Evacuation analysis

AENEAS-Dampfer

Modelling, Simulation, Analysis

  

Manual for the seminar „AENEAS“ on 1st of. July 2002 in Hamburg

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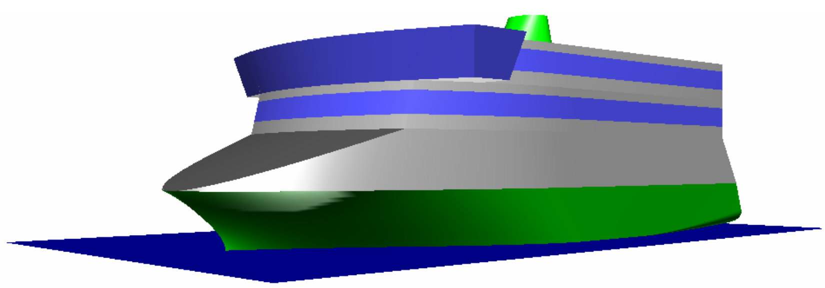

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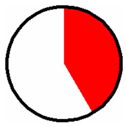
Advice

Evacuation models like AENEAS, who represent specific topics of human behaviour in one single software, cannot seize all the physical, psychological and social measures. The Basis to modelling are especially the individual demand of space and the velocity that is to be reached under various environmental conditions e.g. the density of people (compare fundamental diagram)

1 Introduction

This manuscript is part of the manuals for the „AENEAS"-seminar, which was held combined by the TraffGo GmbH and the Germanischer Lloyd AG on the 1st of July 2002 in Hamburg. The intention of this seminar was to demonstrate the procedure of the evacuation analysis (who meets the IMO requirements) of a passenger ship by means of a simple example. The sample was constructed as simple as possible but also as complex as necessary. It was the intention to include on the one hand simple geometry that is straightforward and on the other hand all the essential mechanisms of an evacuation.

The procedures and the operating time are documented for an experienced user. The working time necessary for each step is displayed through the elapsed time of a clock.



Pict. 1: Example of the necessary working time of a working step. In this case it would take 25 minutes.

This analysis made use of the software ***AENEAS-ed*** (consecutively called *EDITOR)* for the discretisation and editing of a CAD-drawing, as well as of ***AENEAS-sim*** for the implementation of the simulation.

Basic to this evacuation simulation are the IMO requirements „Interim Guidelines for Evacuation Analyses for New and Existing Passenger Ships" (MSC/Circ.1033), which can be downloaded from

http://www.GermanLloyd.org/aeneas.html

as a PDF-Document.

1.1 Status quo of technology

Recently the planning of safety exits gained importance for designing and constructing ships. With this movement a change from descriptive methods (describing only geometrical features of safety exits) to up-to-date, performance based analytical methods can be noted.

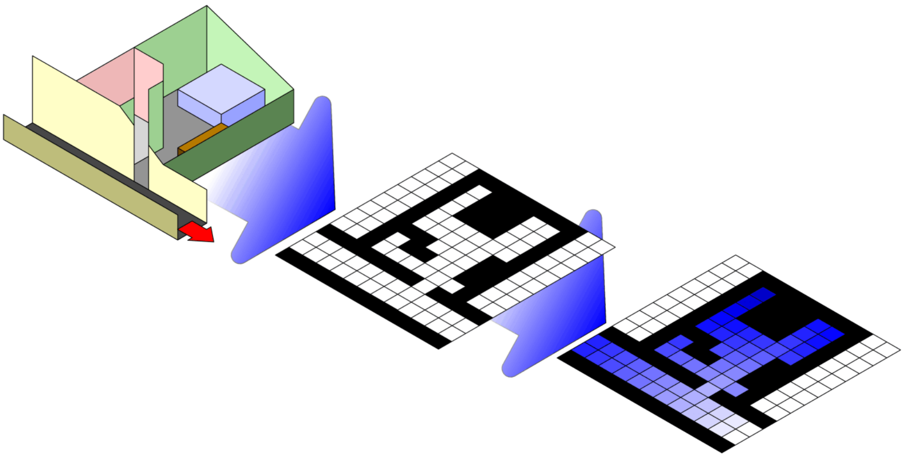
Since 1999 the IMO prescribes a numerical analysis of the evacuation process for RoPax vessels. In addition to the valid *„Simplified Method"* simulation software as ***AENEAS*** may be used for the analysis since June 2002. It.offers immense benefits to the accountable , since the analysis can be conducted fast, efficiently and very descriptive The model used by ***AENEAS*** is based on scientific findings of the research project BYPASS, which was conducted by the chair of

Physics of Transportation and Traffic under the direction of Prof. Michael Schreckenberg at the *Gerhard-Mercator University Duisburg*.

It was implemented by the TraffGo GmbH in cooperation with the Germanischer Lloyd onto the software ***AENEAS***, which is especially suited for the needs of the maritime industry.

1.2 Basics of Simulation

The fundamentals of the microscopic simulation process are based on the illustration of single people moving towards the exits according to the evacuation plan. For this purpose the general plan is divided into quadratic cells, each cell represents the habitation of at maximum one person. The people move along the grid on a simple pattern of rules. The simulation of a great amount of people in a complex environment enables an efficient, close to reality and descriptive demonstration of the muster or the evacuation.



Pict. 2: The continuous compendium is discretised onto the grid of ***AENEAS***.
Afterwards a so called index of direction is applied to enable orientation
(Run of the blue colour).

Further details on this model are illuminated in publications and can be downloaded from

http://www.traffgo.com/en/downloads/pedestrians.html

Continuative annotations can be found on this page as well.

The outcome of this simulation is being influenced by randomised decisions. Hence the outcome of the evacuation analysis is determined by a statistical evaluation of a great amount of simulation runs (realisations).

The IMO prescribes at least 50 runs of one scenario but this offers a low level of confidence. Thus it is advisable to conduct far more than just 50 realisations. Due to the immense computation rate of ***AENEAS*** this can be done trouble-free.

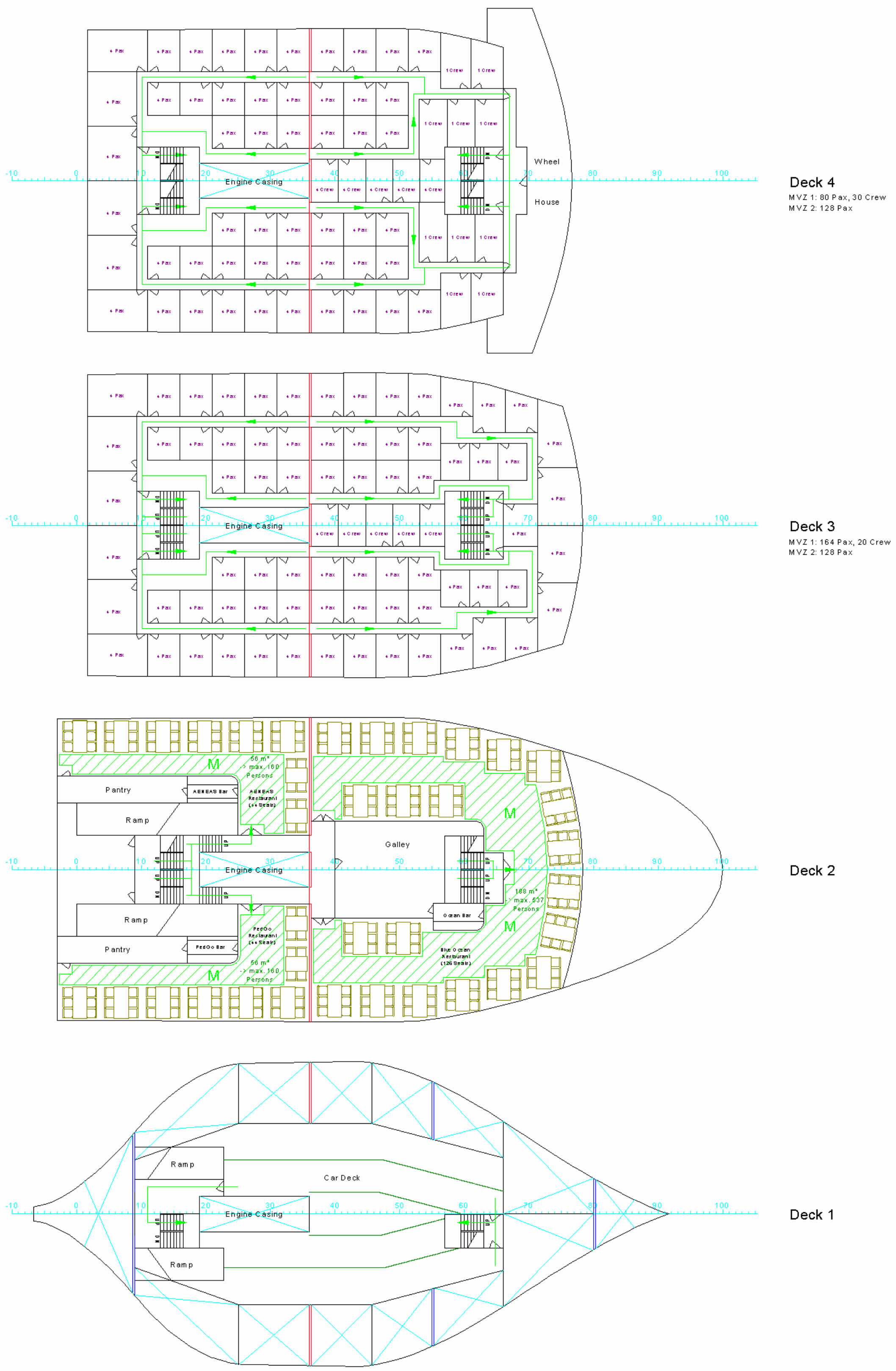
1.3 AENEAS-Dampfer

The *AENEAS*-Dampfer (compare. Pict. 3) was designed as an example, with whom all essential aspects of an evacuation analysis can be acted out comprehensively. At present an evacuation analysis is only prescribed for RoPax vessels, hence this type of ship was chosen. The *AENEAS*-Dampfer consists of a loading area for vehicles on the lowest deck, which can be entered through the two ramps on rear of the vessel

For realistic plans of ships no significant additions occur, the analysis only demands a greater expenditure of human labour.

The complete ship consists of two fire zones (Main Vertical Zones, MVZ) and four decks with the regular width of a ship. To obtain a large density among occupants -thus creating the evacuation scenario very pretentious- the two upper decks were chosen as very small and mainly occupied by four people.

The second deck includes only public facilities such as restaurants, which are used as mustering stations during an evacuation scenario. According to the IMO directives MSC/Circ.1033 the usage of simulation only calculates the so called *Travel Time* thus people can be marked as saved when arriving at the mustering station.



Pict. 3: The compendium of *AENEAS*-Dampfer.

2 Conceptual formulation

Through the use of numerical analysis it has to be verified for RoPax vessels that the capacity of the lodes and the conceptual framework of the evacuation plan are sufficient to evacuate the complete ship within 60 minutes

The composition of the population is determined by the directive MSC/Circ.1033 . Further it is assumed that the people follow the primary escape route to the mustering station.

There are four different cases prescribed. An evacuation analysis has to be prepared for each case.

	Complete availability of the escape route	Limited availability of the escape routes
Night	Case 1	Case 3
Day	Case 2	Case 4

Since there is no significant difference in the procedure among the four cases, only case1 (complete availability of the escape routes during night) will be examined in detail and case 3 (limited availability of the escape routes during night) only comparatively marginal

3 Allocation of People

For the allocation of the people it is assumed, that the ship is operating at full capacity. This counts as well for passengers, as for the crew. According to chapter 13 of the FSS Code the distribution of the occupants during night time is as follows:

- All passengers are within the cabins,
- 2/3 of the crew are within their cabins and
- 1/3 of the crew are at their station of work.

According to MSC/Circ.1033 the last third is to be distributed:

- 50% at their stations of work,
- 25% assist the evacuation and are not explicitly taken into account and
- 25% reside at the beginning of the evacuation on the mustering stations and move reversely to the escape route towards the cabins at which they turn to follow the escape routes towards the mustering stations.

Thus the crew is distributed on the ship as follows:

	Firezone 2	Firezone 1
Deck 4		Cabins: 20
Deck 3		Cabins: 13
Deck 2	Mustering station: 2 Restaurants: 2	Mustering station: 2 Restaurant: 2
Deck 1	Loading deck: 1	

Tab. 1: Distribution of the crew according to the directives.

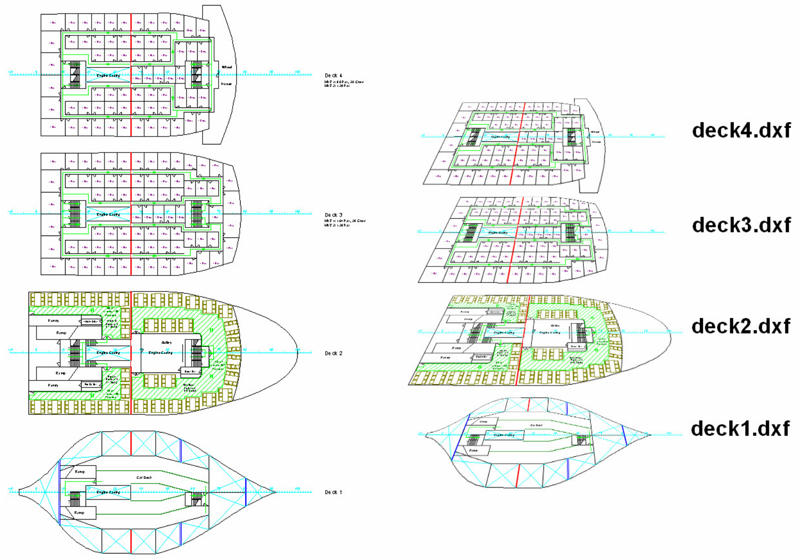
4 „Clearance“ of the Plan

Since the general plan is mainly based on a numerical evacuation analysis, it contains to many. or inexpediently formatted data. For this reason it has to be cleaned up, to assure a smooth import of data into *AENEAS-ed*. The disciplined usage of layers accelerates the editing.

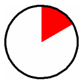
4.1 Several Decks in several Data Files

Each deck must exist as a single data file. Remember to place the coordinate origins carefully in each data file. If they do not comply the stairwells will not align.

The decks are imported separately as dxf-formatted-data files into the editor. For this reason the drawings have to be split up in separate data files according to the decks. To assure an exact positioning of each deck one upon the other the points of origin must be redefined on the same spot obverse to the frame muster for every single file..



Pict. 4: Fragmentation and alignment of the decks into separate data files.



4.2 Clearance of useless Elements

The exact shape of a wash basin or other details of the furnishing have no impact on the outcome of the simulation and decelerate the workflow. Erase all these details!

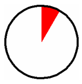
Often CAD drawings contain elements that are excrescent for the simulation. Especially the insertion of drawings of sub-suppliers inflates the plan needlessly.

Guide and drawing tools, not describing any geometry and thus not influencing the movement of the occupants can be erased thoughtlessly. Among these -are beside the guide lines- the lines and arrows that mark the escape routes.

Furnishing should be removed from the plan as well. Across the board one can assume that the furnishing of the cabins is unsubstantial for the complete evacuation process. But all elements that bias the cross sections of the escape routes (e.g. columns, lounges) should be regarded. In this case simple outlines are sufficient.

Consistent usage of layers abbreviates this working step considerably. Specific attributes can be allocated to objects used as a link (e.g. door impact) and then later on be filtered out.

(see chap. 5)

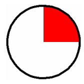


4.3 Inscription

Figures are supposed to characterise only the group of people. Erase the rest of the figures.

Alpha numerical figures in the plan are automatically interpreted as a person group by the editor. Insofar all characters not resembling the person group should be blinded out on a separate layer or simply erased. Especially the insertion of drawings of suppliers leads to difficulties, because e.g. a small object was measured but still the measured value appears in the drawing.

The denotation of the cabins should be (as in this case „Pax 4“) converted in to integer numbers, thus 4.



4.4 Decamping of Lines

In a solid wall a door cannot be identified. Separate solid elements.

In the preliminary layouts doors are often marked with the help of a impact, who is drawn onto a solid line, that symbolizes a wall. To be able to identify a door as a passage (after dying) the solid wall must be interrupted.

Pict. 5: Splitting of a solid wall at the door.

4.5 Editing Time

The operations described in this chapter demanded the following editing time:

Activity	Time /min
Several Decks in several Data Files	5
Clearance of useless Elements	10
Inscription	5
Decamping of Lines	15
Sum	**35**

The use of innovative tools, that are being developed. at present , will enable a partly automation of the editing process and reduce the efforts.

5 Allocation of Attributes

Different colours enable the allocation of characteristics to objects e.g. lines. Use this opportunity and thus accelerate the discretisation in the editor.

The transfer of the colour-attributes during the export of dxf data files is a function that is offered by most commercial CAD programmes. Through the colour of the object the editor identifies , which object to mark and automatically allocates the correct attribute to corresponding cell. Every colour can only reflect one single attribute . The following cell-attributes are available:

Wall	:	Walls and furnishing. They cannot be entered.
Door	:	Sills. Occupants reduce speed to a quarter while passing the sills.
Stairs	:	Steps. Occupants reduce speed contingent of whether they move up or down stairs.
Upwards	:	First step of a the stairs leading upwards.
Downwards	:	First step of the stairs leading downwards
Ignore	:	Elements with these attributes are being ignored and not allocated to a cell.

The allocation of the colours to the attributes must be effective for the complete general plan, but may differ for each shipyard or project.

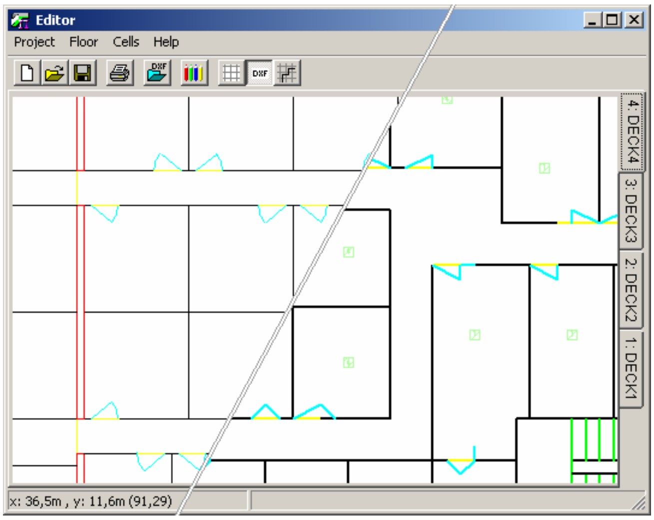
Pict. 6: After separating the elements they can be dyed. In this case turquoise is being ignored but yellow identified as a door

6 Discretising

The data files of the several decks are now being exported into dfx-formatted data files by the CAD programme and then imported by the *AENEAS* Editor

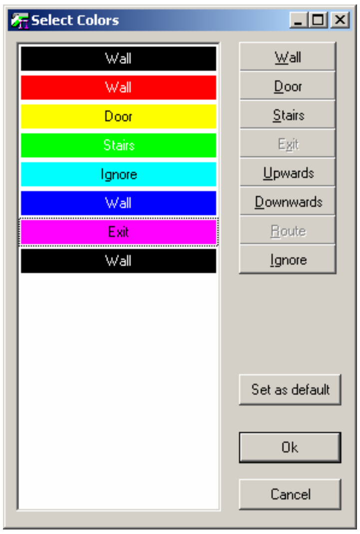
6.1 Import and Edit

The continuous data files are rounded onto the grid during the reading.



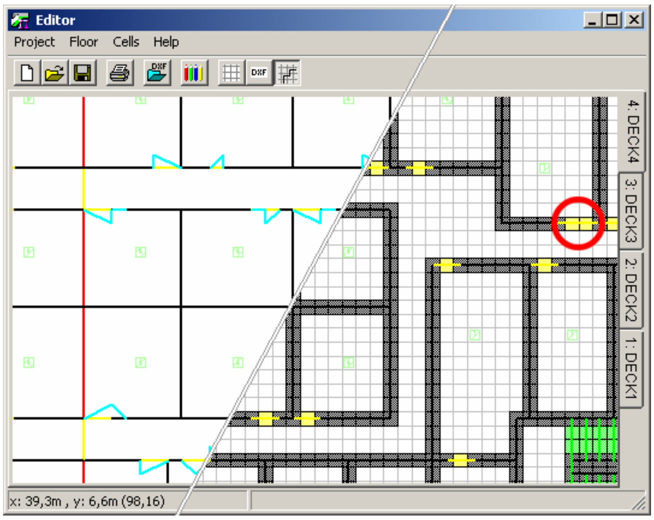
Pict. 7: The continuous dxf-elements (left) are being rounded by the editor onto the discrete grid of the simulation (right).

As depicted the colours of the elements are connected with the attributes. This occurs in the editor through the use of a dialog window:



Pict. 8: The dialog window „*Color Coding*“, which allocates the attributes to the utilised colours

Now that the attributes of the objects can be identified by the colour, the editor allocates the attributes to the corresponding cells.



Pict. 9: On the basis of the colour allocation cells receive the essential information.. Due to discretising rounding errors may appear (e.g. at the red marked door cells).

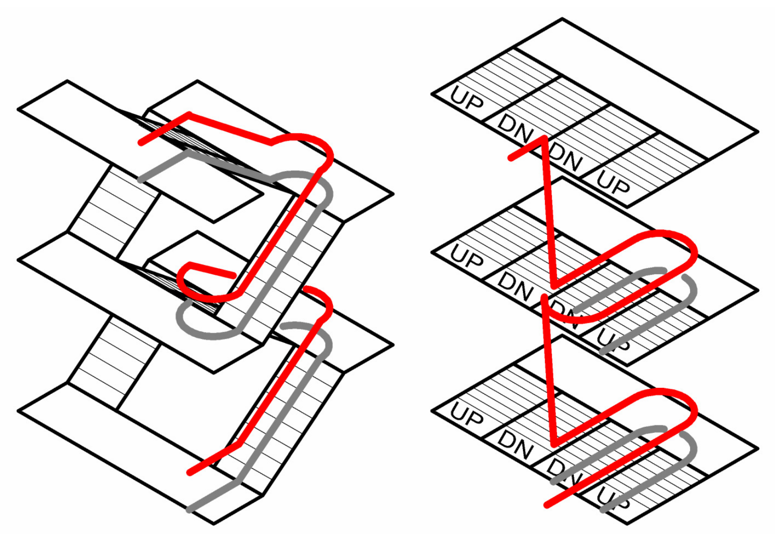
Due the rounding of the continuous dfx-elements onto the discrete grid inaccuracies may occur. For this reason the plan must be reviewed by hand and on occasion single elements edited by hand. The editor offers a few simple tools that allow the following actions:

- Screening,
- Scrolling,
- Drafting and
- Deleting elements.

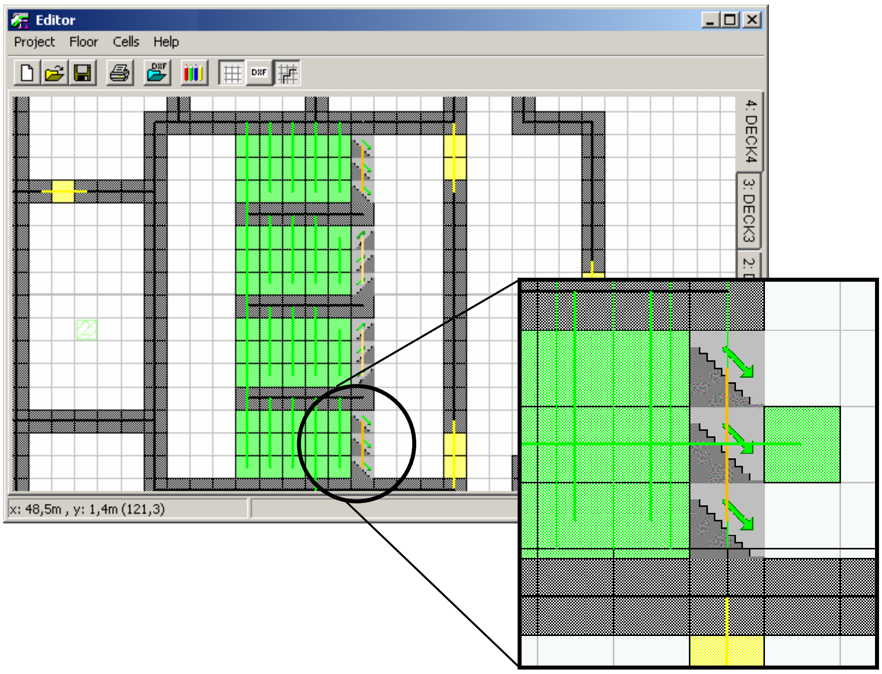
6.2 Stairways

Stairways connect the several decks. Because persons either move up or down a deck when entering the stairways –it depends on from which end they come from- it is so important that the decks are centred in correlation to the newly defined zero point. For safety reasons this alignment should be revised by the user.

Afterwards the first steps of the stairway are replaced by cell information, which indicate, in which direction the slope of the stairway moves (Upwards/Downwards)



Pict. 10: The cell information *Upwards* (UP) or *Downwards* (DN) indicates, in which direction the slope of the stairway moves. Out of this result the indicated paths.



Pict. 11: The UP- and DN-cells of the front stairways.

6.3 Define Routes

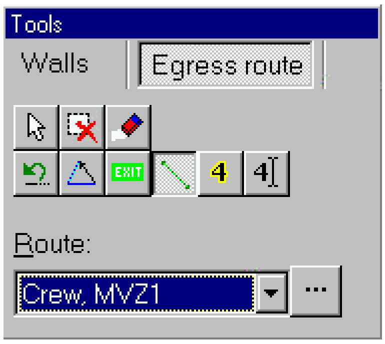
The routes denote how people move on to their destination. At maximum 256 routes may be denoted. In order to meet IMO directives there are two different types of routes. The only difference between them is the people following each route .

1. Passenger-Route: People reaching their destination are regarded as safe
2. Crew-Route: People on the crew route arriving at the destination, are allocated to a passenger route and then move towards their destination..

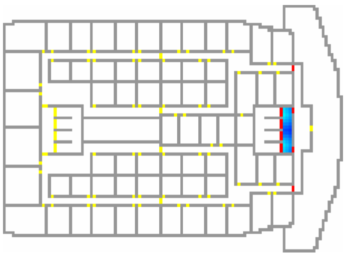
   This type of a route is applied to provide group of the occupants moving reversely away from the mustering stations towards the cabins, from where they move on towards the destination of the passenger route. (This is prescribed by the IMO directives)

The routes denoted by the user are mainly marked by doors and stairways, over which the index of direction spreads which again is used for orientation to persons.

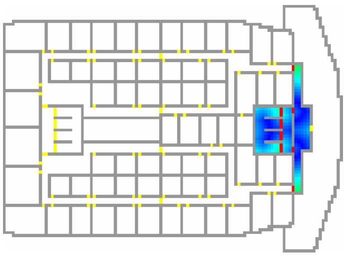
Starting at the exit or destination cells it spreads out within the bordering rooms and from there on through emergency exits into to succeeding rooms. If no further emergency exits can be found, it spreads out through the bordering doors. The following series of pictures display the single steps of how the index of direction spreads. Yellow cells represent regular doors and red doors mark emergency exits.



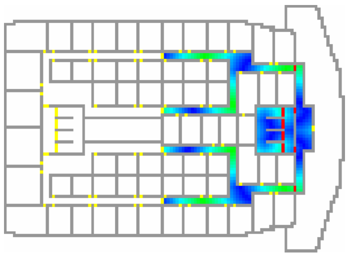
Pict. 12: Dialog window to define routes, in this case determination of the destination for the occupants of zone 1



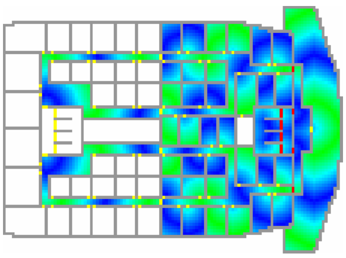
Step 1: The index of direction reaches the upper deck through the stairway.



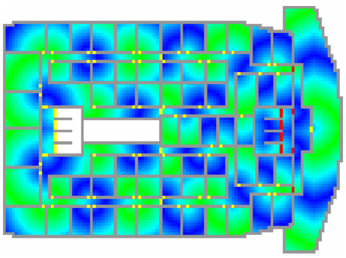
Step 2: The index of direction spreads along the marked doors and stairways



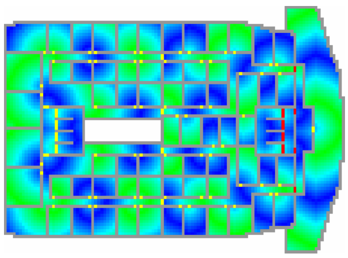
Step 3: Passing the last marked door the index of direction reaches the cabins



Step 4: There are no further emergency exits. Hence the index of direction passes through the next regular door



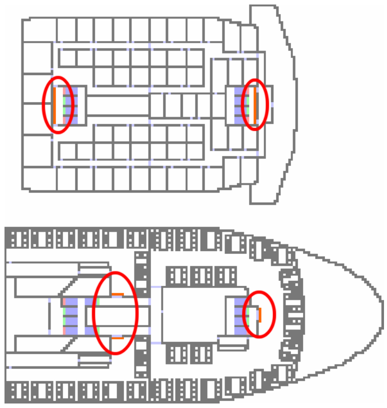
Step 5



Step 6: The index of direction has spread across all accessible cells

Overall four routes are allocated in this concept:

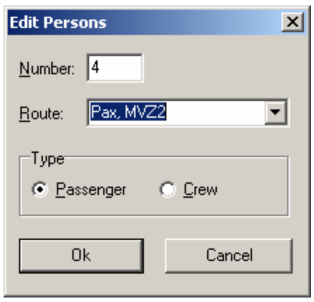
Nr.	**Typ**	**MVZ**	**Destination**
1	Pax	1 (front)	Mustering station (Blue Ocean Restaurant), Deck 2, front
2	Pax	2 (abaft)	Mustering station, (*AENEAS* and Ped*Go* Bar) Deck 2, abaft
3	Crew	1 (front)	Stairwell, Deck 4, front
4	Crew	2 (abaft)	Stairwell, Deck 4 abaft



Pict. 13: The cells of destination (orange) on Deck 2 and 4.

6.4 Allocation of Persons

The amount of people in each room is ,as depicted earlier, included in the dxf-data file in form of a text element and automatically interpreted by the editor. The persons still have to be assigned to their destinations and individual attributes have to be applied to them. There are two types of a person according to the IMO directives : Passenger and crew



Pict. 14: The dialog window for submission of the amount of people, assigned route and the type of person per room or defined area .

The persons can either be assigned to a given rectangular area or to a room. At the beginning of the simulation ***AENEAS-sim*** allocates them randomly on the corresponding cells of the base

6.5 Editing Time

: The operations described in this chapter demanded the following editing time

Activity	**Time /min**
Import and Edit	10
Stairways	10
Define Routes	10
Allocation of Persons	15
Sum	**45**

Innovative tools can reduce this expenditure of labour.

7 *Analysis*

7.1 Basics

The decisions and parameter of the simulated persons are subject to stochastic influences. Thus each run of simulation provides a different time frame for the evacuation process. This can also be noted for runs starting at the same conditions. The following random decisions have an impact on the course of the simulation

1.Option of the running direction,

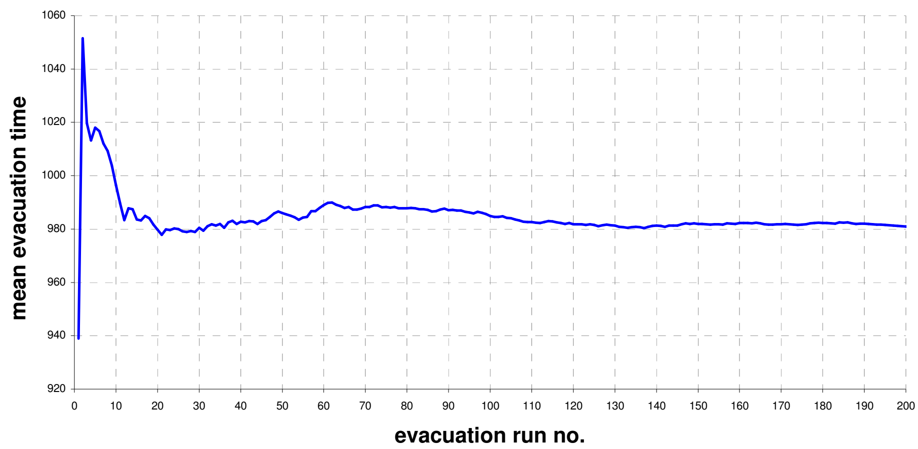
2.Solving situations of conflict (several persons on one single cell),

3.Hang behind and

4.Option of the route when reaching the destination of a crew route.

At the beginning of each run the parameters of the persons along with their points of origin are relocated to ensure a stochastically distribution among the population.

Due to the statistical characteristics of the outcome several runs have to be conducted, allowing a statistical analysis of strong reliability. IMO directives prescribe at least 50 runs. Because of the fast computing of *AENEAS* more than ten times as many runs may be conducted to ensure high reliability. The amount of conducted calculations mainly depends on the time available of the user.

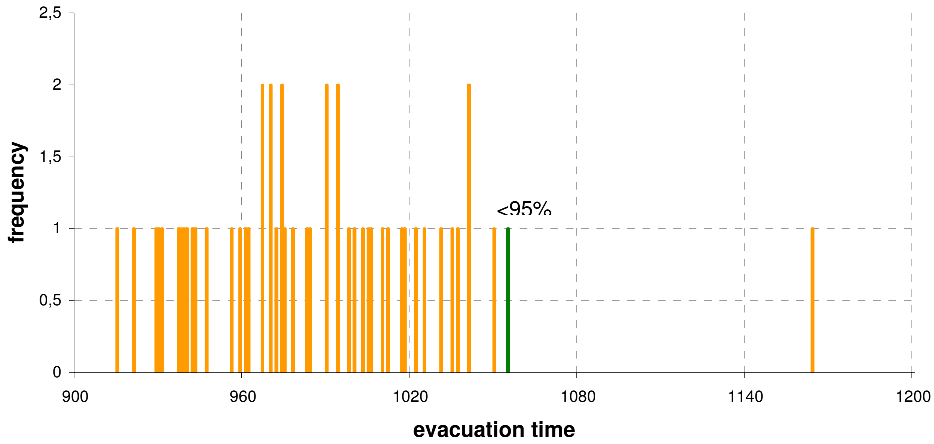


Pict. 15: The drift of the mean obtains a stationary value after 100 runs

The random generator of *AENEAS* is being initialised before each run . The initial value is defined as *Seed*. Thus it characterizes each run. The result of the mean calculation is emitted in a preformatted text file, which can be imported into *Microsoft Excel*® easily. Every line denotes a single run. Along with the calculated time every seed of each evacuation run can be read, so that single calculations may be repeated through the use of .the seed.

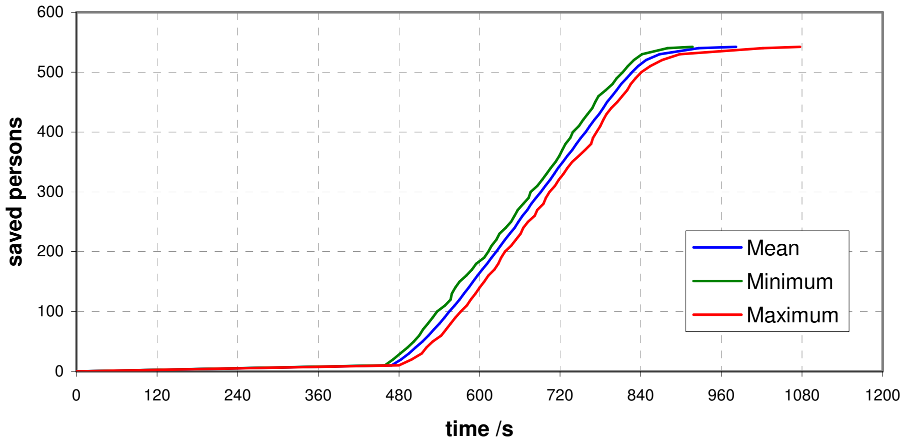
7.2 Mean Calculation, Case 1

The analysis of „Case 1“ of the ***AENEAS***-Dampfers (542 persons) demands approximately 2 minutes of computing time for 50 runs. According to MSC/Circ.1033 is that evacuation duration relevant, that is greater than 95 % of the complete set of evacuation time. The computed running time accounts for 17’42” minutes. The standard deviation of all results is 42 seconds. The following chart can be attained from the file::



Pict. 16: Distribution of the evacuation times.

In the following chart– the evacuation curve – the amount of rescued persons at each point in time is applied. Thereby the computed means but also the minimum and maximum values are applied .

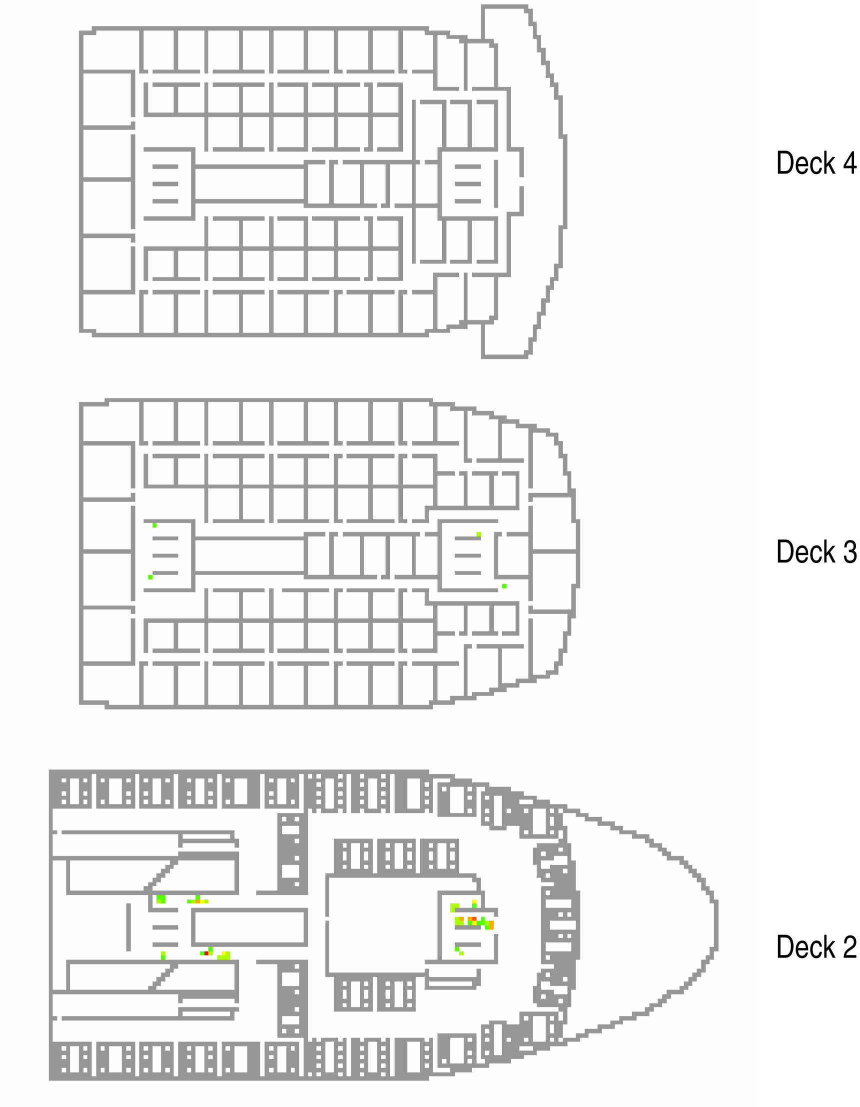


Pict. 17: The evacuation curve denotes the amount of rescued persons at every point in time

7.3 Single Calculation, Case 1

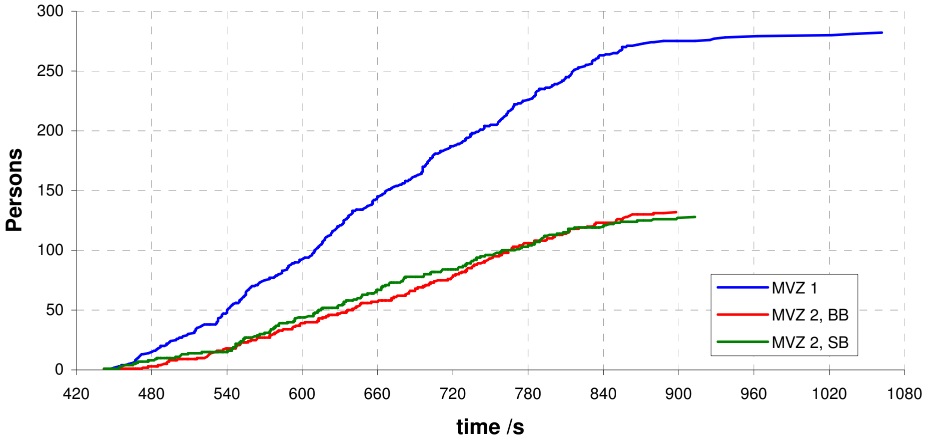
Furthermore a simulation is conducted to evaluate and visualise significant congestions in detail (compare. MSC/Circ. 1033: significant congestions), whose evacuation time complies to the computed *Travel Time*. It can produce the following data files:

1. Text file including detailed information of each person,
2. Animation for the visualisation of the complete process,
3. Density plot to define *significant congestions* as well as
4. Screenshots in various time slices.

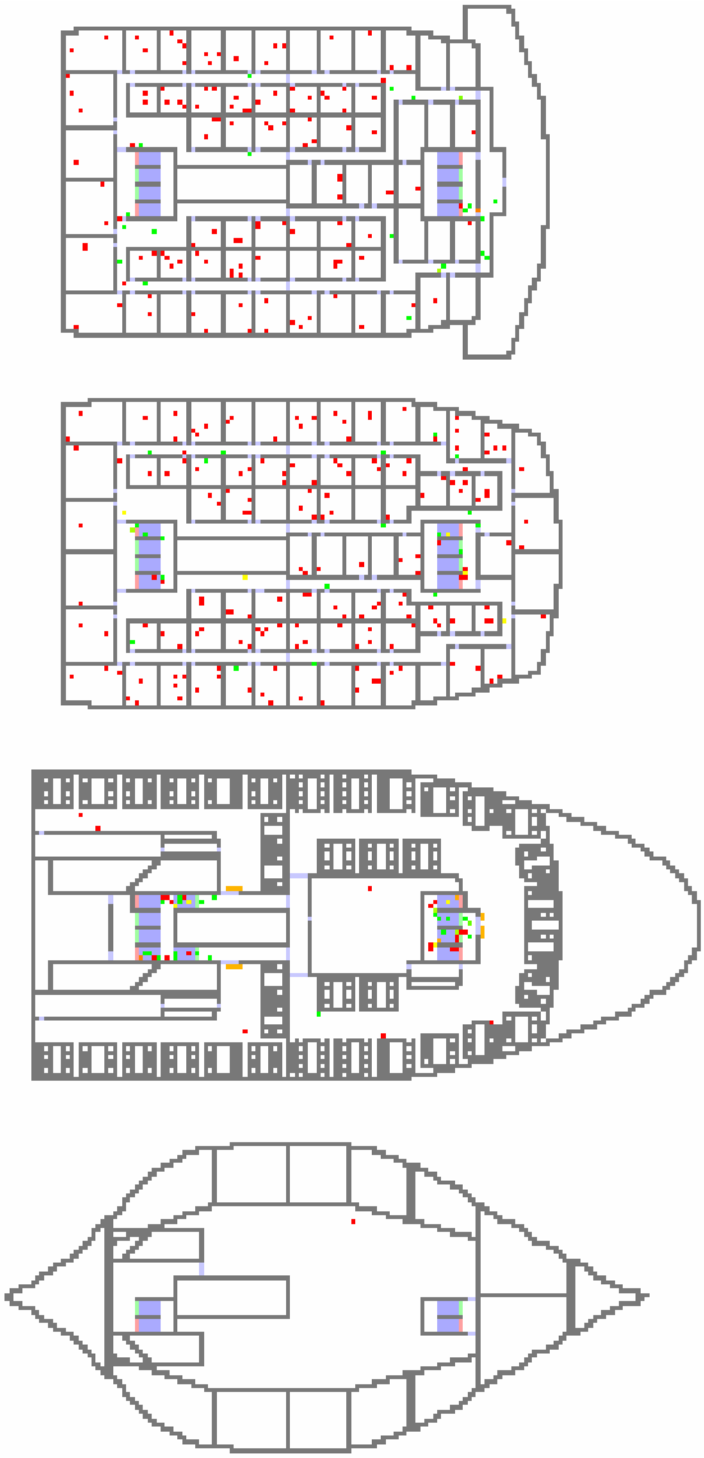


Pict. 18: Density plot: The red marked areas display sections where the significant density of four persons per square meter during 10 % evacuation duration is exceeded i.e. *Significant Congestions* (compare definition in MSC/Circ. 1033) appeared *Case 1* showed only few congestions

Using the detailed information of the files evacuation curves of every destination can be determined. From this it becomes clear that the evacuation of the fire zone up front(MVZ 1) lasts 149 seconds (=2'29" min) longer than the zone upfront.



Pict. 19: Evacuation curve of each mustering station



Deck 4

Deck 3

Deck 2

Deck 1

Pict. 20: Screenshot of the simulation at the time t = 600 s.

7.4 Editing Time

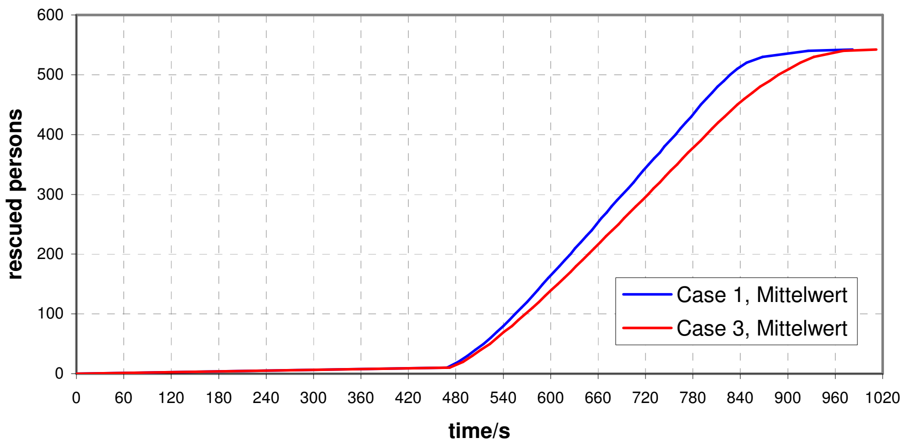
The operations described in this chapter demanded the following editing time

Activity	**Time /min**
Mean Calculation, Case 1	5
Single Calculation, Case 1	5
Sum	**10**

7.5 Case 3 in Comparison

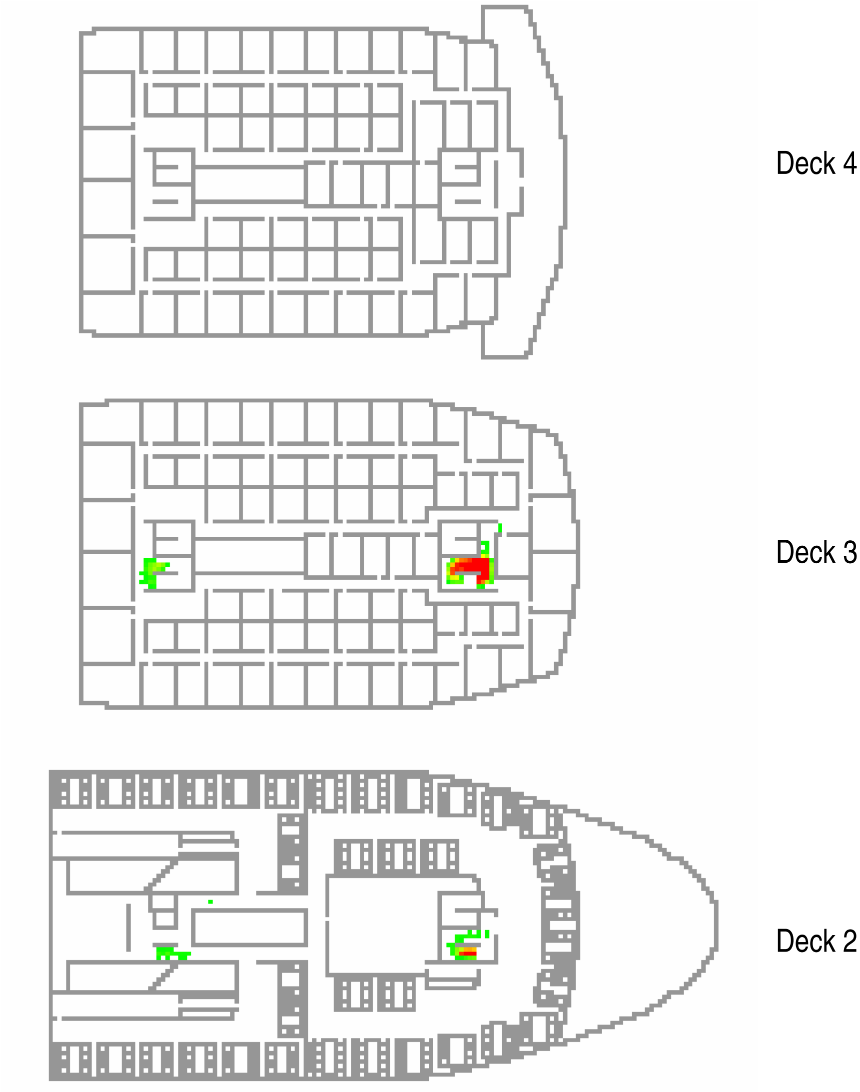
For comparison this chapter briefly addresses the results of Case 3. According to MSC/Circ.1033 this is a night time scenario and deals only with the fire zone, which has the longest evacuation duration. In this case it is MVZ 1, the zone upfront. The capacity of the stairways is halved according to the directives.

To be able to compare both cases, the complete ship is regarded and half of the stairwells are inaccessible..



Pict. 21: Comparison of *Case 1* and *Case 3*.

The running time of this case in accordance with MSC/Circ.1033 is 17'47" minutes and lasts only 5 seconds longer. Thus this ship meets the directives of the IMO. If one takes a look at the evacuation curves of both cases, it becomes clear, that the slope of Case 3 is smaller but still both curves converge near the end. Insofar the time span is mainly affected by late reactions and slow tempo of a few persons. But Case 3 delivers special significant congestions in the fore stairway.



Pict. 22: Density plot of *Case 3*. According to MSC/Circ.1033 only the fore fire zone at halved capacity of the stairways had to be regarded. In this case significant congestion appear.

8 Evaluation

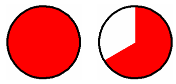
According to MSC/Circ.1033 an additional safety loading of 10 minutes has to be added to the computed running time of Case 1. *Travel Time* computes as follows:

$$T_c = 17'42''\,\mathrm{min} + 10\,\mathrm{min}$$
$$\underline{\underline{T_c = 28'42''\,\mathrm{min}}}$$

The total evacuation time :

$$T = T_c + \frac{2}{3}(E + L)$$
$$T = 28'42''\,\mathrm{min} + \frac{2}{3} \cdot 30\,\mathrm{min}$$
$$\underline{\underline{T = 48'42''\,\mathrm{min}}}$$

Since in this the case the computed time *T* is smaller than 60 minutes, the evacuation concept of the *AENEAS*-Dampfers is acceptable and meets IMO-directives. *Case 1* shows no significant congestions, thus no constructive modifications are necessary.



The total working time of this analysis was 100 minutes.

9 Literature

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