


Certification

PedGo and AENEASsim, version 2.7
PedGo Editor and AENEASed version 2.7

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Title: Certification of the software programs PedGo and AENEAS version 2.7		
Abstract: This document explains and demonstrates the application of the software programs PedGo and AENEAS version 2.7 for the test cases of IMO MSC.1/Circ.1533.		
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1 Comments

PedGo and AENEAS are software programs for the microscopic simulation of evacuation processes. The verification of the software is done according to the *Revised Guidelines on Evacuation Analysis for New and Existing Passenger Ships* (IMO MSC.1/Circ. 1533). All of the following references refer to this guideline.

1.1 Documentation of the model

The model is documented according to Annex 3, Appendix 1, Chapter 6.

1.1.1 Model assumptions

For the model used in the simulation programs PedGo and AENEAS, the minimum assumptions of chapter 3.2 of the *Revised Guidelines on Evacuation Analysis for New and Existing Passenger Ships* (IMO MSC.1/Circ. 1533, Annex 2) were applied.

The algorithms of the model and the internal parameters contain no further simplifications.

1.1.2 Documentation of the used algorithms

1. The movement of an agent (modelled person) is characterized by her walking speed and direction (PedGo/AENEAS user manual).
2. The relation between the variables and parameters as well as the basic algorithms are described in the user manual (PedGo/AENEAS user manual) which can be downloaded from TraffGo HTs homepage (www.traffgo-ht.com).
3. The update of the agents movement is random sequential which by its qualitative result resembles a parallel update.
4. According to table 3.5 (Appendix 1) stairs lead to a reduction of the walking speed. This is taken into account by a reduction factor (PedGo/AENEAS user manual) which stochastically complies with the guidelines.
5. Doors lead to a reduction of the walking speed (PedGo/AENEAS user manual).
6. If according to Chapter 5.5 (Annex 1) the embarkation and launching time (E+L) is assumed to be 30 minutes, the muster process (R+T) is assumed to be completed, when all agents have reached their assembly station.
7. If data is available according to Chapter 5.4 (Annex 1), the embarkation phase begins, when all agents have reached their muster station and the signal for embarkation is given.
8. The actual PedGo/AENAEAS user manual is attached to this document.

1.2 Validation/Examination of the Simulation

The validation and examination of the simulation is done according to IMO MSC.1/Circ.1533, Annex 3. The following twelve tests are taken from annex 3. A detailed description of the realization is given in the test journal.

Test 1: Statistically correct.

Test 2: Statistically correct.

Test 3: Statistically correct.

Test 4: The exit flow rate is less than 1.33 P/s.

Test 5: The response durations lie between 10 s and 100 s.

Test 6: The corner is rounded without penetrating the walls.

Test 7: The distribution of walking speeds is statistically consistent to the specified values.

Test 8: The total time increases with the number of agents moving in opposite direction.

Test 9: The total time to leave the room approximately duplicates, when only two of the former four doors are available.

Test 10: The assignment of exits works as specified.

Test 11: Congestions occur due to the reduction of the walking speeds and bottlenecks at the exit of the room and at the lower end of the stair.

Test 12: The flow reduction at high densities appears in the fundamental diagram.

2 Test Journal

2.1 Test 1: Corridor

2.1.1 Preparations

- Draw corridor with a CAD program.
- Import dxf file into Editor.
- Remove projection errors.
- Define exits.
- Insert agent.

2.1.2 Perform Simulation

- Load project file.
- Adjust demographic parameters:
 - $v=2$ to 3 Cells per second (equally distributed values).
 - All other parameters are set to minimum values (e.g. Sway=1) in order to achieve straight walking.
- Execute mean value simulation with 100 runs.

2.1.3 Results

Duration Overall /s	Duration Walking /s	Frequency	Speed /m/s
34	33	46	1,21
35	34	4	1,18
51	50	46	0,80
52	51	4	0,78
Sum/Evaluation	41,58¹	100	1,00²

Tab. 1: Duration distribution and resulting speed.

The minimum walking duration of all runs is 34 s (46 times) and the maximum is 52 s (4 times). Since one second is required for saving the agent on the exit cell, the walking durations have to be reduced by it. Following, the weighted average walking speed (by speed and frequency) is 1.00 m/s.



Fig. 1: RSET³ plot of test 1.

¹ Weighted Walking Duration = Sum (Walking Duration * Frequency) for all Walking Durations divided by Sum of all Frequencies

² Weighted Average Speed = Sum (Speed * Frequency) for all Speeds divided by Sum of all Frequencies

2.2 Test 2: Stair Upward

The walking speed on stairs is determined automatically in PedGo/AENEAS, based upon a reduction factor of 0.45 (walking upward). When the walking speed on flat terrain is set to 5 cells/s (=2,0 m/s), an agent walks up the modelled stair in 10 s.

2.2.1 Preparations

- Draw stair with a CAD program.
- Import dxf file into Editor.
- Model Geometry, define exits, insert agent.

2.2.2 Perform Simulation

- Load project file.
- Adjust demographic parameters:
 - $v=5$ Cells per second.
 - All other parameters are set to values which do not take effect on the result.
- Execute mean value simulation with 100 runs.

2.2.3 Results

Duration Overall /s	Duration Walking /s	Frequency	Speed /m/s
10	9	6	0,98
11	10	37	0,88
12	11	57	0,80
Sum/Evaluation	10,51	100	0,84

Tab. 2: Duration distribution and resulting speed.

The weighted mean value for the overall duration is 10,51 s, so the weighted average speed is 0,85 m/s.

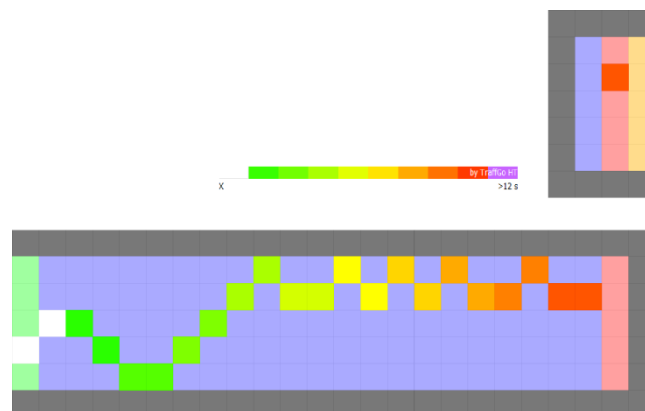


Fig. 2: RSET plot of an agent walking up a stair.

³ RSET (Required Safe Egress Time) plot: For each cell, the time is logged when it was last exited. In combination with a given threshold value "critical areas" can be visualized.

2.3 Test 3: Stair Downward

The walking speed on stairs is determined automatically in PedGo/AENEAS, based upon a reduction factor of 0.55 (walking downward). When the walking speed on flat terrain is set to 5 cells/s (=2,0 m/s), an agent walks up the modelled stair in 10 s.

2.3.1 Preparations

- Draw stair with a CAD program.
- Import dxf file into Editor.
- Model Geometry, define exits, insert agent.

2.3.2 Perform Simulation

- Load project file.
- Adjust demographic parameters:
 - $v=5$ cells/s
 - All other parameters are set to values which do not take effect on the result.
- Execute mean value simulation with 100 runs.

2.3.3 Results

Duration Overall /s	Duration Walking /s	Frequency	Speed /m/s
8	7	3	1,26
9	8	45	1,10
10	9	45	0,98
11	10	7	0,88
Sum/Evaluation	8,56	100	1,03

Tab. 3: Duration distribution and resulting speed.

The weighted mean value for the overall duration is 8,56 s, so the weighted average speed is 1,03 m/s.

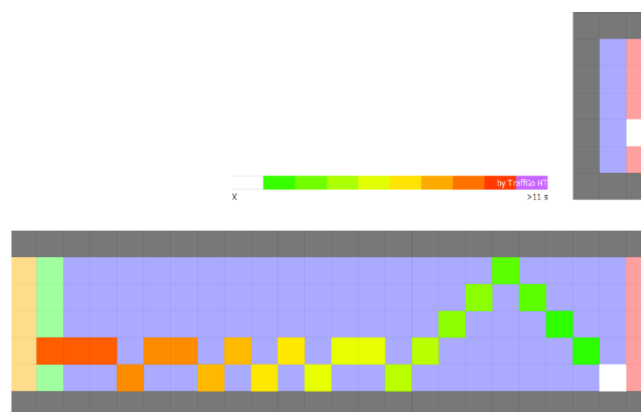


Fig. 3: RSET plot of an agent walking down a stair.

2.4 Test 4: Exit Flow Rate

2.4.1 Preparations

- Draw room with a CAD program.
- Import dxf file into Editor.
- Model Geometry, define exits, insert 100 agents.

2.4.2 Perform Simulation

- Load project file.
- Set demographic standard parameters.
- Perform mean value simulation with 100 runs.
- Repeat minimum run and determine exit flow rate by log point.

2.4.3 Results

The mean flow rate is determined through:

$$\text{flow} = \text{number of agents} / (\text{duration} * \text{exit width})$$

The minimum evacuation duration of all runs is 102 s. Although the exit flow rate is temporarily exceeded, the mean exit flow rate remains within 1,33 P/ms.

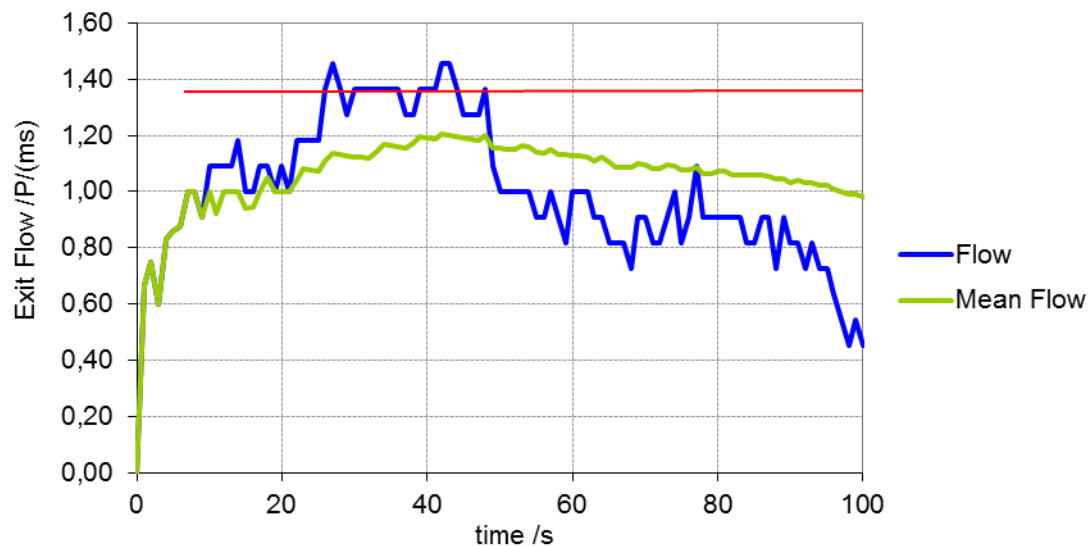


Fig. 4: Exit flow rate (minimum run).

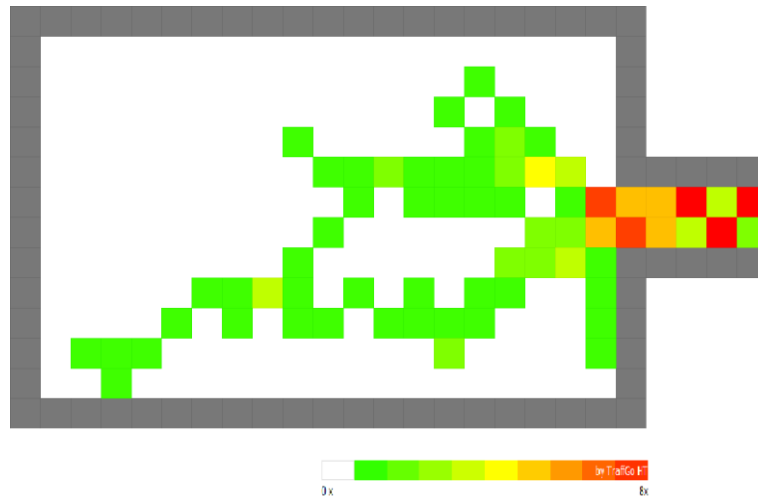


Fig. 5: Path plot⁴.

⁴ A path plot visualizes, how often a cell has been accessed by agents.

2.5 Test 5: Response Duration

2.5.1 Preparations

- Change agent numbers of test 4.

2.5.2 Perform Simulation

- Load project file.
- Adjust demographic standard parameters.
- Set response duration equally distributed to 10 – 100 s.
- Execute single simulation.

2.5.3 Results

The response duration of the agents can be evaluated from the result file. The reaction durations for the significant run (seed=4721) are within the range of 10 to 100 seconds with a mean reaction duration of 55 s.

Agent #	1	2	3	4	5	6	7	8	9	10
$t_{\text{react}} / \text{s}$	81	85	19	48	99	58	19	25	99	19

Tab. 4: Distribution of reaction durations.

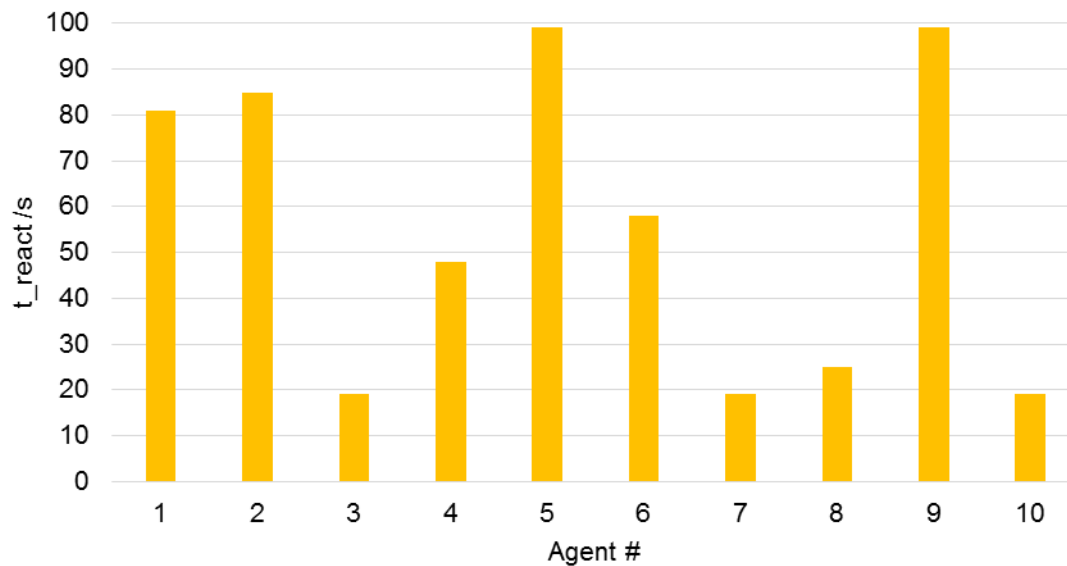


Fig. 6: Distribution of reaction durations.

2.6 Test 6: Rounding Corners

2.6.1 Preparations

- Draw corridor with a CAD program.
- Import dxf file into Editor.
- Model Geometry, define exits, insert 20 agents.

2.6.2 Perform Simulation

- Load project file.
- Adjust demographic standard parameters.
- Execute demo-simulation.

2.6.3 Results

All agents successfully round the corner without penetrating the walls.

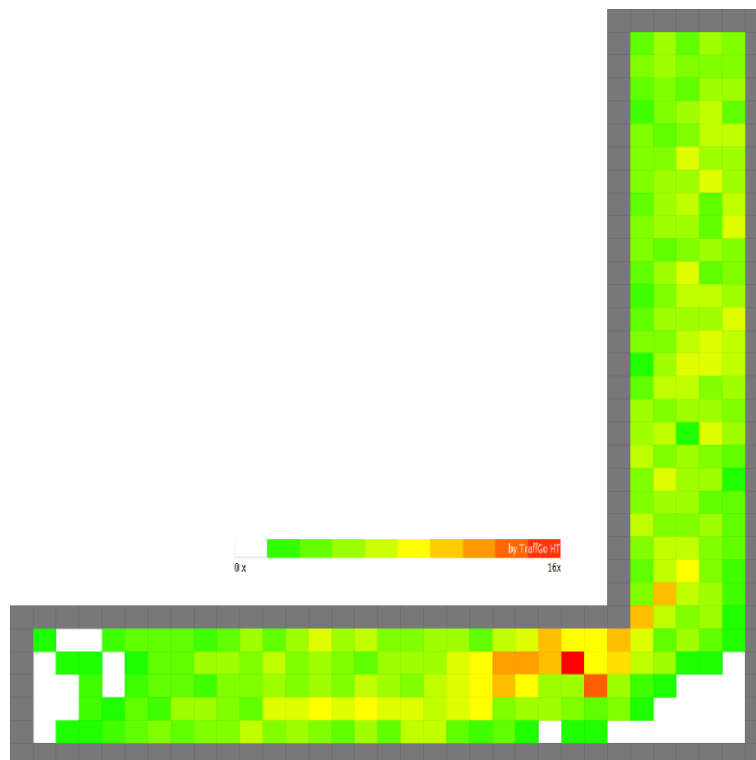


Fig. 7: Path plot of test *Rounding Corners*.

2.7 Test 7: Assigning Parameters

2.7.1 Preparations

- Change number of agents from Test 5 to 50.

2.7.2 Perform Simulation

- Load project file.
- Adjust demographic standard parameters.
- Adjust walking speed (IMO: 0,97 to 1,62 m/s equals PedGo/AENEAS: 2 to 4 cells/s).
- Execute single simulation run.

2.7.3 Results

The parameters of the agents can be evaluated from the result file. The distribution of the velocities in the simulation is in accordance with the specified distribution in the guidelines. No speeds outside of the defined distribution were detected.

The speed distribution is evaluated from the mean simulation run.

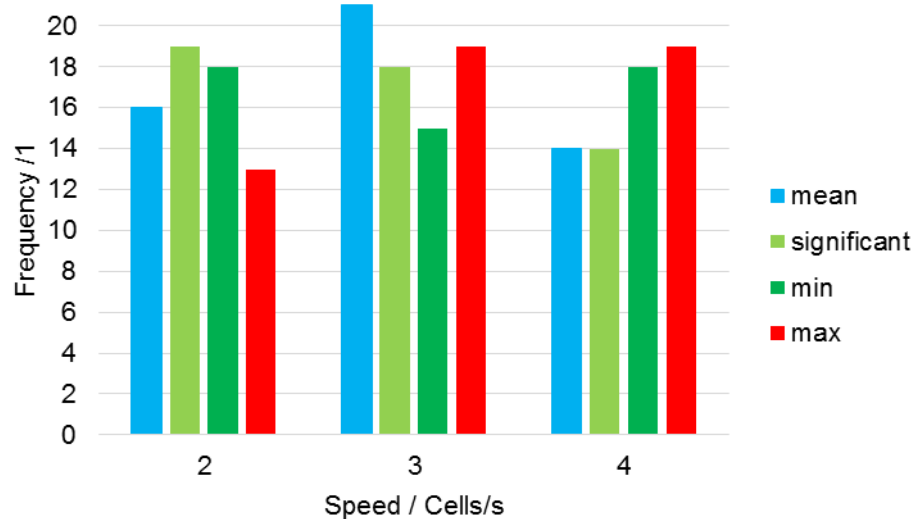


Fig. 8: Speed distribution of Test 7 *Assigning of Parameters*.

2.8 Test 8: Counterflow

2.8.1 Preparations

- Draw corridor with a CAD program.
- Import dxf file into Editor.
- Model Geometry, define exits, insert agents.

2.8.2 Perform Simulation

- Load project file.
- Adjust demographic standard parameters.
- Adjust walking speed (equally distributed to 2-4 c/s).
- Patience disabled in order to avoid route changes.
- Response duration = 0 s.
- Execute mean value simulation with 100 runs.

2.8.3 Results

The stronger the counter flow, the longer it takes for the agents to reach their goals. Therefore the significant durations increase.

agents left	agents right	v2.7 /min	remark
100	0	01:56	
100	10	02:09	
100	50	06:19	
100	100	13:20	
100	100	06:18	enforced lane formation

Tab. 5: Results of counter flow test.

With enforced lane formation, the duration for the 100/100 case can be reduced to 6:18 min.

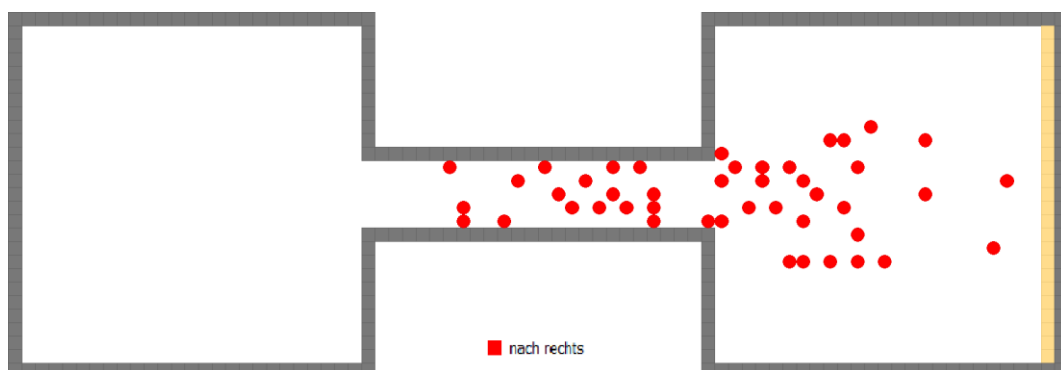


Fig. 9: Counter flow with 100 agents from the left after 60 s.

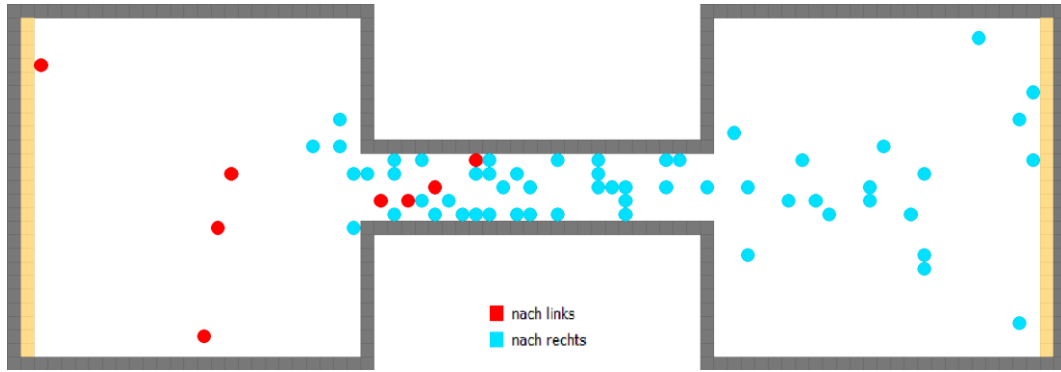


Fig. 10: Counter flow with 100 agents from the left and 10 agents from the right after 60 s.

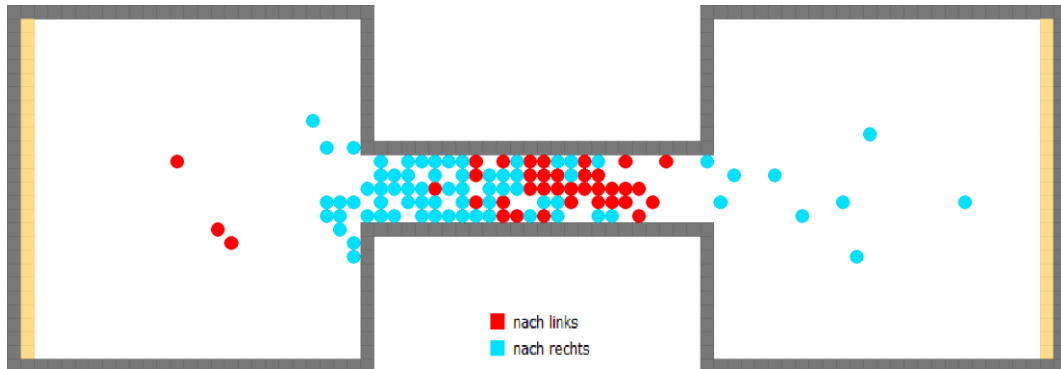


Fig. 11: Counter flow with 100 agents from left and 50 agents from the right after 195 s.

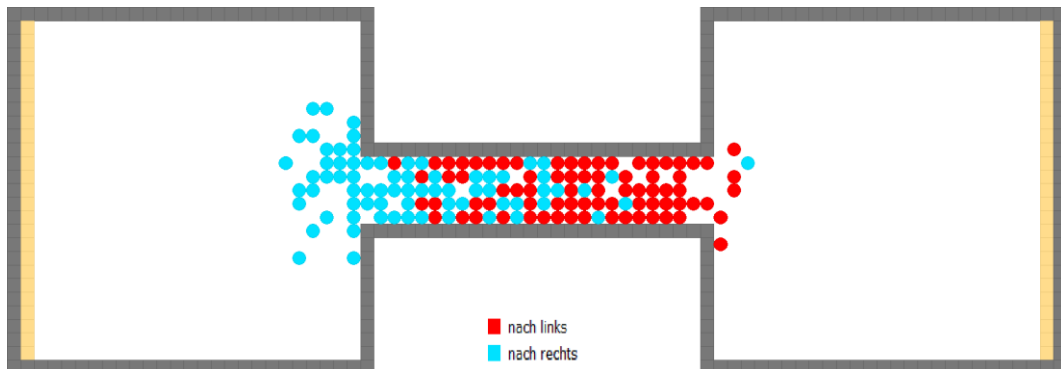


Fig. 12: Counter flow with 100 agents from the left and 100 agents from the right after 405 s.

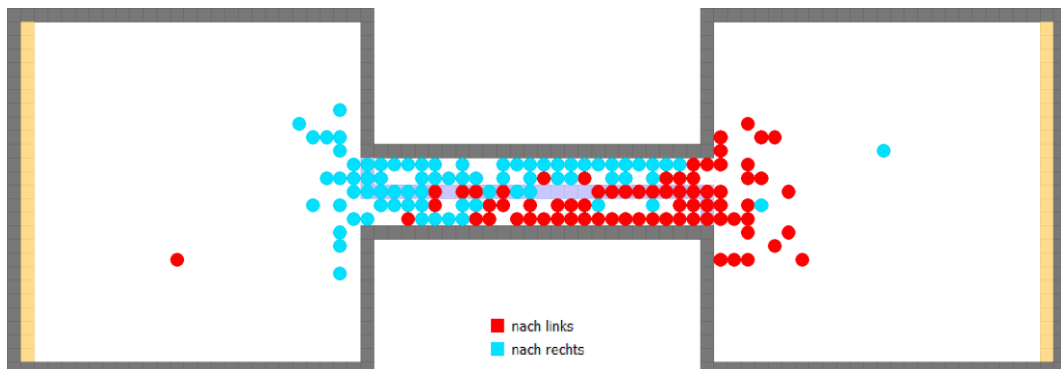


Fig. 13: Counter flow with enforced lane formation with 100 agents from the left and 100 agents from the right after 195 s.

2.9 Test 9: Big Room

2.9.1 Preparations

- Draw room with a CAD program.
- Import dxf file into Editor.
- Model Geometry, define exits, insert agents.
- Save as two projects (4 and 2 doors).

2.9.2 Perform Simulation

- Load project file.
- Adjust demographic standard parameters.
- Adjust walking speed (equally distributed to 2-4 c/s).
- Execute mean value simulation with 100 runs for each case.

2.9.3 Results

case	$t_{\text{sign}} / \text{min:s}$
4 doors:	2:59
2 doors:	5:31

Tab. 6: Results of exit flow of big room case.

It seems unusual that the evacuation duration is not duplicated when half of the doors are closed. However, when only two doors are available, the exit flow per door is homogeneous for a longer duration and the usage of the door therefore more effective.

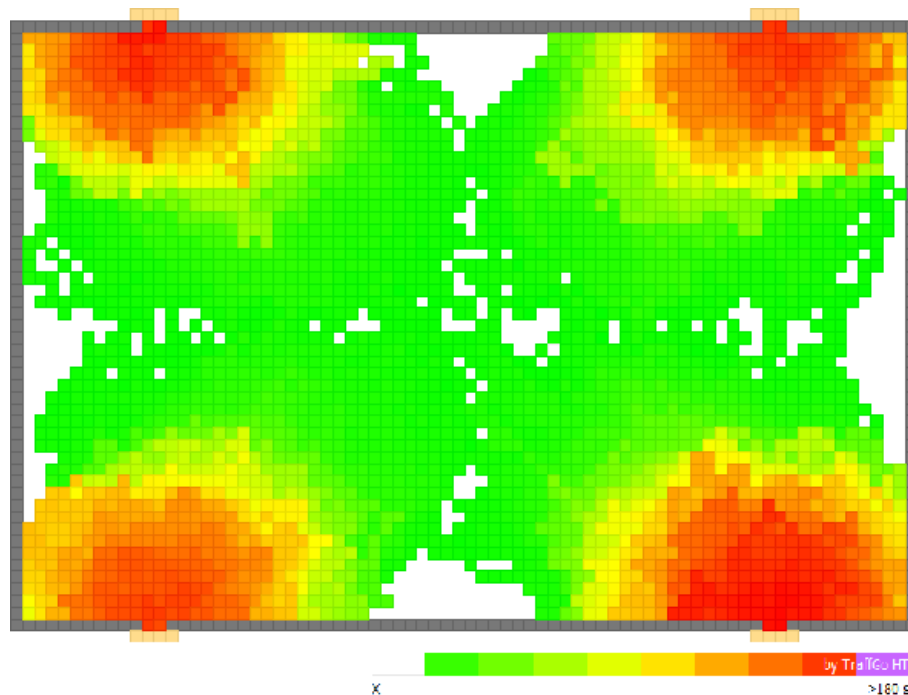


Fig. 14: RSET plot of big room with 4 exits used.

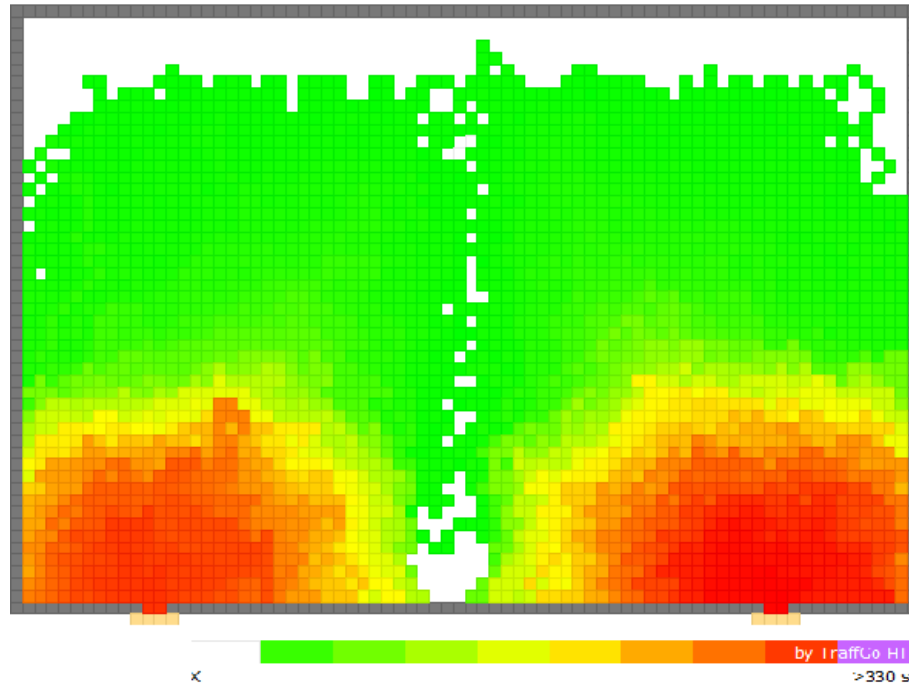


Fig. 15: RSET plot of big room with 2 exits used.

2.10 Test 10: Assignment of Exits

2.10.1 Preparations

- Draw corridor with a CAD program.
- Import dxf file into Editor.
- Model Geometry, define exits, insert agent.

2.10.2 Perform Simulation

- Load project file.
- Adjust demographic standard parameters.
- Adjust walking speed (equally distributed 2-4 cells/s).
- Execute single simulation run and create 3D log file.

2.10.3 Results

The screenshot and path plot show each agent moving to its assigned exit.



Fig. 16: Screenshot after 6 s.

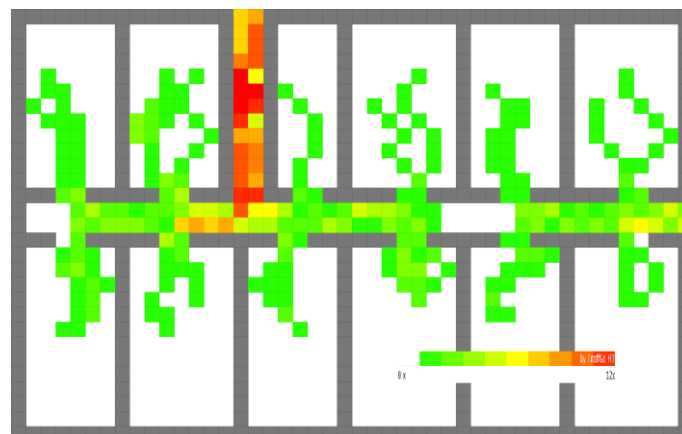


Fig. 17: Path plot.

2.11 Test 11: Room and Stair

2.11.1 Preparations

- Draw geometry with a CAD program.
- Import dxf file into Editor.
- Model Geometry, define exits, insert agents.

2.11.2 Perform Simulation

- Load project file.
- Adjust demographic standard parameters.
- Adjust walking speed (equally distributed to 2-4 cells/s).
- Executing a demo-simulation.

2.11.3 Results

The density plot shows congestions at the exit of the room as well as on and in front of the stairs.

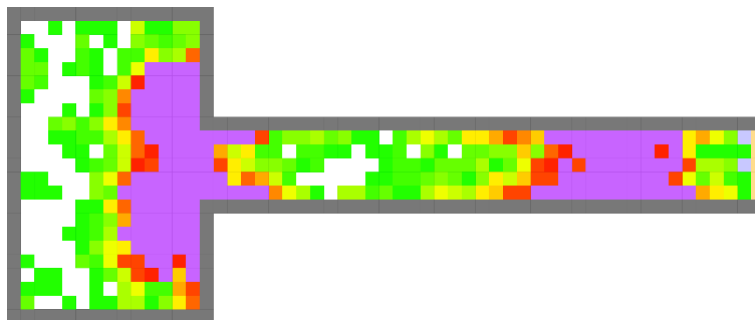


Fig. 18: Density plot⁵.

⁵ The density plot visualizes congestions which have a significant impact on the result. If a density threshold of 4 P/m² is exceeded, a congestion occurs and if this congestion exists longer than 10% of the overall evacuation duration, it is called a significant congestion (see MSC.1/Circ.1533).

2.12 Test 12: Flow Density Relation

2.12.1 Preparations

- Draw geometry with a CAD program.
- Import dxf file into Editor.
- Model Geometry, define exits, insert agents.

To verify the flow of agents at different population densities in a corridor without any obstructions, the following model was designed.

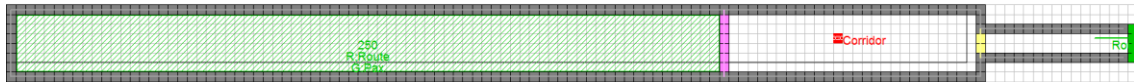


Fig. 19: Corridor model with bottleneck at the right.

The 250 agents start on the left side of the corridor and enter the measuring area on the right. Due to the bottleneck, a congestion forms and the density in the measurement area slowly rises. Resulting, a fundamental diagram is measured. The IMO day case parameters are assigned with a reaction time distributed between 0 and 10 s.

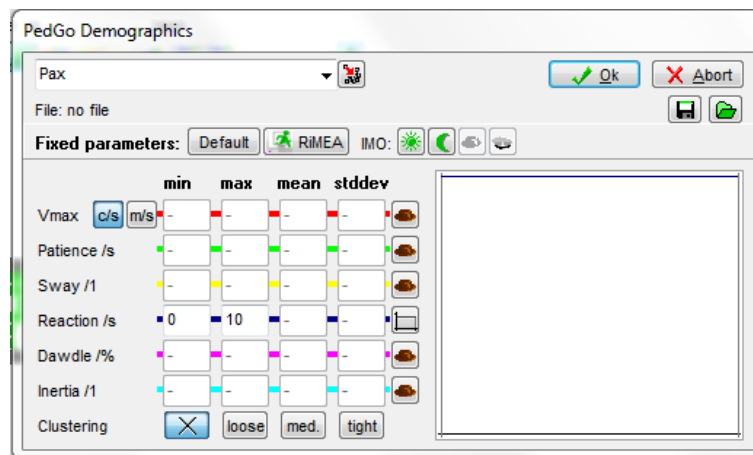


Fig. 20: Demographic settings (IMO day case).

2.12.2 Perform Simulation

- Load project file.
- Adjust demographic parameters.
- Execute a single run.

2.12.3 Results

Fig. 21 shows the flow of agents in dependence of the density for the measurement area. This diagram is called *Fundamental Diagram*. The curve shows the resulting mean values.

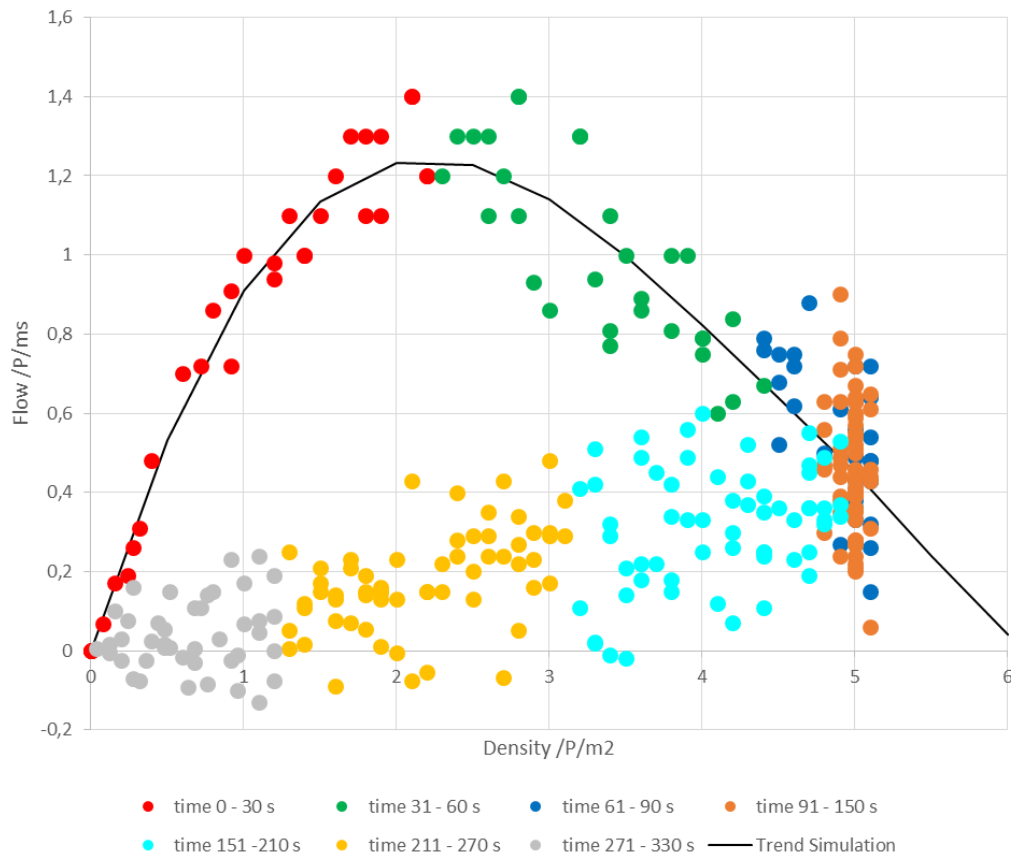


Fig. 21: Fundamental diagram.

Fig. 22 shows the time dependent development of the density in the measurement area as shown by the following screen shots. After approximately 80 s, the maximum density in the measurement area is reached and maintained until ~140 s. After this, the density slowly declines since the formed congestions is slowly dissolved.

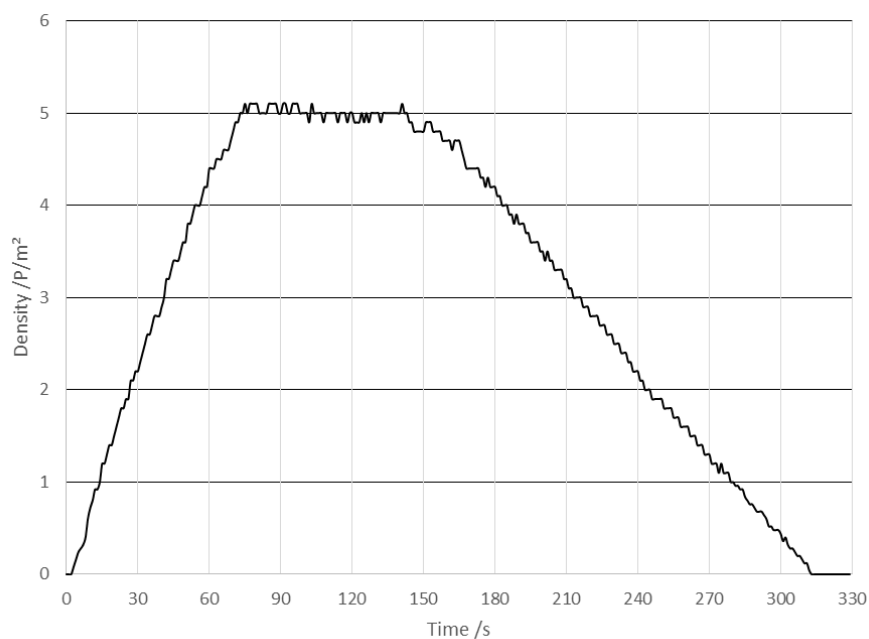


Fig. 22: Density diagram.

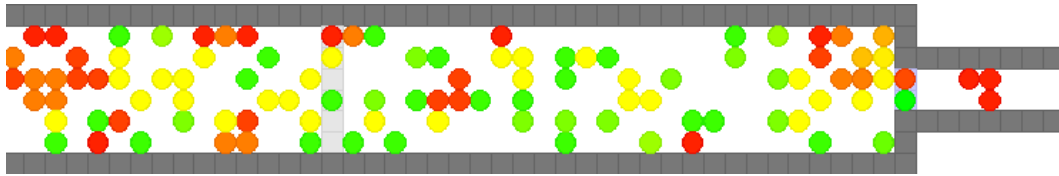


Fig. 23: Screen shot at 30 s.

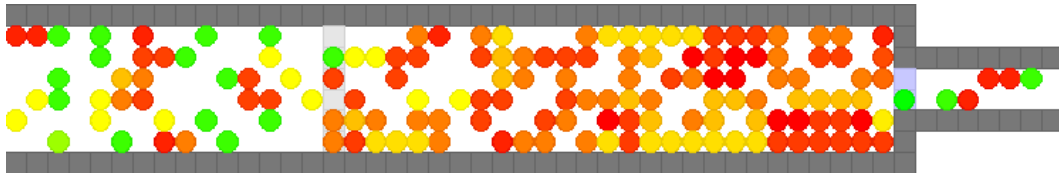


Fig. 24: Screen shot at 60 s.

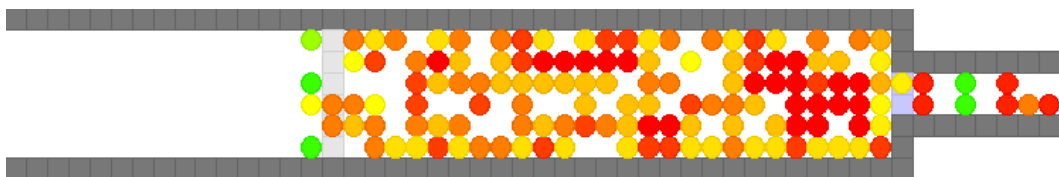


Fig. 25: Screen shot at 150 s.

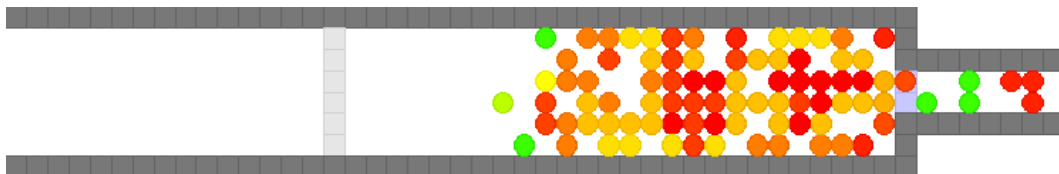


Fig. 26: Screen shot at 210 s.



Fig. 27: Screen shot at 270 s.

3 Annex

3.1 Distribution of Reaction Durations

The following figures show the reaction durations calculated analytically according to MSC.1/Circ. 1533, Annex 3, 3.2.2 and the reaction durations assigned in PedGo/AENEAS (10,000 agents).

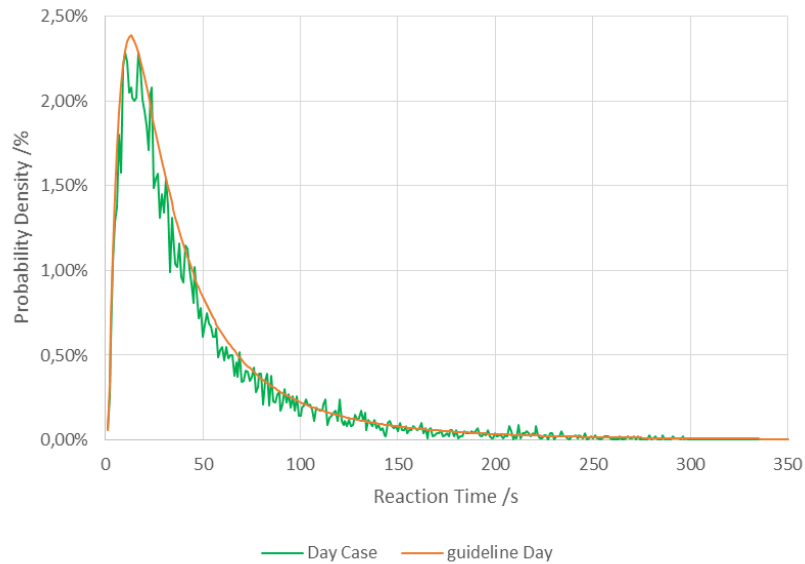


Fig. 28: Comparison of distributed and analytically calculated reaction durations, Day Case.

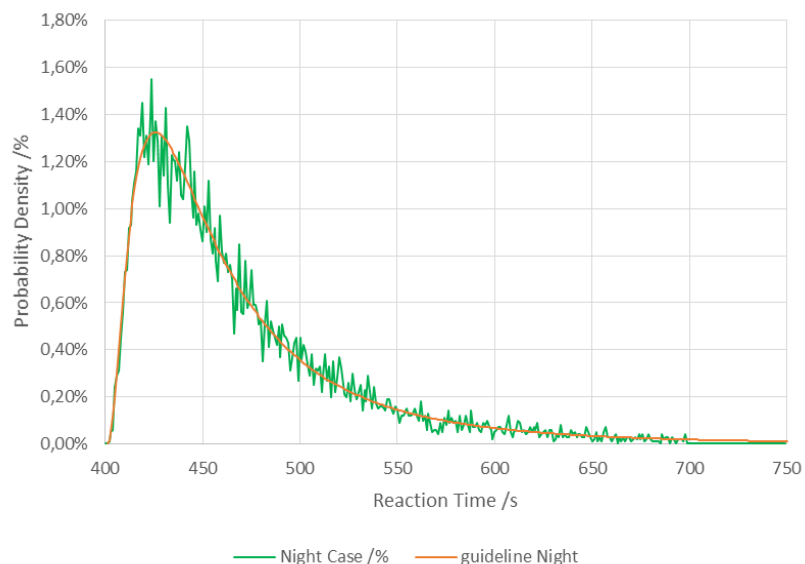


Fig. 29: Comparison of distributed and analytically calculated reaction durations, Night Case.

3.2 User Manual

The user manual of PedGo/AENEAS is publicly available at www.traffgo-ht.com.