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Collaborative project No. 218532, **FLOODSTAND**
Integrated Flooding Control and Standard for Stability and Crises Management

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Testing the "*Crisis Management*" Approach in Ship Design Practice

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Presentation Outline

Scope	Testing the approach for design purposes
Method	The methods for Time to Capsize
Data	Background and assumptions
Results	Results and discussion
	Concluding remarks

Ship in Operation & Design (1/2)

- The effectiveness of the approaches (elaborated in FLOODSTAND) in rating decisions for casualty mitigation were tested within working environment for
  - Ship in **operation** (**onboard** applications)

    two approaches: *crisis management* & *flooding control*
  - Ship in **design** (**office** applications)

    one approach: *crisis management*

Ship in Operation & Design (2/2)

- The applications for ship in Operation (onboard appl.) and in Design (office appl.) differ with respect to:
  - **Available Data**

    (damage extent, specific ship loading and environmental conditions)
  - **Computational Efficiency**

    (reliable analysis in strait or abundant time)
  - **Objectives**

    (develop of counteracts and casualty response measures, or develop design options and support design decisions)

Testing for Ship Design (1/2)

- The '*Crisis Management*' approach (one of the two method elaborated for Onboard applications) is tested for ship in design too.

- For this method the risk of people against ship flooding is founded on the '*safety condition*': TOE < TTC

Where	TOE	Time to Orderly Evacuate the ship
	TTC	Time to Capsize after the damage incident

Testing for Ship Design (2/2)

- The TTC, (one of the two determinant factors of the elaborated approach, in ship design context is a random variable counting for **all** the potential damage cases throughout the ship design life.

- The probability distribution of TTC is determined by
  - the probabilistic assumptions for the **design environment**, and
  - the **models** applied for the survivability of the flooding ship

Probability Simulation

- The *statistical probability* of the TTC can be simulated by evaluating the survivability of the ship for a large number of potential damage cases throughout the design life of the ship

$$F(t) = \frac{\sum[\text{cases with } (TTC < t)]}{(\text{total sampled cases})}$$

The simulation comprises of two main components:

1. Probability simulation with **Monte Carlo** method
2. Random **sampling** of TTC from:
   - Analytical formulation (*Analytical Approach*)
   - Numerical simulation (*Numerical Approach*)

1) The *Analytical* formulation for TTC

- The analytical formulation assumes the **conditional** probability of TTC, i.e. for specific ship loading and damage case, as a function of ship survivability in waves

Conditional Probability: *F*(*t* | *case*) = F(*survivability in waves*)

The survivability counts for the survival wave conditions, i.e. for wave heights lower than the **case-dependent** critical wave height

Analytical formula:

$$F(t \mid H_s) = 1 - \left[1 - \Phi\left(\frac{H_s - H_{scr}}{0.061 H_{scr}}\right)\right]^{\frac{t}{30}}$$

Critical wave height:

$$H_{scr} = 4\left(\frac{GZ_{\max}}{0.25} \cdot \frac{Range}{25.0}\right)$$

(modified estimator of SOLAS'09)

2) The *Numerical* Simulation for TTC

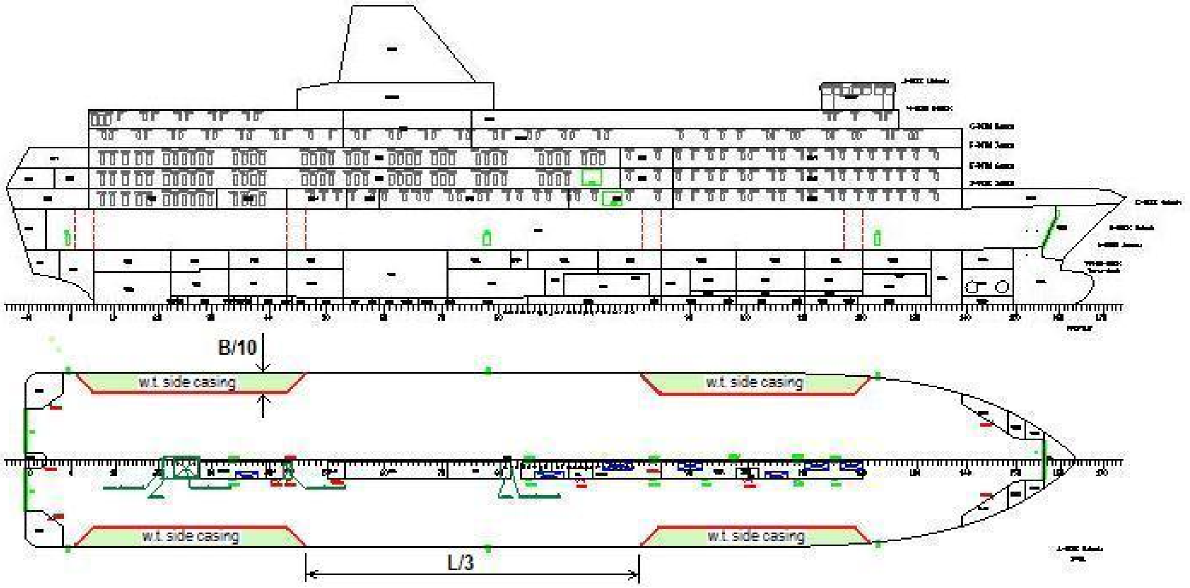
- The ship flooding in time domain can be analyzed with numerical simulation, which comprises of the **flooding process** through the assumed hull breach and the **progressive flooding** of watertight rooms through the internal connecting openings.

- Basic assumptions:
  - Flooding process governed by *modified Bernoulli*
  - Calm water conditions
  - Homogeneous permeability for the rooms
  - No shift of cargo

- Numerical simulation is of *higher accuracy,* however *computationally heavy*

Design Scenario for ROPAX Ship

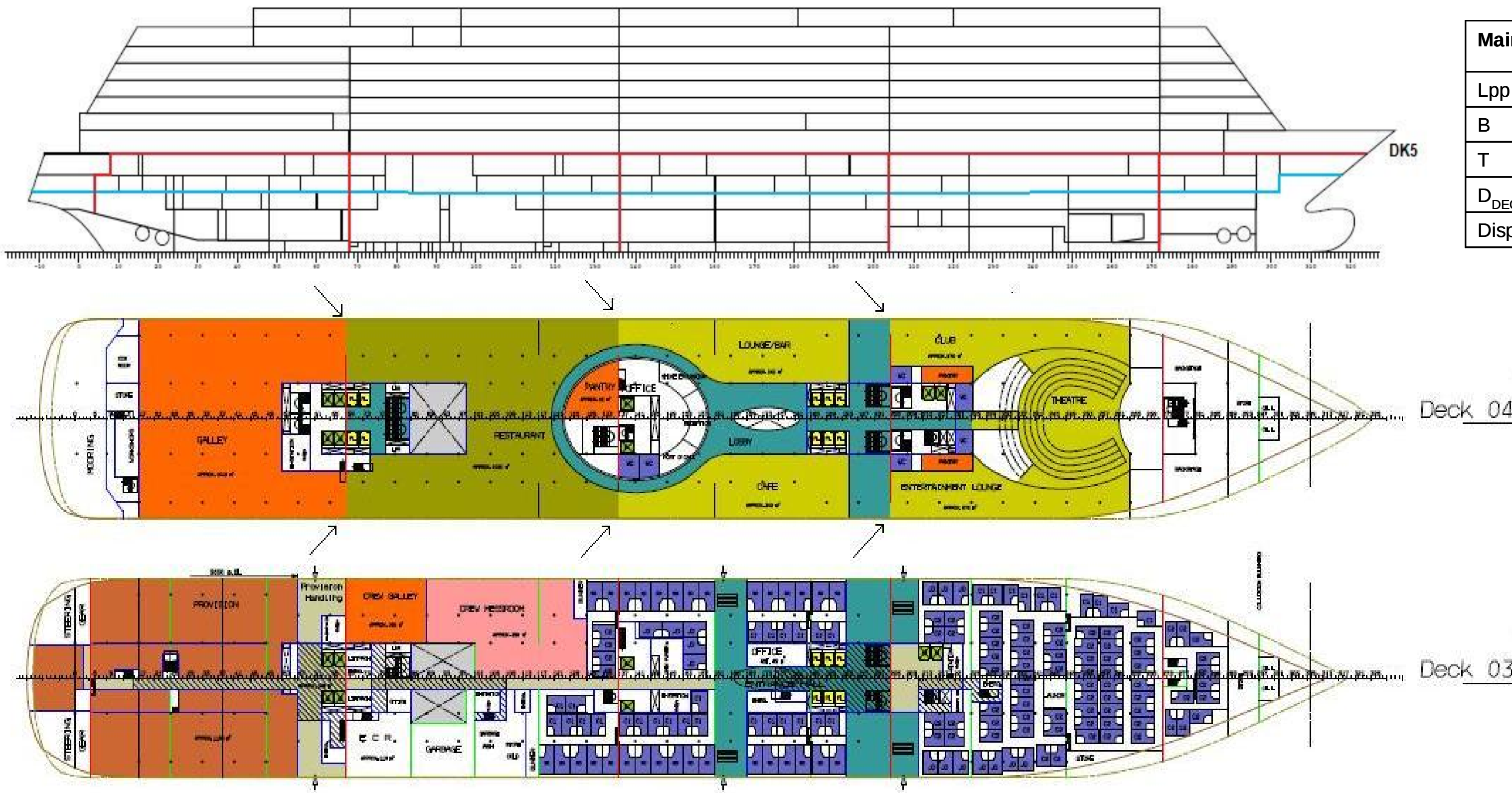
- To add four side casings (totally 10% of deck area)
- Distance between casings ensures single casing damages
- Intact vehicle space is assumed watertight
- Impact on stability of larger heeling angles



Main Dimensions	
Lpp	137.4 m
B	24.2 m
T	5.39 m
D_{DECK}	9.1 m
Displ.	12300 tn

Design Scenario for Cruise Ship

- Watertight vertical zones extended up to deck No 5
- Modifications on deck No 4 (as shown below)
- Impact on larger heeling angles

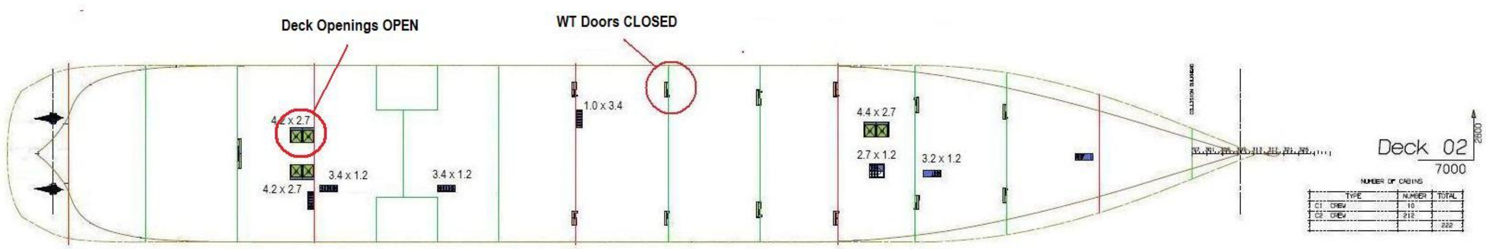


Main Dimensions	
Lpp	216.80 m
B	32.20 m
T	7.20 m
D_{DECK}	9.80 m
Displ.	35000 tn

Subdivision Assumptions (1/2)

- The subdivision modeling considers (*longitudinal* and *vertical*) watertight boundaries (i.e. transverse bulkheads and decks)
- Thus, WT Rooms inside the main WT compartments are defined
- The Rooms are connected with specific internal openings

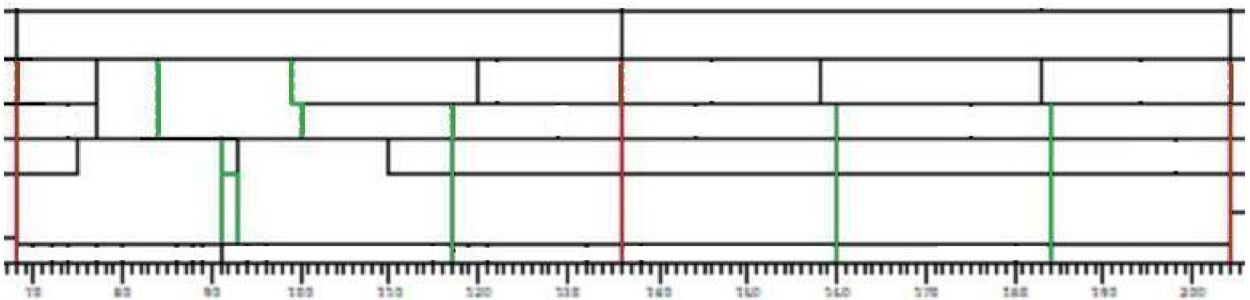
  (i.e. doors, stair and lift wells)



Subdivision Assumptions (2/2)

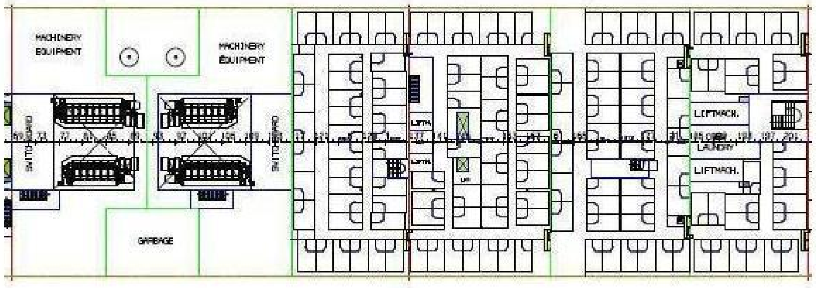
- Rooms inside WT compartments (vertical subdivision)

SIDE VIEW - MVZ 2, 3

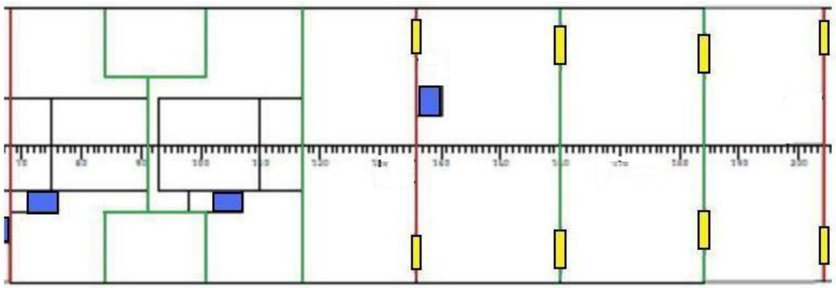


- Homogeneous permeability for the rooms, disregarding non-WT (partial WT) boundaries and other details

DECK 2 - MVZ 2, 3



DECK 2 - MVZ 2, 3

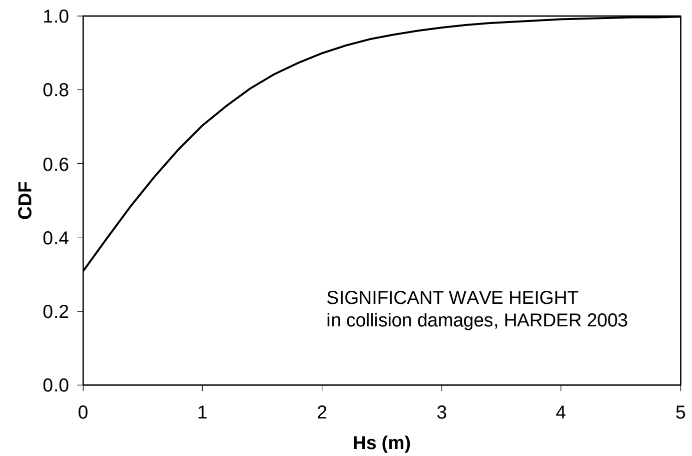


Design Environment

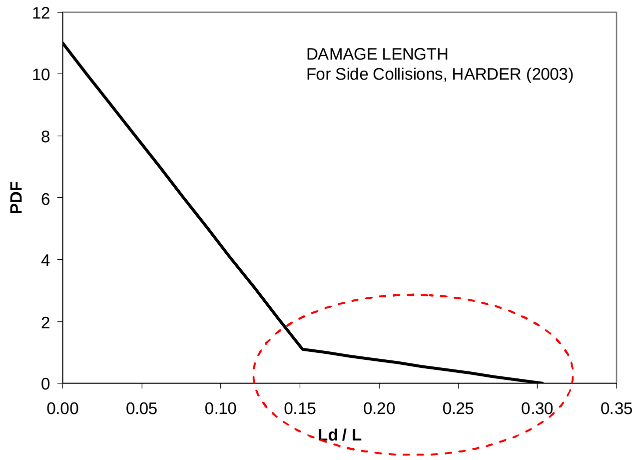
probabilistic assumptions (1/2)

- **Side Collision Damages**

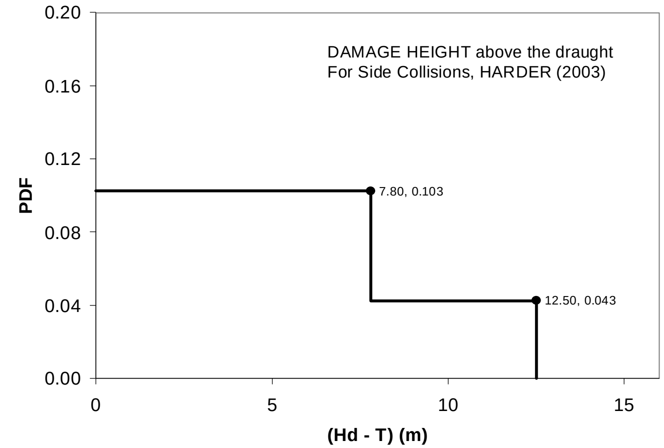
  Probability models:
  - Significant wave height
  - Location and main Dimensions of the hull breach
- Grounding damages are not considered



WAVE HEIGHT



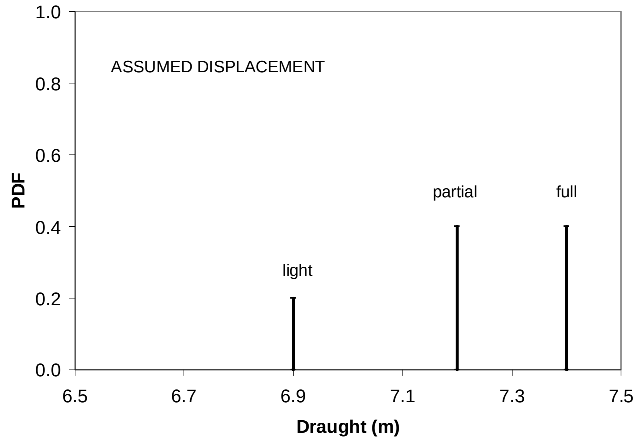
LENGTH

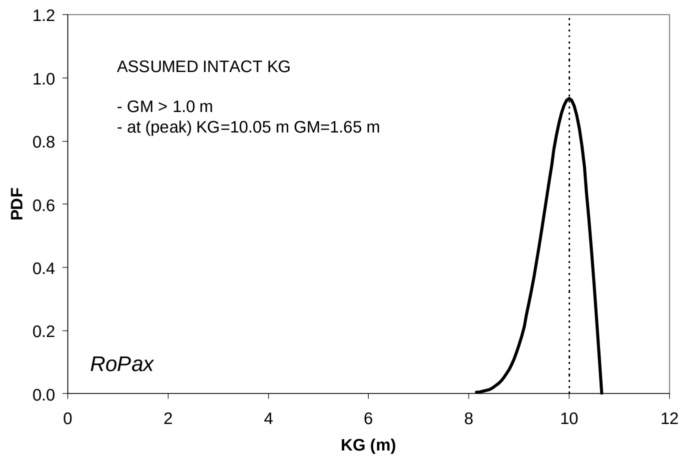


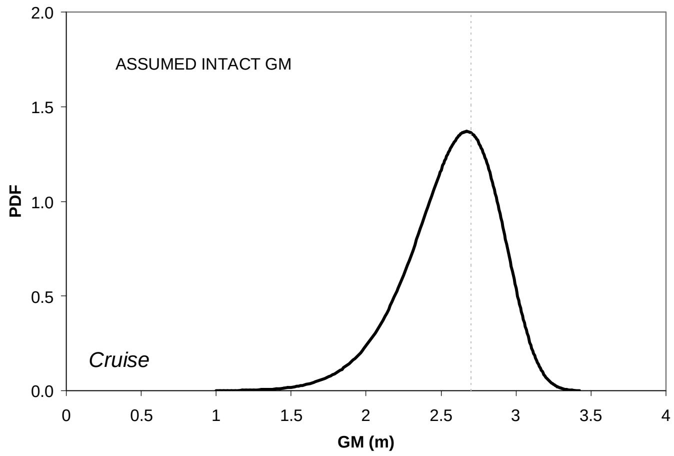
PENETRATION

Design Environment
probabilistic assumptions (2/2)

- Intact Ship Loading
  - Displacement: 3 draughts (S2009)
  - KG: nominal values plus variations
  - Trim: zero
  - Permeability: homogeneous

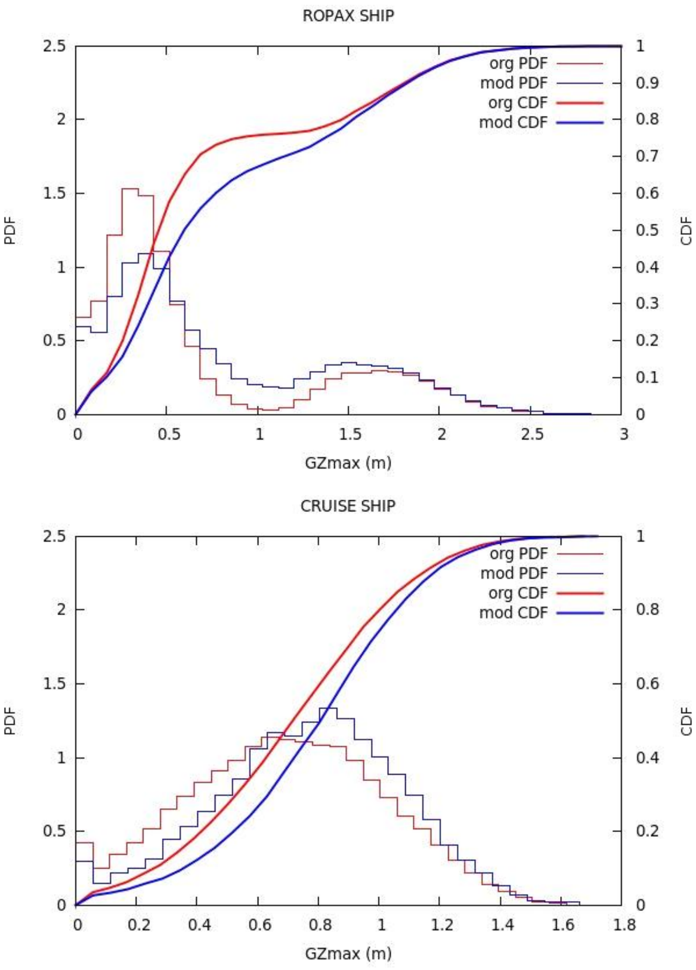






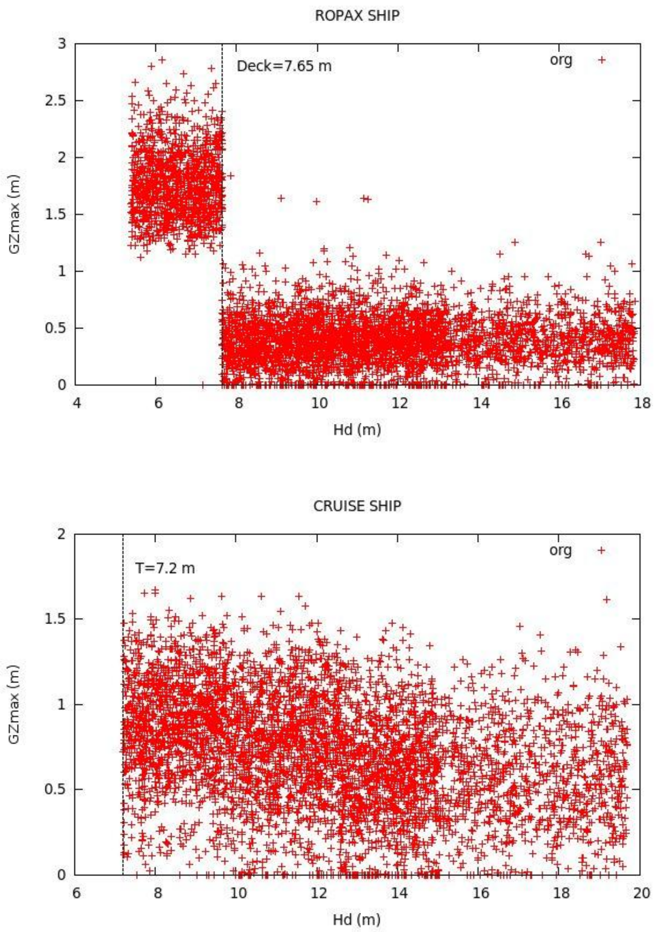
Stability after Damage (1/3)

- Probability distributions for the *GZmax* after damage
- Improved stability due to design modifications for both vessels
- For the RoPax ship the stability results to
  - notably of larger variance (car deck effect) and,
  - of double probability for the range of lower *GZmax* values (including zero stability)



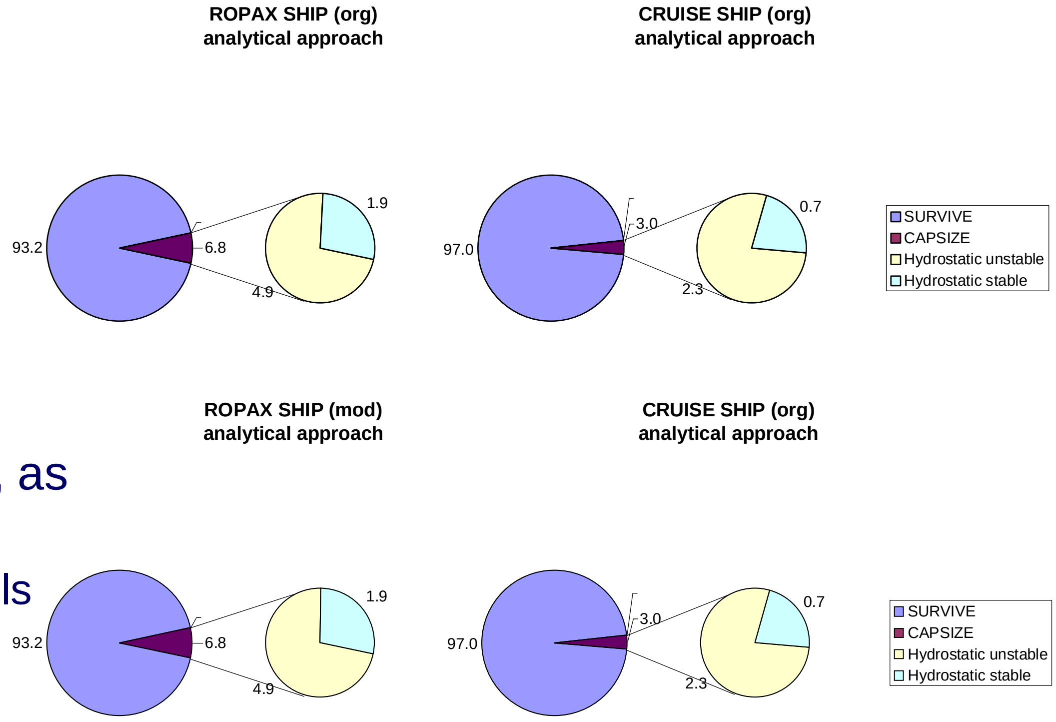
Stability after Damage (2/3)

- The effect of the vertical extension of the damage openings on the GZ_{max} after damage
- ROPAX vessel maintains very large GZ_{max} when the Car Space remains intact after the collision
- No particular effect for the Cruise vessel
- All the side damages are assumed to extend from BL up to a height above the waterline



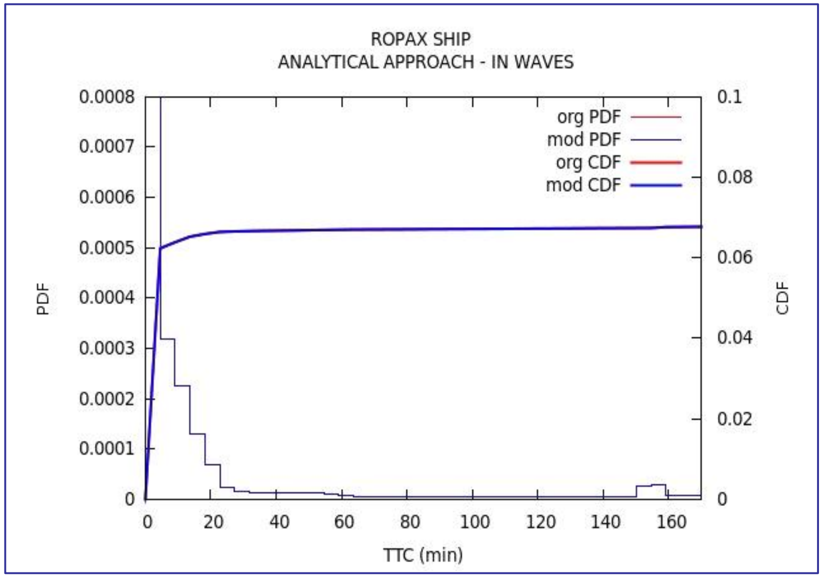
Stability after Damage (3/3)

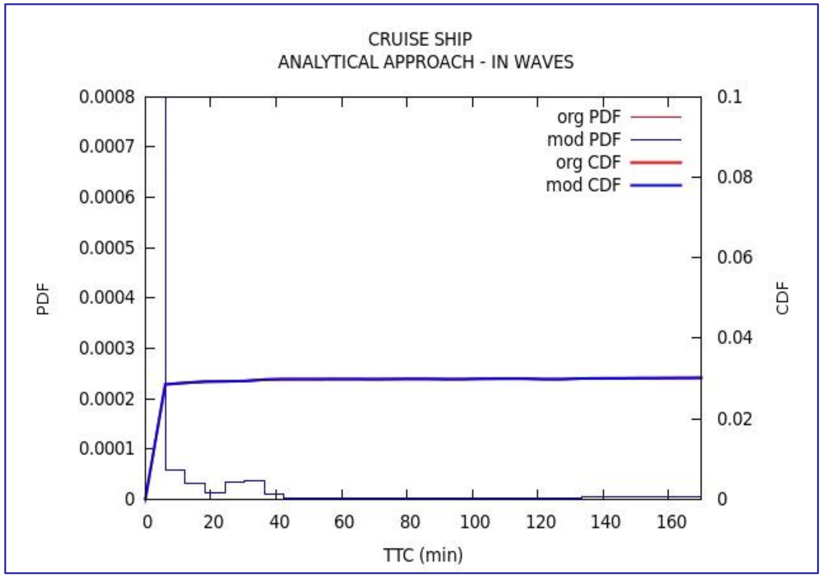
- The capsize conditions after damage are analyzed to
  - *Hydrostatically unstable* (zero stability)
  - *Hydrostatically stable* (positive stability)
- The calm water conditions dominate the ship survivability, as
  - The *unstable* conditions are prevailing, and then the vessels capsize regardless of the presence of waves
  - For Passenger ships, the collisions occur in calm water for the large percentage 40-70% (Harder'03, Goalds'11 statistics)



Time to Capsize (1/3)

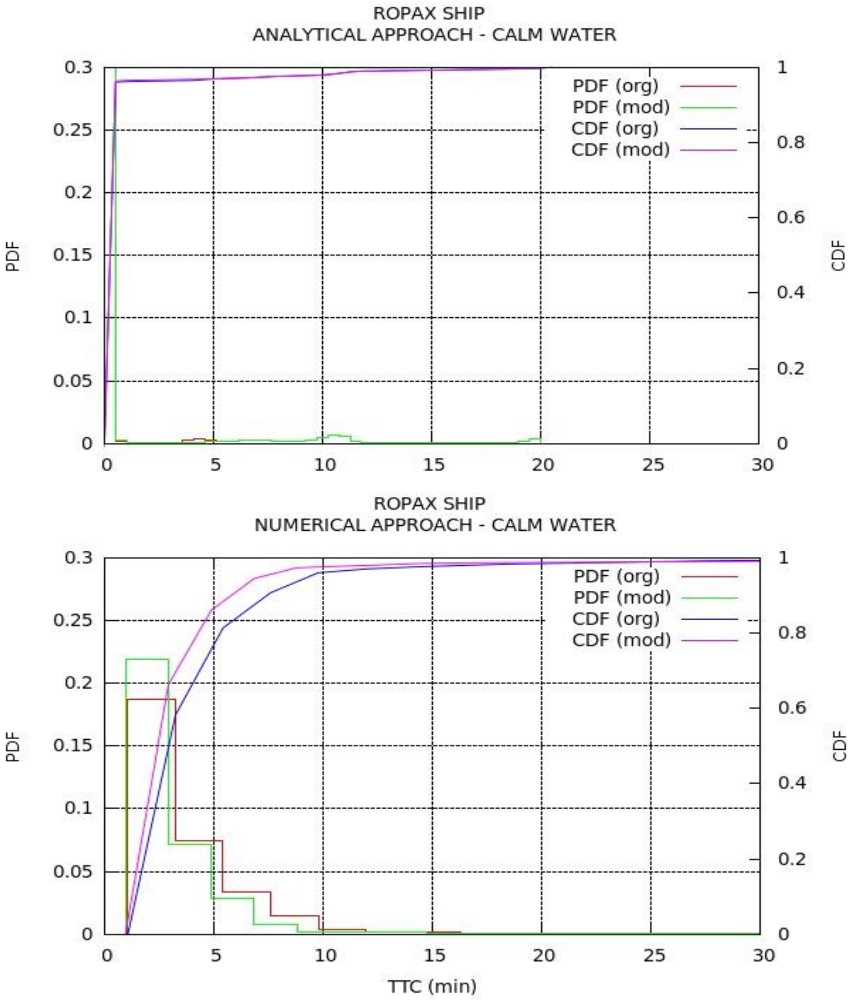
- Probability of the TTC within 3 *hours* (from the damage incident, including waves) is fast analyzed with the **analytical** approach
- Capsize events are practically limited within 30 *min*
- Negligible probability for late capsize events can be easily inferred
- No sensitivity to the tested design scenarios





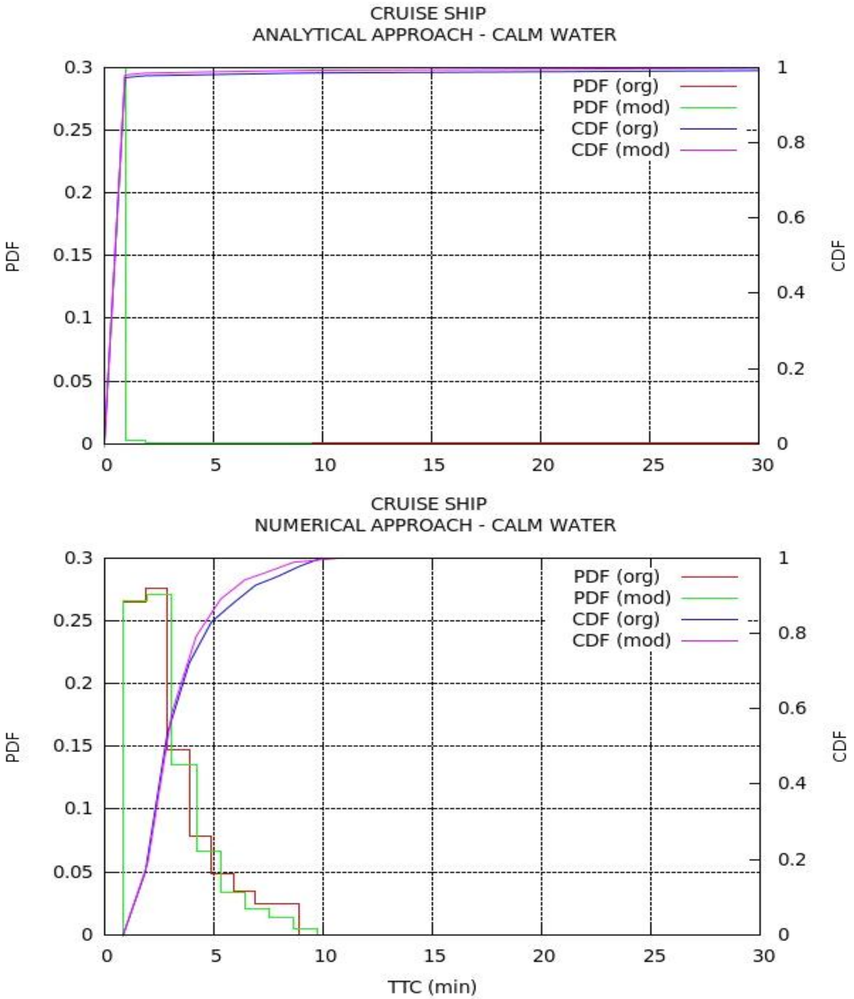
Time to Capsize (2/3)

- Probability distribution of the TTC in calm water for the RoPax ship
- Capsize events distributed within 1st quarter of time (15 *min*)
- Analytical approach appears insensitive in this range of short times



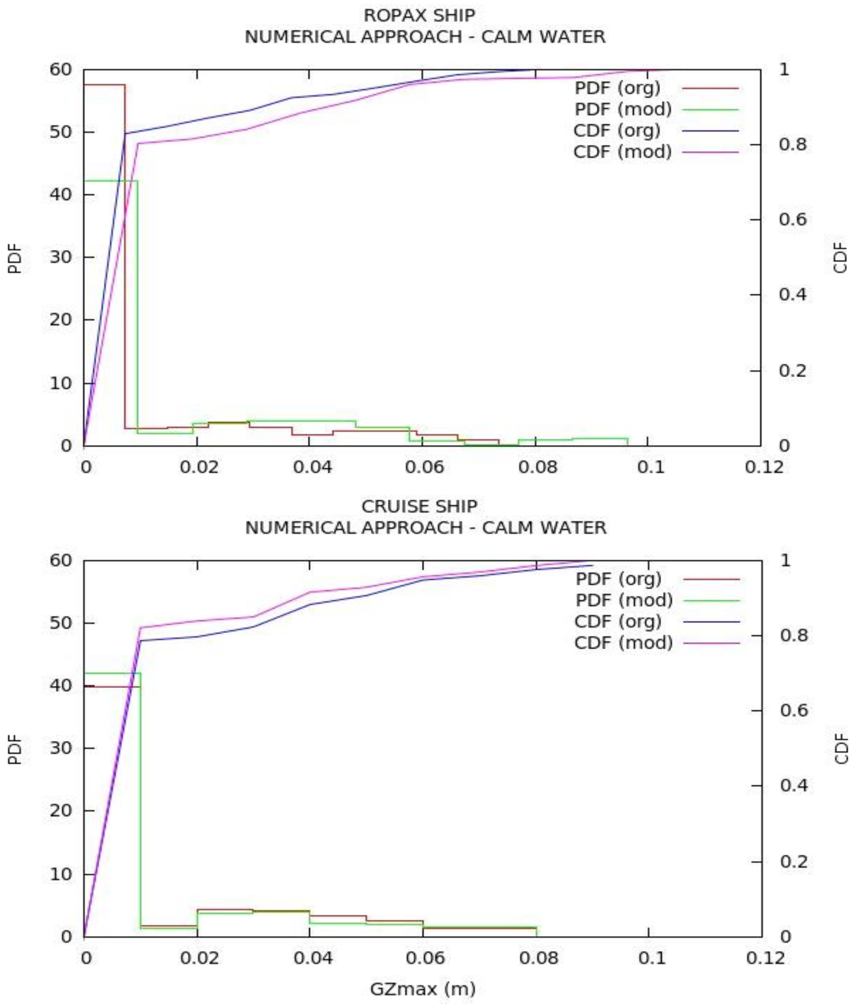
Time to Capsize (3/3)

- Probability distribution of the TTC in calm water for the Cruise ship design
- Capsize events distributed within 1st quarter of time (15 *min*)
- Analytical approach appears insensitive in this range of short times



Residual Stability for Capsize Events

- Probability of *GZmax* after damage for the capsize events in calm water is shown
- Instability is limited for *GZmax* below 0.10 m (and practically below 0.05 m) for both ships, limits with practical interest for the stability regulations currently in force (Solas'09)
- In order to additionally sustain the wave conditions (~1-2%) this limits would be increased



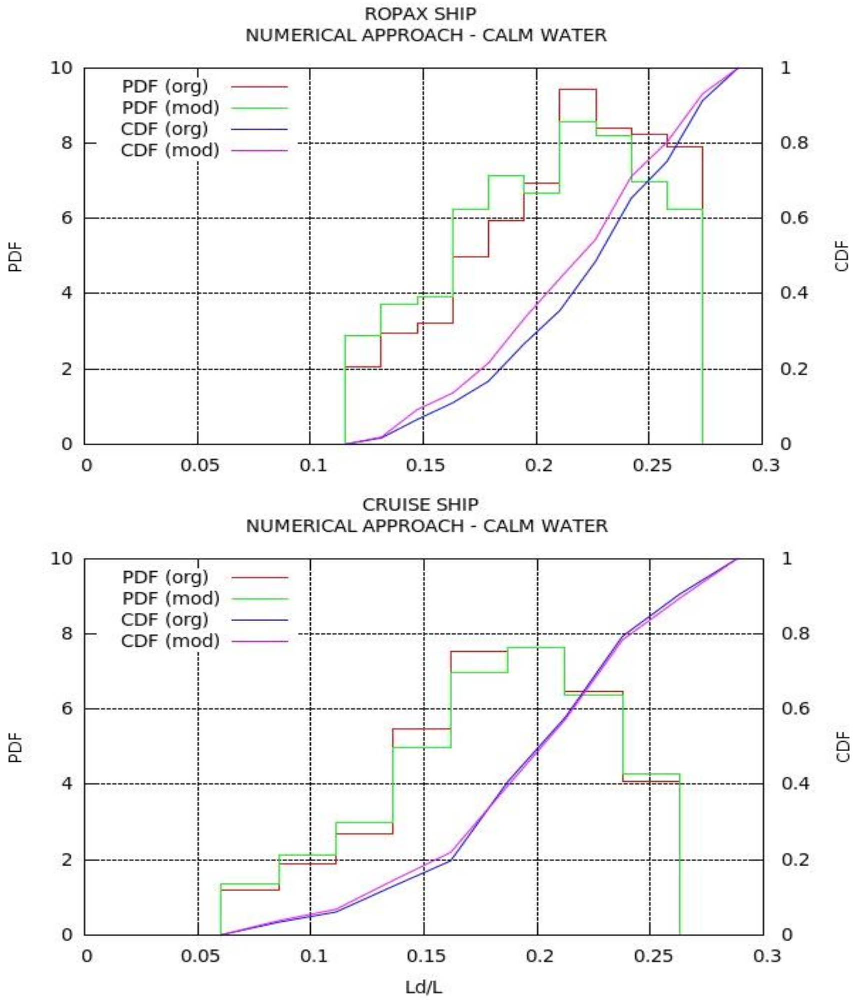
Length of Breach

- The probability distributions of the damage length for the capsize events are shown

  Both ships are vulnerable to large damages only (**3 WT compartments damaged and more**)

- An average damage length close to 20% of the ship length for both ships

  While the average incident damage length is approx. 5% of ship length



Orderly Evacuation of the Ships

- **Time to orderly Evacuate TOE the ship**
  Conservative estimations (Floodstand - WP5)

	RoPax	Cruise
people on board	1000	2600
Mustering (awareness & traveling)	20	40
Abandonment (embarkation & launching)	20	40
Time to Evacuate	**40 min**	**1 hr 20 min**

- **Time to capsize TTC** (average survive time for ship in capsize events)
  Both ships **30 min**

- **TTC < TOE (!)**

Orderly Evacuation for non-survive damages: INCOMPLETE

Closing Remarks (1/2)

- The ***fast capsize*** of ships in collision damages
  - was further confirmed for the most <u>*generic*</u> design assumptions
  - is a consequence of vulnerability to very <u>*large*</u> damages

- The tested analytical approach is founded for longer capsize times, consequently it appears insensitive in the range of short times and its ***applicability*** in the design practice could not be concluded.

Closing Remarks (2/2)

- The subdivision-dependent safety of the people on board against flooding due to side collision damages can be practically assumed as ***time-independent,*** and rather an immiscible ship survivability problem.
- Mitigation of the casualty risk for people on board remains ***open challenge*** (especially when large number of passengers) and points towards
  - enhanced subdivision requirements and
  - faster abandonment operations

Technical Report

The presented research is detailed reported by:

*Spanos, D., Papanikolaou, A., Report on the applicability of the standard for design practice, FLOODSTAND-deliverable **D7.3**, public report*

Issue date: Feb. 2012 (expected)

Available from: FLOODSTAND website

http://floodstand.aalto.fi