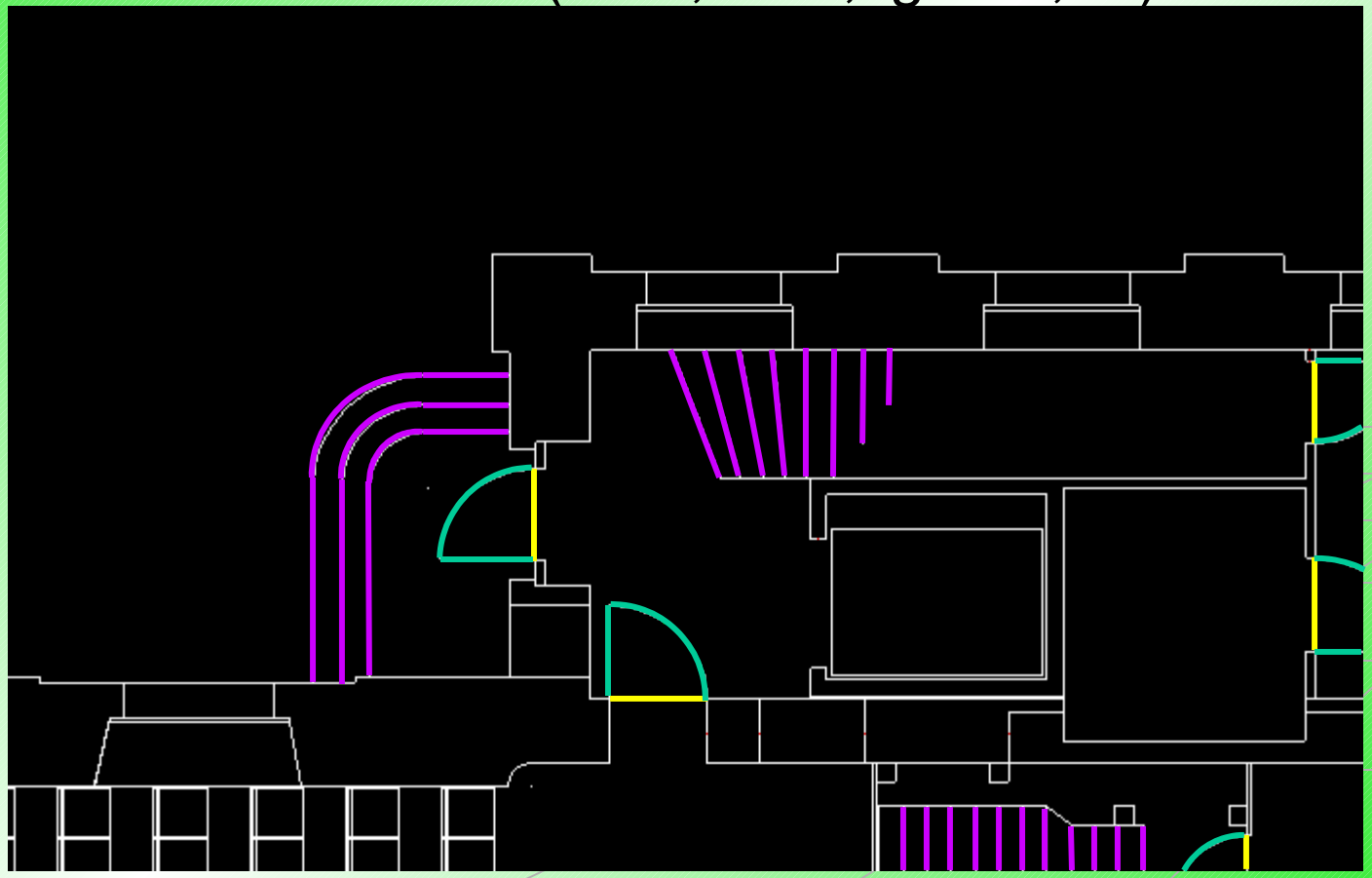
Remove irrelevant equipment (like faucets)



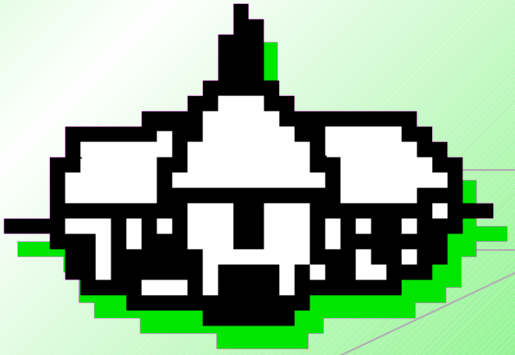
Preprocessing
Coloring

Preprocessing, Coloring

Color = Information (door, stair, ignore, ...)

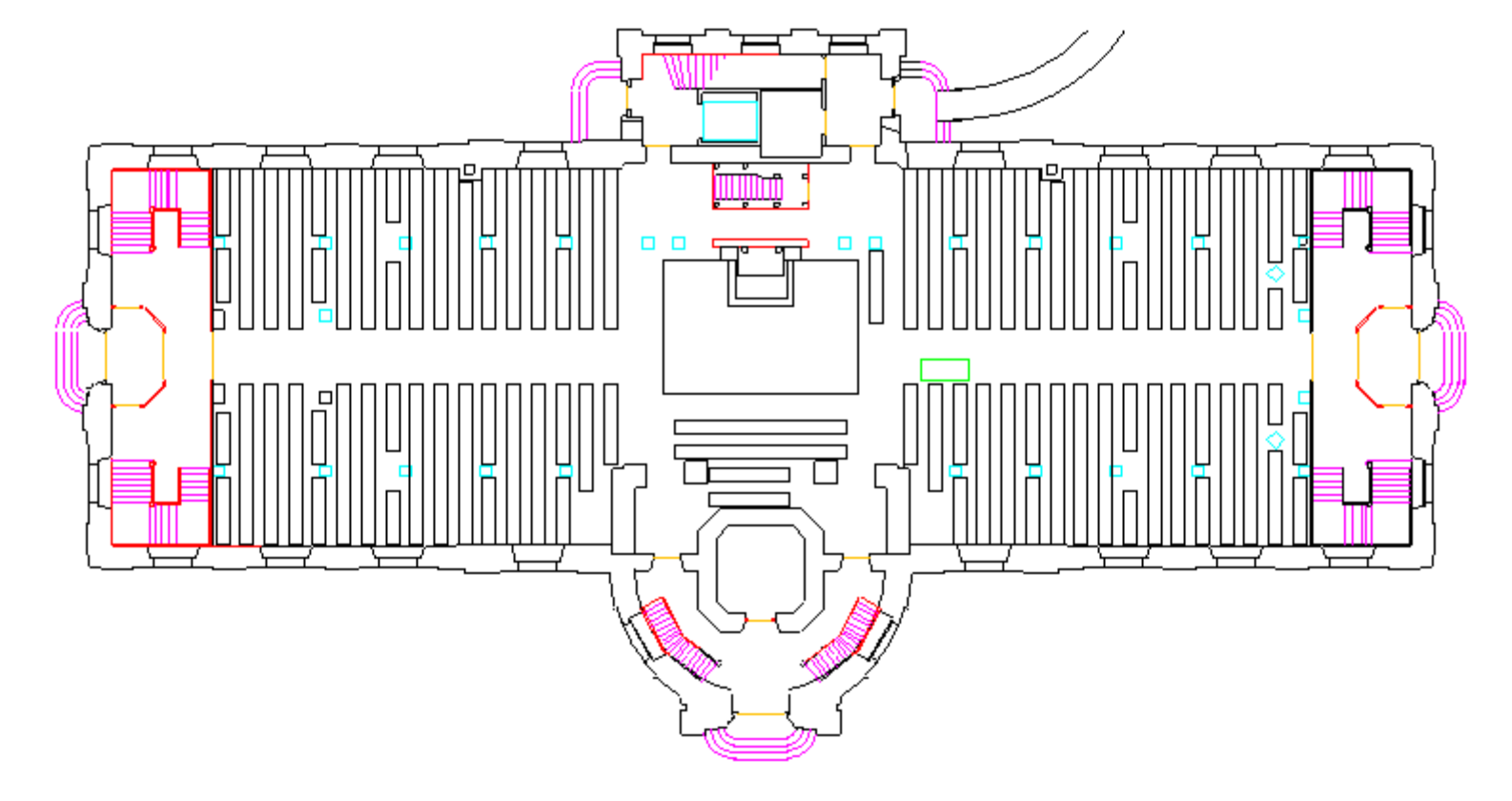


Modeling



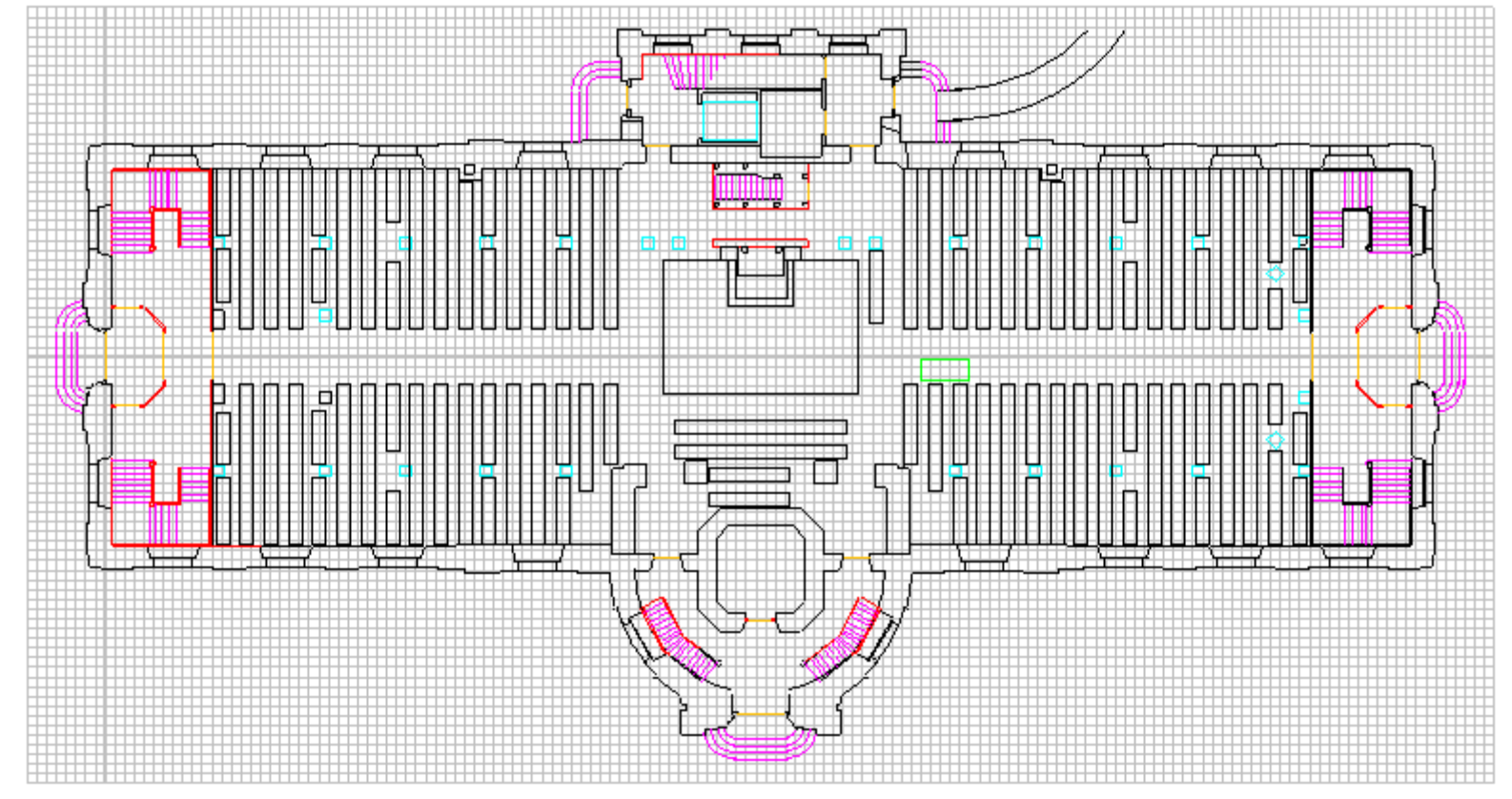
Preprocessing, Modeling

Import the pre-processed files (dxf)



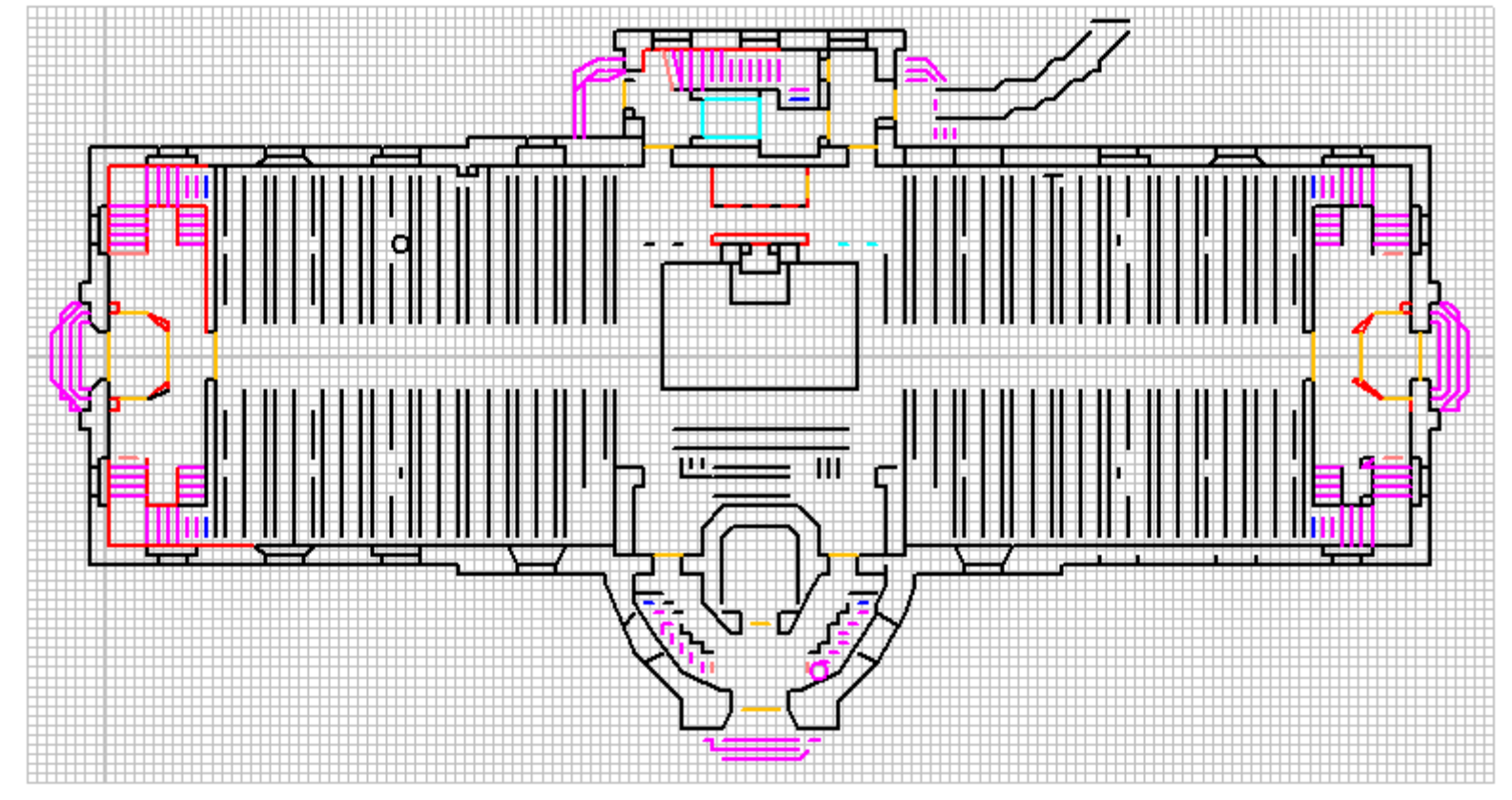
Preprocessing, Modeling

Automatically superimpose grid



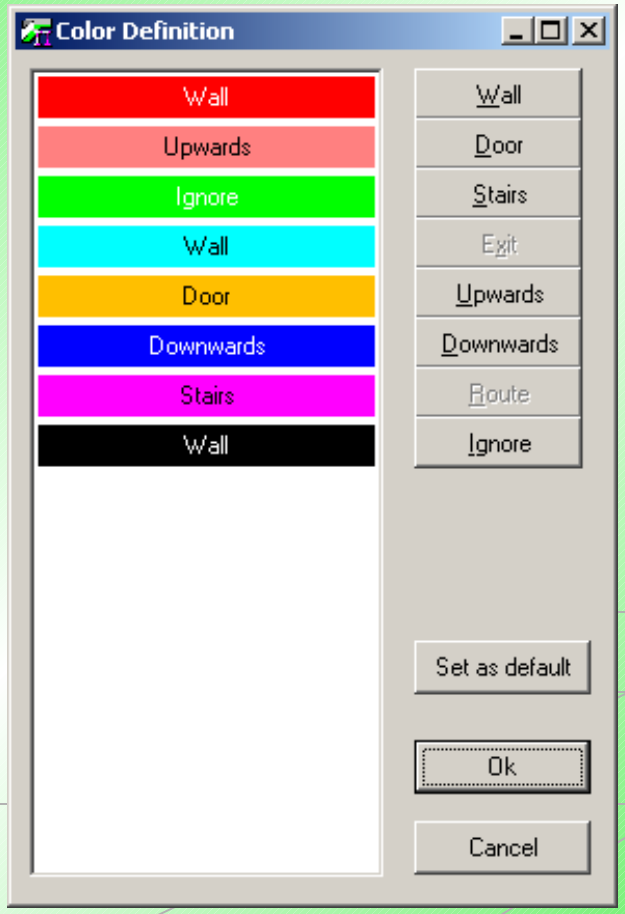
Preprocessing, Modeling

Automatically project to grid



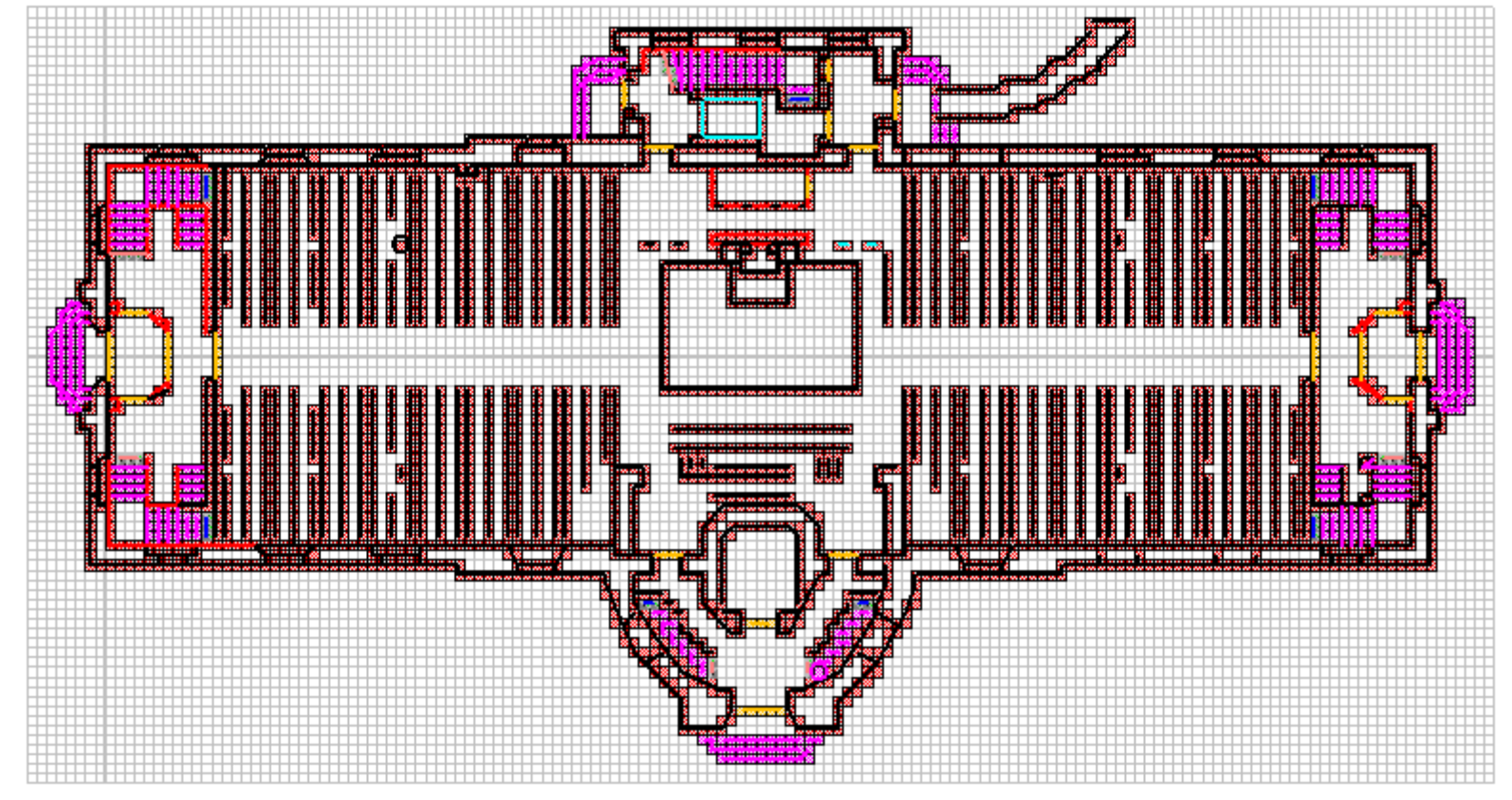
Preprocessing, Modeling

Definition of colors (mapping to function)



Preprocessing, Modeling

Automatically assign cell information

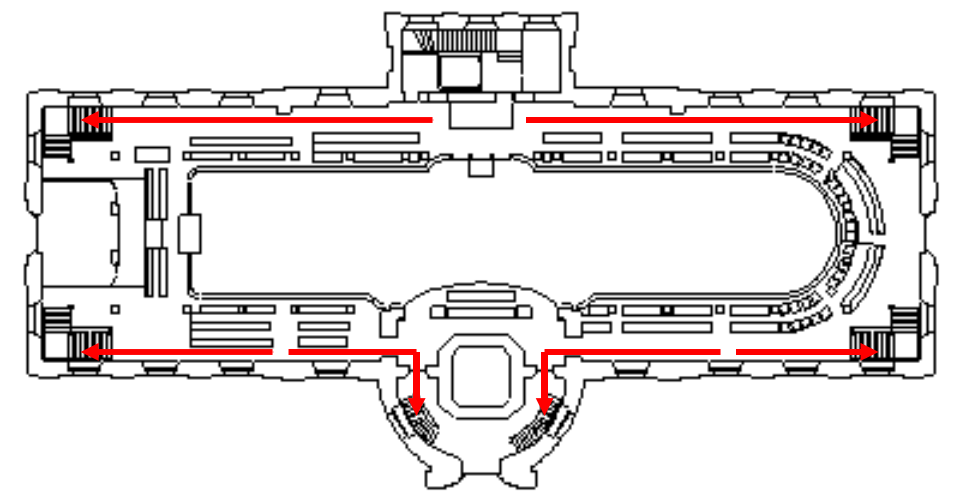


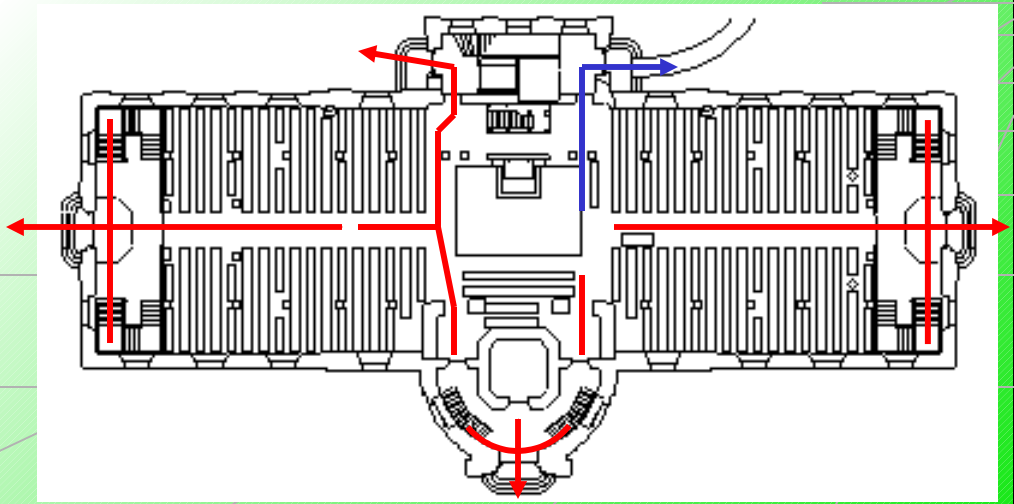
Assessment based on Simulation Results

Scenarios

Scenarios, Case 1 (standard)

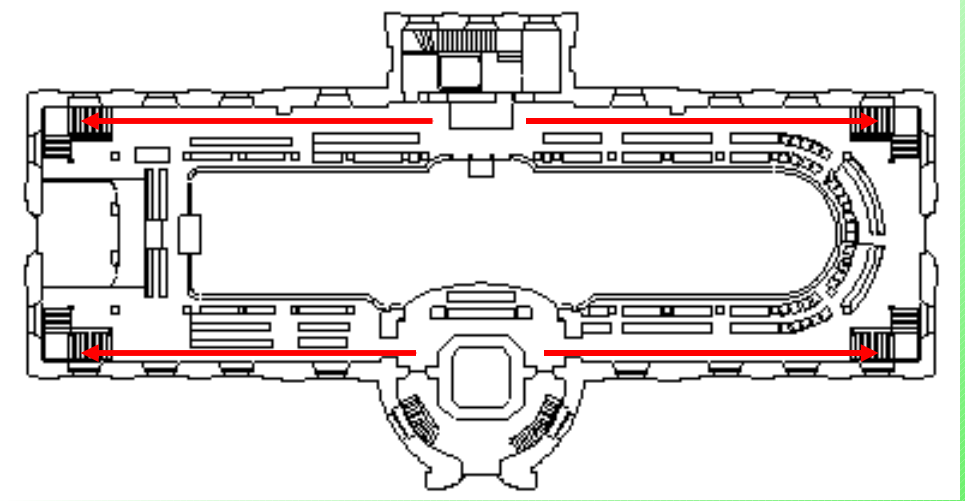
Persons leave the building via the main egress routes.

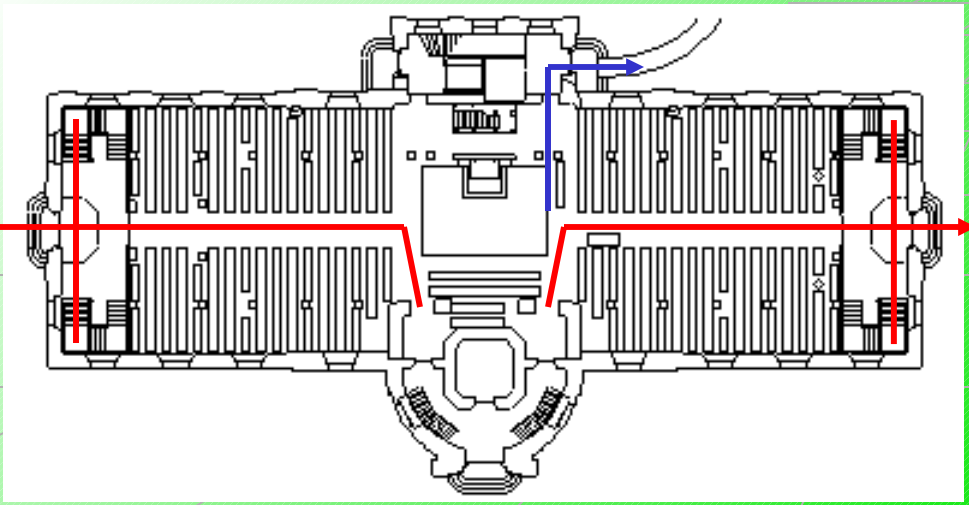




Scenarios, Case 2 (peripheral)

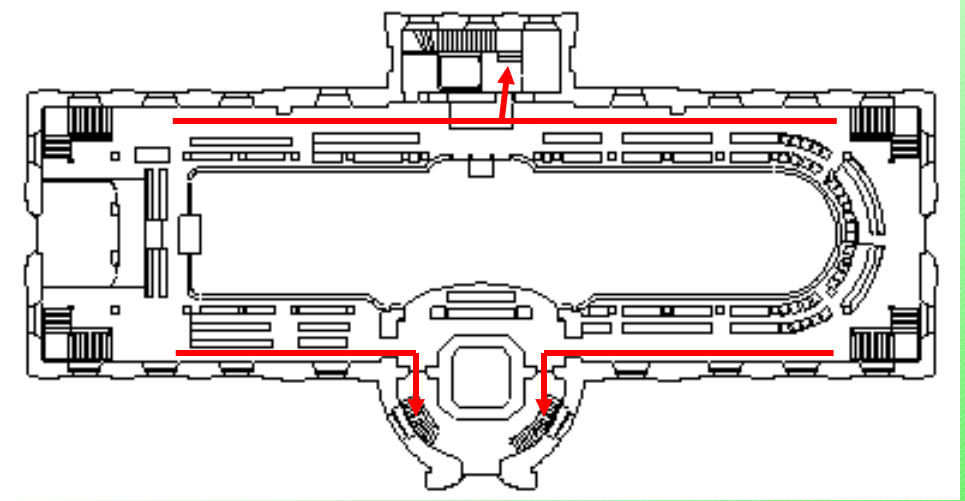
Persons leave the building via the external stairs and exits.

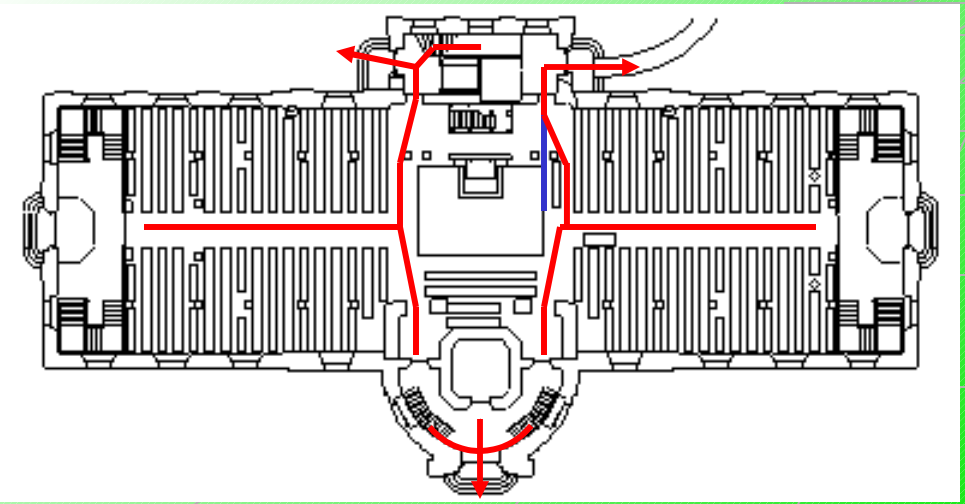




Scenarios, Case 3 (central)

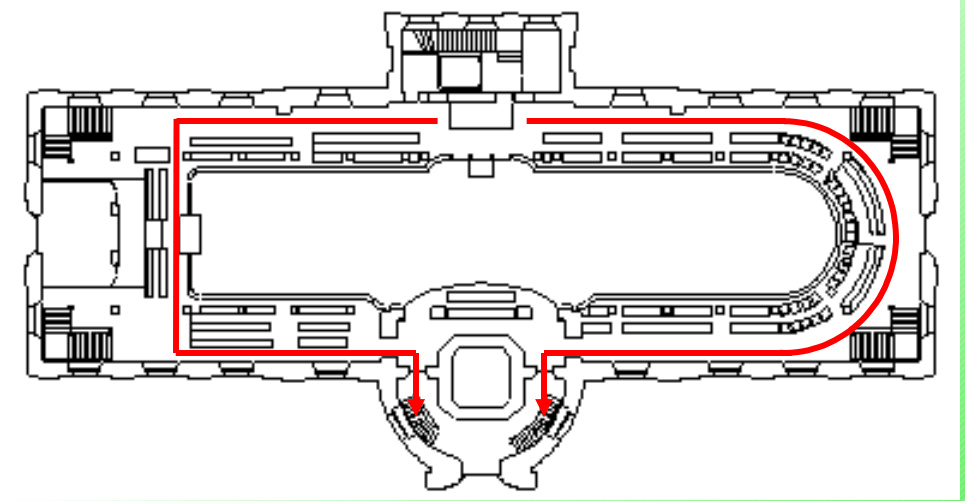
Persons leave the building via the inlaying stairs and exits.

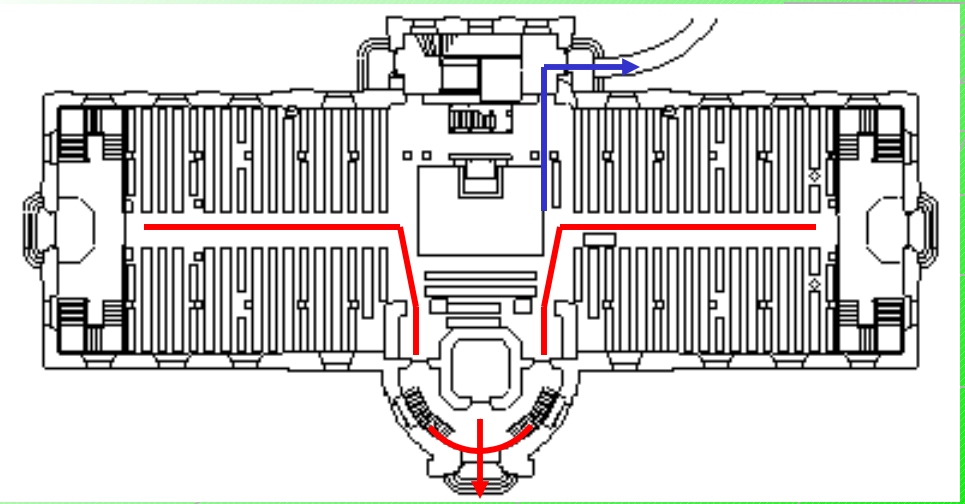




Scenarios, Case 4 (only main)

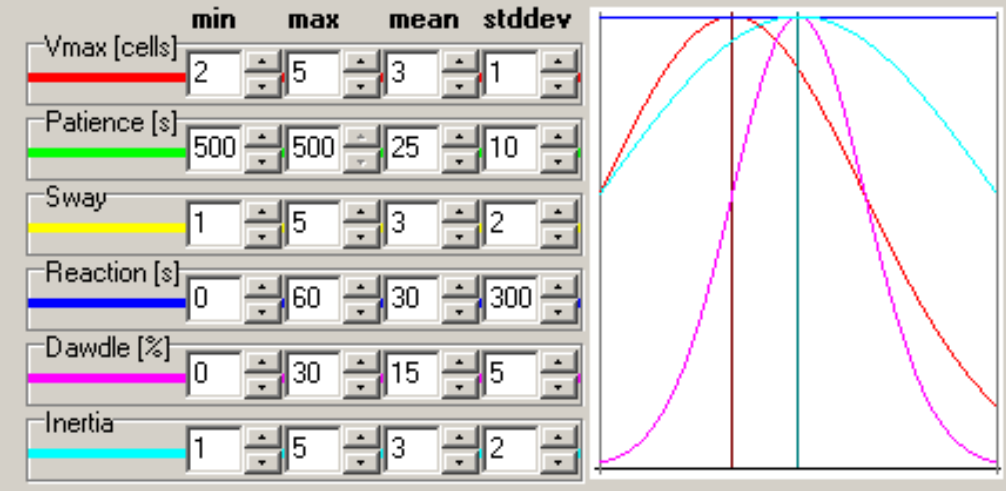
All persons leave the building via the main exit.



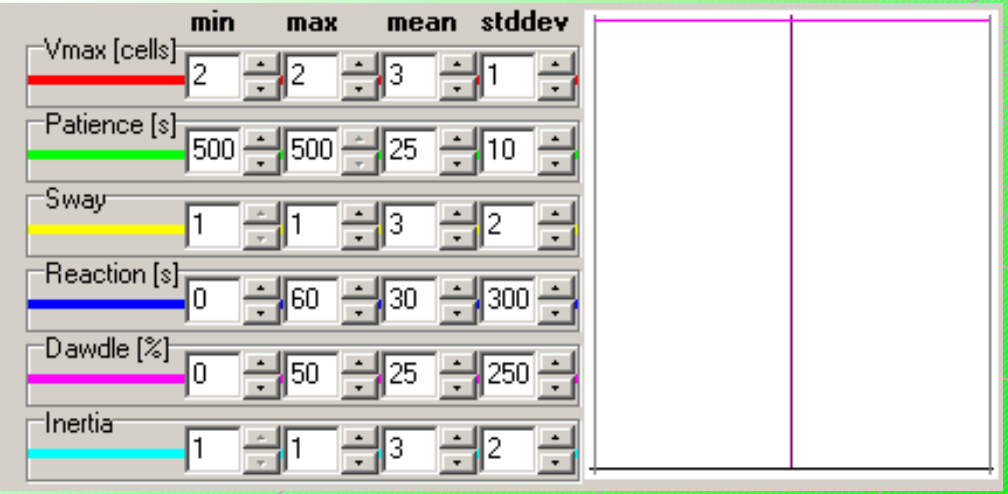


Population

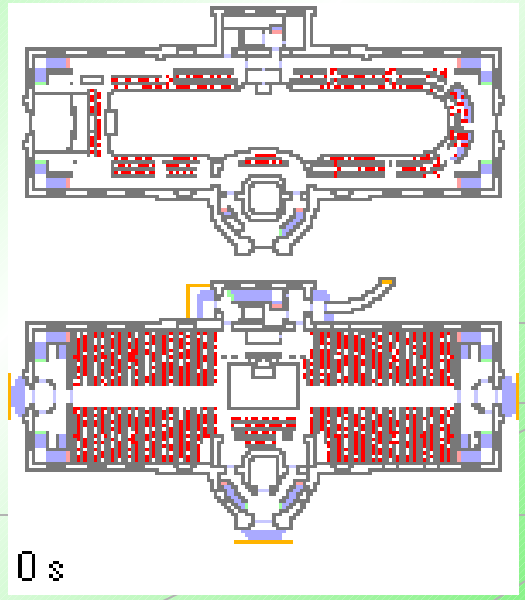
Standard Population:



Wheelchairs:



Simulation - Animation



Simulation - Cases

- 500 simulation runs per case
- Simulation speed:
  - Celeron; 450 MHz → 20 min
  - Pentium IV; 2,2 GHz → 5 min
- Additional variation of reaction time for Case 1 (equally distributed):
  - 0-10 s
  - 0-60 s
  - 0-120 s

Results, Egress times

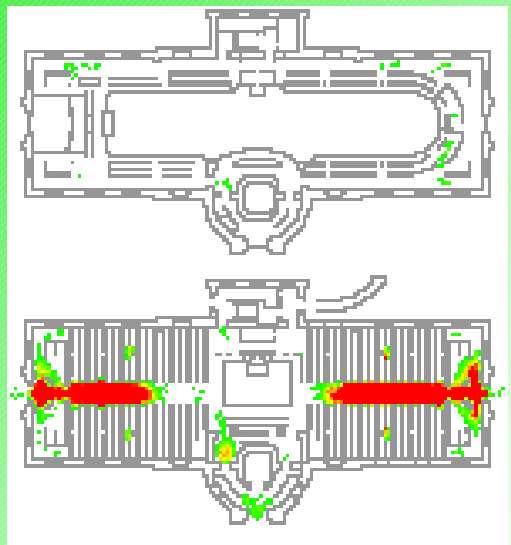
Case	Significant time
1.1 (0-60 s)	5:16 min
1.2 (0-10 s)	5:03 min
1.3 (0-120 s)	5:38 min
2 (outdoors)	5:42 min
3 (indoors)	5:21 min
4 (main exit)	9:33 min

Conclusion:

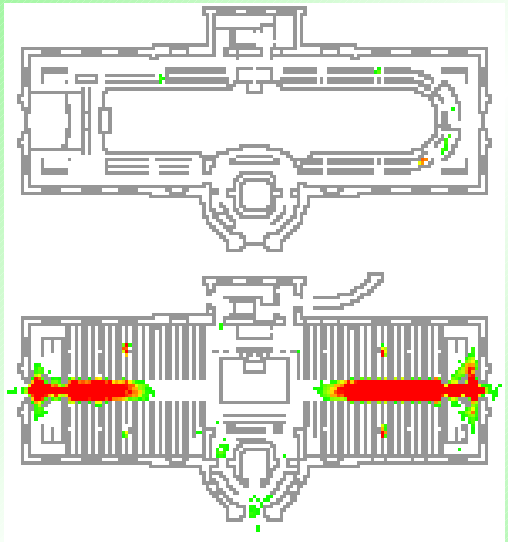
- Reaction time influences egress time only insignificantly.
- Route choice may have a major influence on egress time.

Results, Congestion

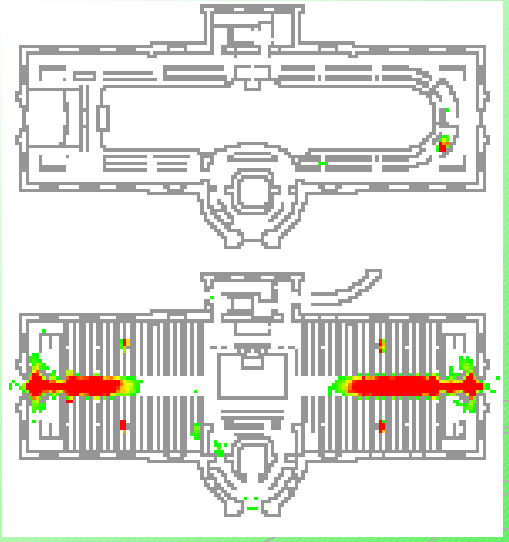
Case 1.2 (0-10 s)



Case 1.1 (0-60 s)



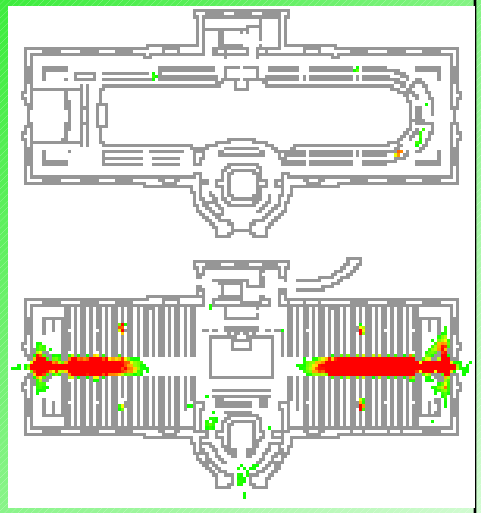
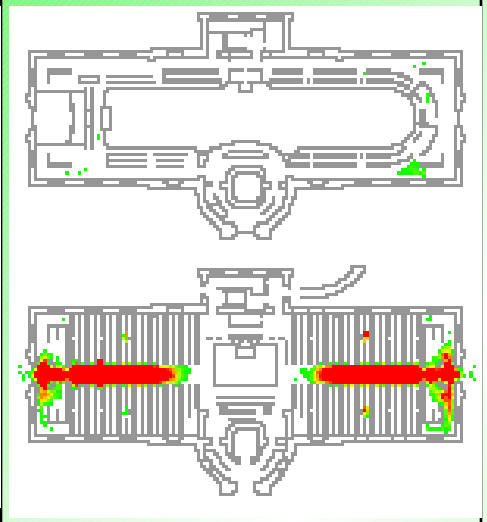
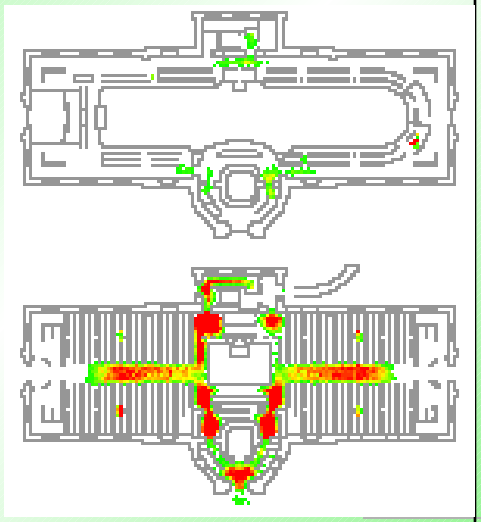
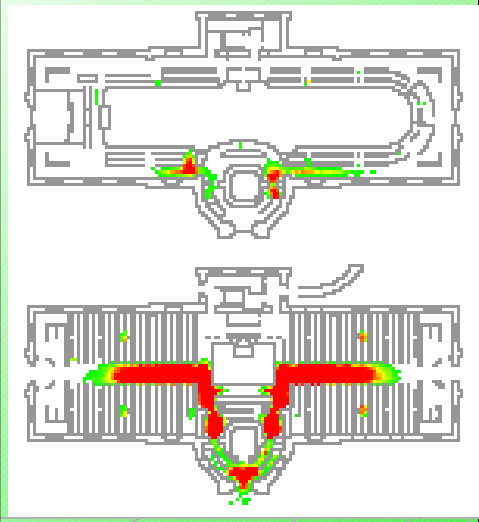
Case 1.3 (0-120 s)



Conclusion:

- The size of the jams increases with decreasing reaction time.
- There is hardly congestion on the gallery due to the low initial density.

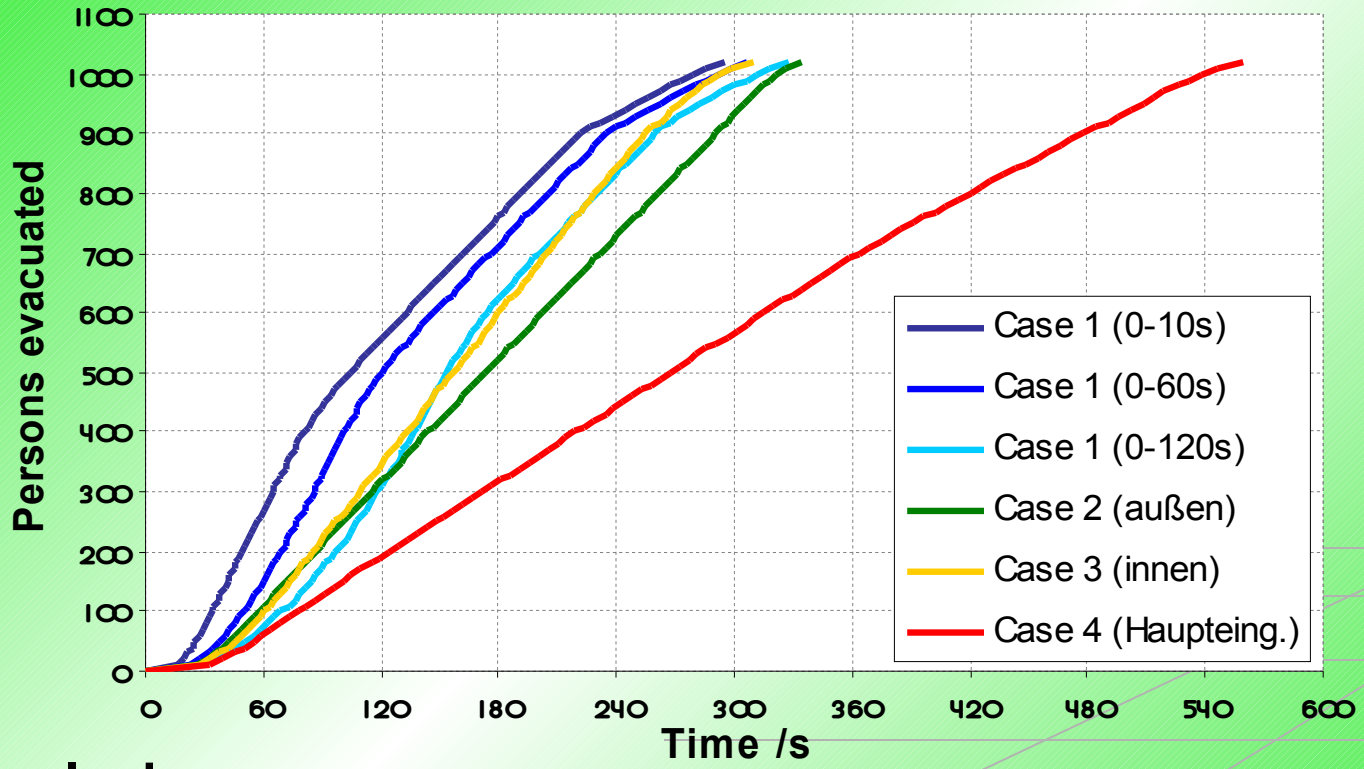
Results, Identification of congestion

Case 1.1 (standard)	Case 2 (outside)	Case 3 (inside)	Case 4 (only main)
			

Conclusion:

- Hardly congestion on the gallery due to low initial density.
- There is always congestion in the central corridor (ground floor) and in front of the main exits.

Results, Egress curves



Conclusion:

- Cases 1-3 are similar to each other.
- Case 4 is the worst case.

Limits Principal, Time, Memory

Restrictions

Geometry: 100m x 100m
Population: 100.000
Many Psychological Aspects
Details of Deployment
and Embarkation

Aker Genesis

~ 8.000 persons
21 decks
> 360 m long
Editor (pg2)
(show decks)

PedGo - Program

Night case

Open PedGo

PedGo - Simulation

Night case

Animation Decks 3 to 7

The end

Presentation, Publications, Manual, Information, Links

www.traffgo-ht.com