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MARITIME

EMSA OP/10/2013

A STUDY ASSESSING THE ACCEPTABLE AND PRACTICABLE RISK LEVEL OF PASSENGER SHIPS RELATED TO DAMAGE STABILITY

08 September 2015

Ungraded

Content

- Introduction and overview of the EMSA III studies (Odd Olufsen)
- Formal Safety Assessment, Risk Models for collision and grounding (Rainer Hamann)
- Methodologies for assessing risk from watertight doors and risk from grounding (Odd Olufsen)
- Sample ships; design and risk control options (Henning Luhmann)
- Summary of results, recommendations for decision making (Odd Olufsen)

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Members of the consortium

- Shipyards:
  - EUROYARDS, representing: Meyer Werft, Fincantieri, Meyer Turku, STX-France
- Designers/Consultants:
  - Knud E. Hansen AS & Safety at Sea
- Operators:
  - Carnival Cruise, Color Line, Royal Caribbean & Stena Line
- Universities:
  - National Technical University of Athens, University of Strathclyde & University of Trieste
- Software developer:
  - Napa OY
- Classification Society:
  - DNV GL

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Background

- Passenger ships transport significant numbers of persons compared to cargo ships
- Therefore, safety of persons on board is in focus in passenger ship design
- The main risk contributors for passenger ships are accidents leading to loss of water tightness, i.e. collision, contact and grounding
- Currently designed ships need to comply with SOLAS 2009 probabilistic damage stability requirements
- SOLAS 2009, to a great extent, was based on research work of the HARDER project
- When introducing SOLAS 2009, the level of R was based on the safety level of the current fleet.

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Overview of completed tasks in the EMSA III project

- Risk acceptance criteria and risk based damage stability
- Evaluation of risk from watertight doors
- Evaluation of risk from grounding
- Damage stability calculations of GOALDS design
- Combined assessments

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Defined tasks and their main elements

Task 1:

Acceptable and practicable risk level of passenger ships

-risk level in comparison with other transport modes

-updated collision risk model

-risk control options(rco) and cost benefit assessment(cba)

-recommending level of the required index R

Task 2:

Evaluation of risk from watertight doors

-collecting records; onboard monitoring cruise and RoPax

-parametric model reflecting number, categorisation and closing time of wtd

-parametric model developed and used to assess risk on the sample ships

-rco and cba carried out for some sample ships

Task 3:

Evaluation of risk from grounding

-updated damage statistics and grounding risk model including contact damages

-side and bottom grounding damage statistics

-NAPA software developed for direct generation of hull breaches from statistics

-attained index for grounding damages

-calculations of A carried out on all sample ships

-rco and cba carried out for some sample ships

Task 4: Combined assessment of cost effectiveness of previous parts, FSA compilation and overall recommendation for decision making.

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FSA and risk models

- In 2002 IMO agreed that adjustment/development of regulations should be prepared using risk analysis (-> Formal Safety Assessment Guidelines)
- Goals of this study:

could damage stability requirements of passenger ships be increased following FSA process

- This study considers
  - Passenger ships: cruise, passenger, RoPax and RoPax-Rail
  - Ships in compliance with current damage stability requirements (reference)

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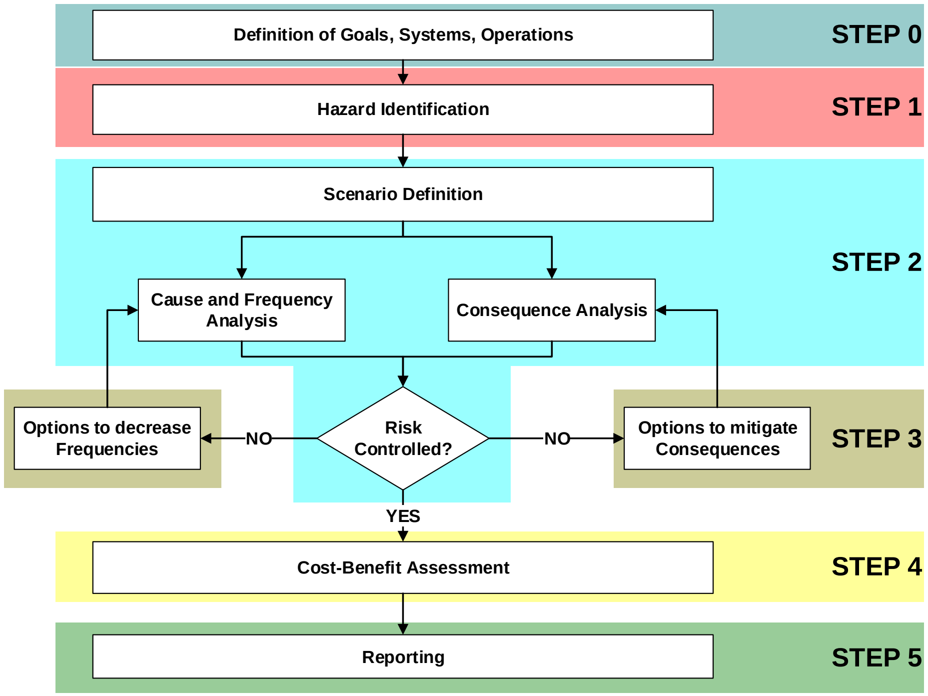
FSA$_1$

- FSA was developed to support IMO decision making by helping to evaluate regulatory changes in terms of benefits and related costs.
- FSA should provide recommendations for decision making

- FSA
  – Comprises a complete risk assessment
    – Hazard identification
    – Risk assessment
    – Risk reduction measures
    – Cost-benefit assessment
    – Reporting
  – Suggests required safety level to be tolerable and ALARP



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ALARP = As Low As Reasonable Practical

Tolerable and ALARP

- Tolerable and ALARP means
  - That risk is not intolerable (-> risk reduction without cost-benefit assessment)
  - ALARP process is applied
- ALARP process:
  - Measures reducing risk (frequency, consequence or both) are identified/developed
  - Measures are assessed with respect to benefits (safety, economic) and costs by
    - Risk reduction is quantified
    - Costs of risk reduction measures are determined
    - Measures are assessed in terms of cost/risk reduction ratio and a criterion specified in FSA Guidelines

ALARP = As Low As Reasonable Practical

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ALARP process

- FSA guidelines provide criteria for cost benefit assessment
  - Gross cost of averting a fatality (GCAF) $GCAF = \frac{\Delta Cost}{\Delta Risk}$
  - Net cost of averting a fatality (NCAF) $NCAF = \frac{\Delta Cost - \Delta Benefit}{\Delta Risk}$
  - An RCO is cost beneficial if GCAF/NCAF are equal to or lower than threshold
- Threshold for GCAF and NCAF provided by FSA Guidelines ($3 million)
- Threshold were determined by means of specified process using social indicators (not static, follows general development)
- The value given in FSA Guidelines was suggested in 1999 (MSC 72/16) considering social indicators until 1988
- In GOALDS project threshold was updated to $7.45 million
- In this study $4 and $8 million has been used.

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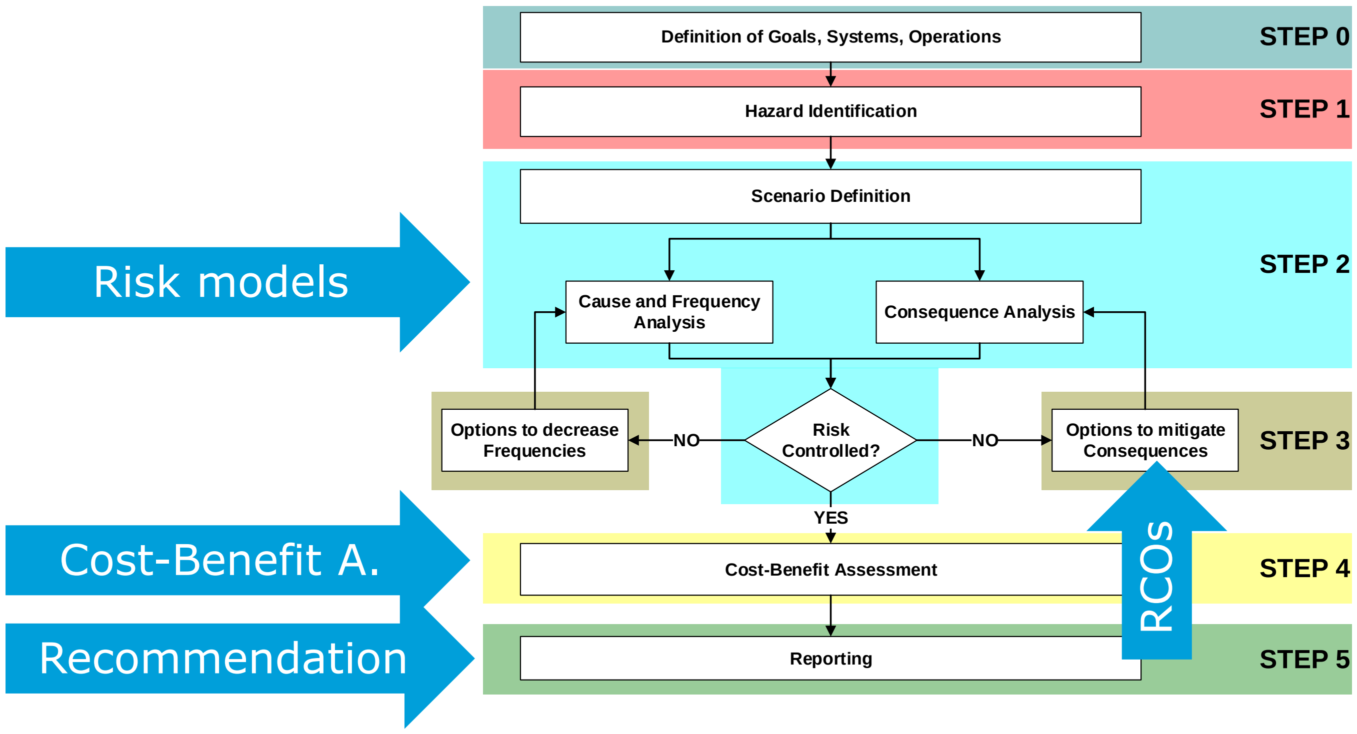
EMSA III study



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Development of risk model

- Analysis of casualty reports to determine main events characterising risk
  - ➡ Develop high-level event sequence
- Analysis of accident statistics to specify representative sample
  - ➡ Development of annual accident frequencies
- Select/review casualty reports
- Develop risk model, e.g. in form of event tree
- Quantify risk model
  - Initial accident frequency
  - Dependent probabilities
    - Numerical model
    - Historical data
    - Expert judgement

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Definition of sample

- Basis:
  - IHS Fairplay casualty database and ship register
  - Lloyds Maritime Investigation Unit database (LMIU)
  - Global Integrated Ship Information System (GISIS)
- Sample characteristics of ships
  - Built after 1981
  - ≥ 1000 gross tonnage
  - ≥ 80 m
  - IACS class at time of accident/today
  - No High Speed Crafts

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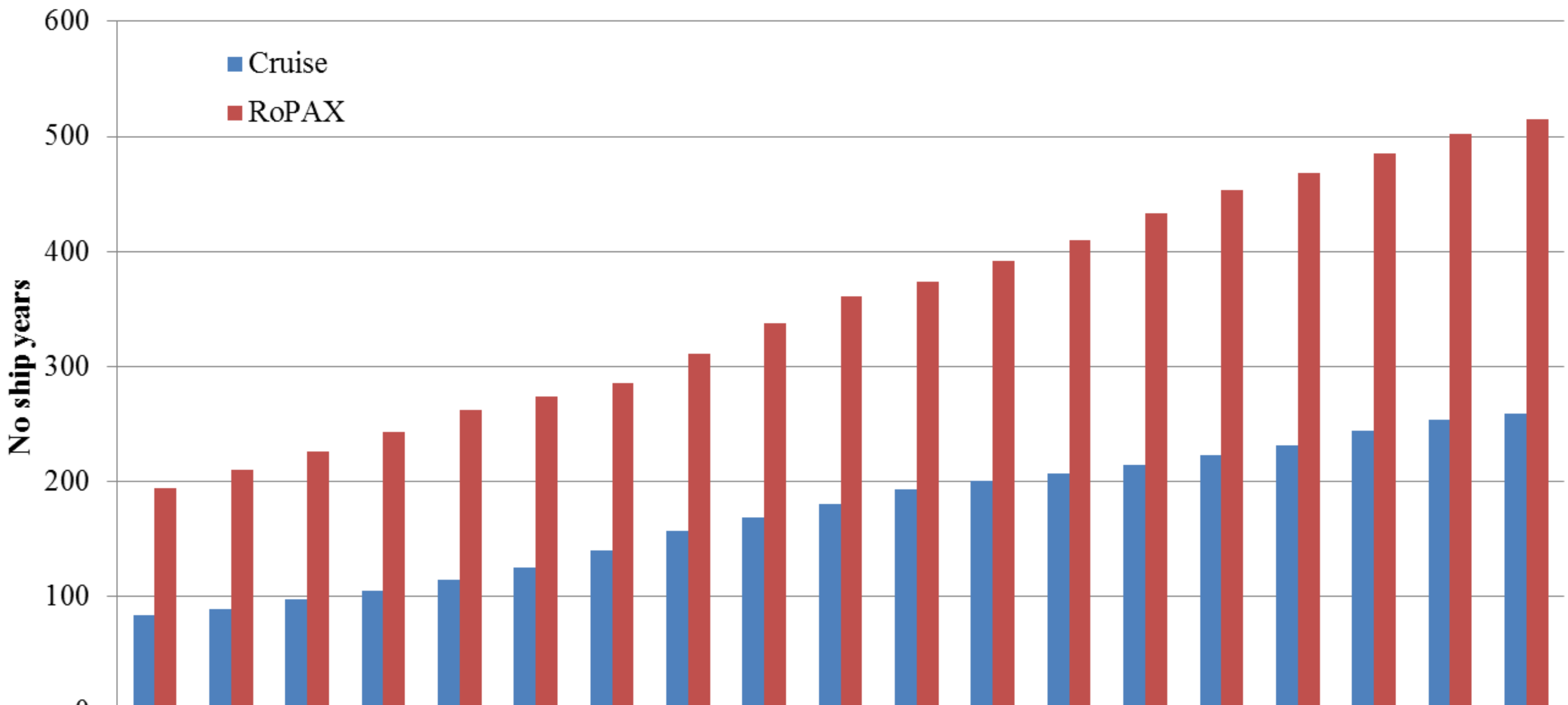
Fleet size



	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Cruise	84	89	98	105	115	126	140	157	169	181	193	201	207	215	223	232	244	253	259
RoPAX	195	210	227	243	262	274	285	311	338	361	373	392	410	433	453	468	485	503	515

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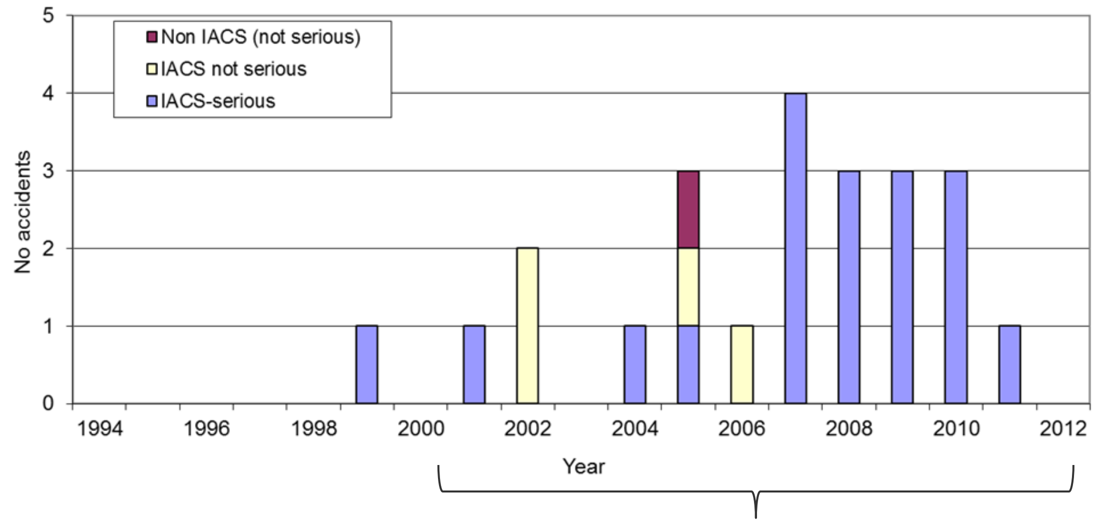
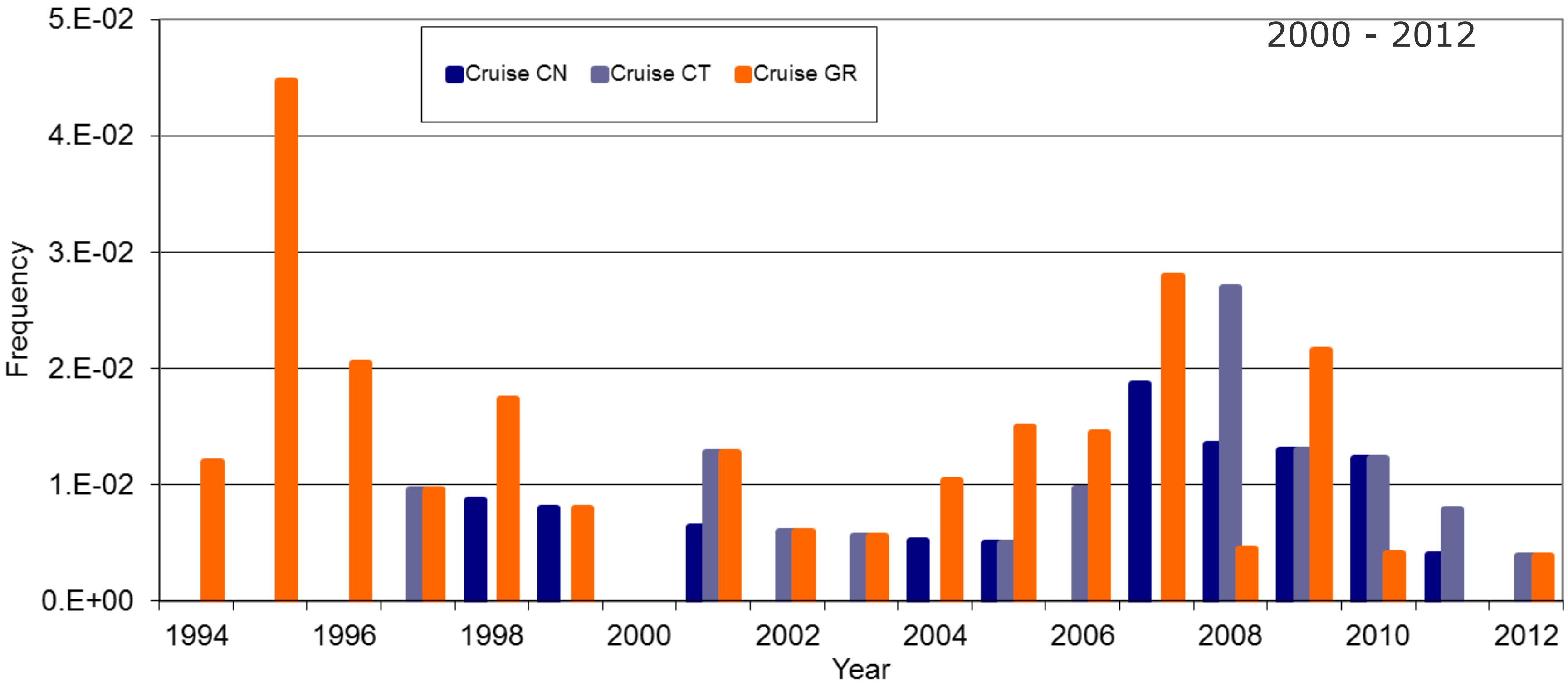
Casualties cruise

CN (serious and not serious collision) accidents between 1994 and 2012 distinguishing IACS and Non IACS cruise ships.





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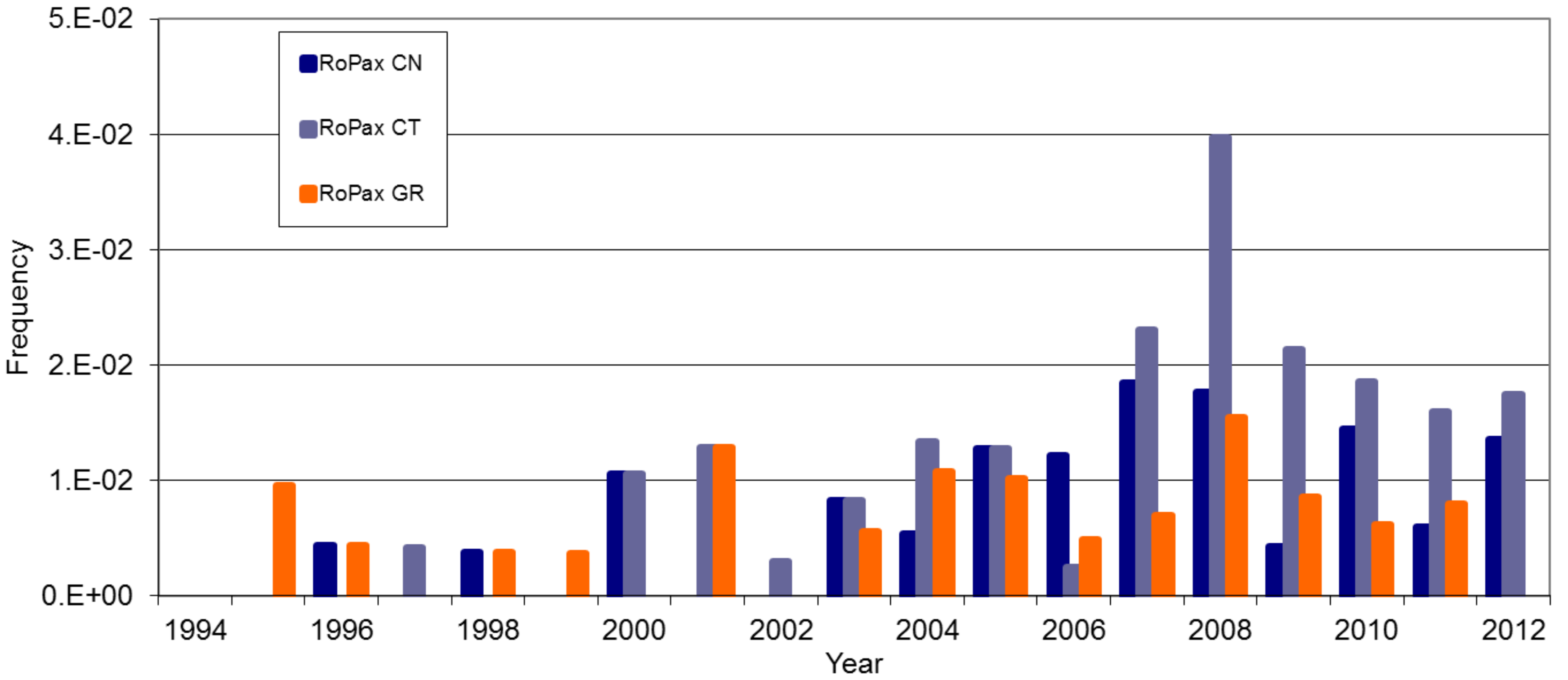
Casualties RoPax



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Casualty database

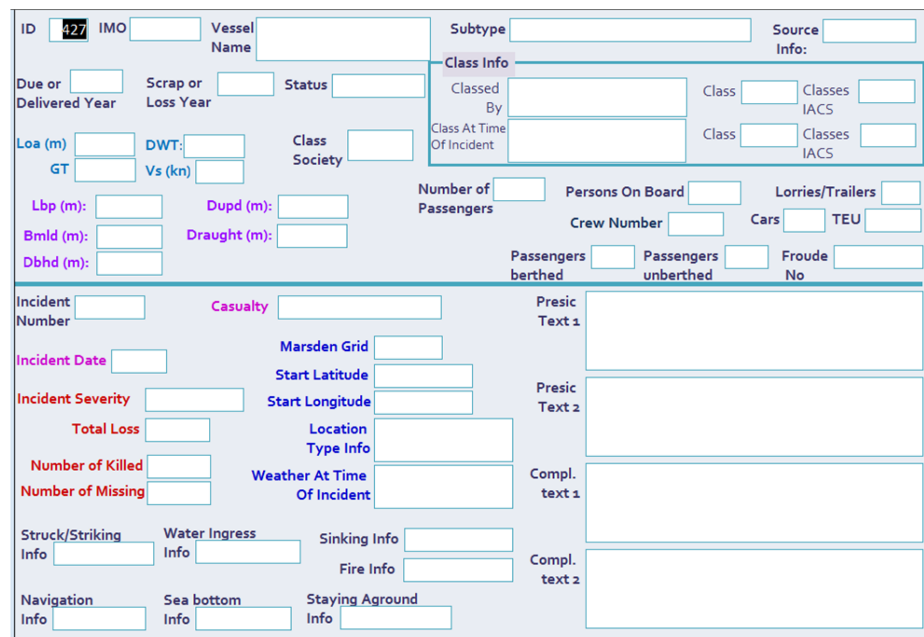
- Basis for this study formed the casualty database developed in GOALDS project extended by reports after 2009

- All records were reviewed and populated accordingly

- By review process casualty reports not relevant for this study were identified and not further considered

- Initial casualty information is coming from IHS database. This information was enhanced from other sources especially in cases where accident investigating reports were available (e.g. GISIS)

- Only casualties considered complying with filtering criteria (ship size, year built etc.)


ID 427 IMO
Vessel Name
Subtype
Source Info:
Due or Delivered Year
Scrap or Loss Year
Status
Class Info
Classed By
Class
Classes IACS
Class At Time Of Incident
Class
Classes IACS
Loa (m)
DWT:
Class Society
GT
Vs (kn)
Number of Passengers
Persons On Board
Lorries/Trailers
Lbp (m):
Dupd (m):
Crew Number
Cars
TEU
Bmld (m):
Draught (m):
Dbhd (m):
Passengers berthed
Passengers unberthed
Froude No
Incident Number
Casualty
Presic Text 1
Incident Date
Marsden Grid
Start Latitude
Incident Severity
Start Longitude
Presic Text 2
Total Loss
Location Type Info
Number of Killed
Weather At Time Of Incident
Compl. text 1
Number of Missing
Struck/Striking Info
Water Ingress Info
Sinking Info
Fire Info
Compl. text 2
Navigation Info
Sea bottom Info
Staying Aground Info

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Risk Model

- For the purpose of this study two risk models were developed for accident categories
  - Collision
  - Grounding (+ contact)
- Only consequences with respect to persons on board are in focus
- Quantitative risk model developed using Event Tree method
- Ship type dependent risk models were developed separately for cruise and RoPax, in order to considering particularities, e.g. for
  - Initial accident frequencies
  - Fatality rates
- Risk models are ship size dependent, with respect to
  - Number of person on board
  - Probability of sinking

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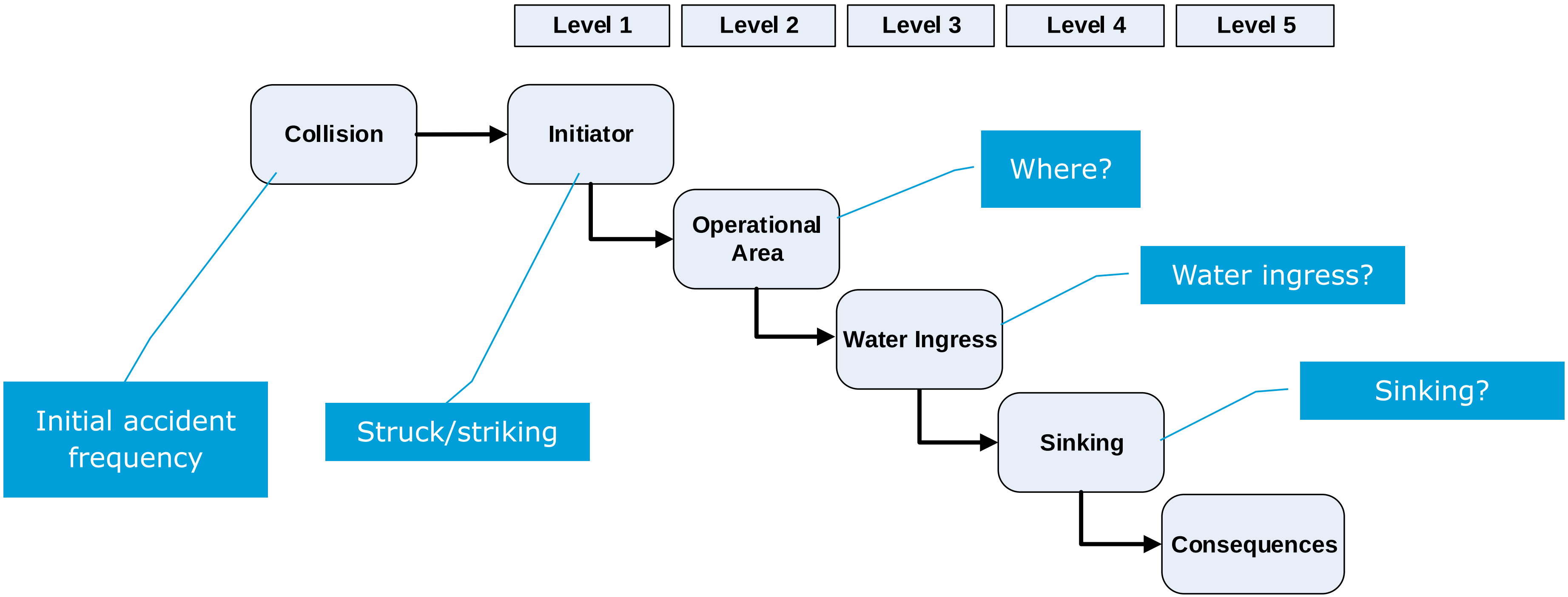
Risk Model: Collision



- High-level event sequence for collision casualties of passenger ship
  - Considers main factors influencing the risk to persons on board

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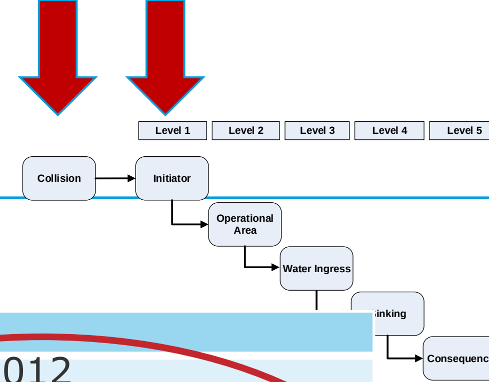

Risk Model: Quantification

- Initial accident frequency

Time Period			
1994 - 2012		2000 - 2012	
No of casualtie s	1/ship year	No of casualties	1/ship year
Cruise			
19	5.78E-03	17	6.36E-03
RoPax			
52	7.72E-03	50	9.38E-03

- Initiator: Struck/striking
  – Small number of casualty reports providing sufficient information for quantifying nodes of risk model
  – Therefore, in the view of reducing uncertainty, casualty reports for cruise and RoPax were merged
  – On average struck/striking probability is about 50% (struck: 43% cruise, 58% RoPax)
  – Analysis of casualty reports showed that collision accident damages are only relevant for ship stability when ship is struck

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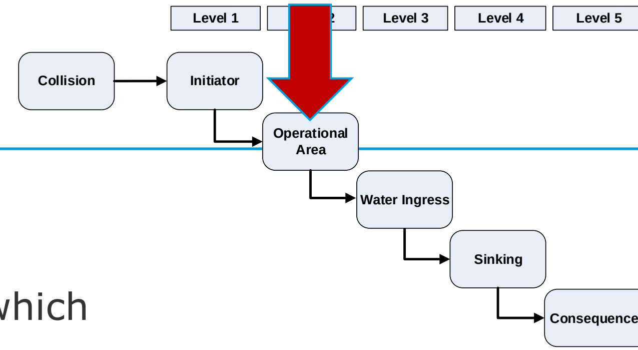
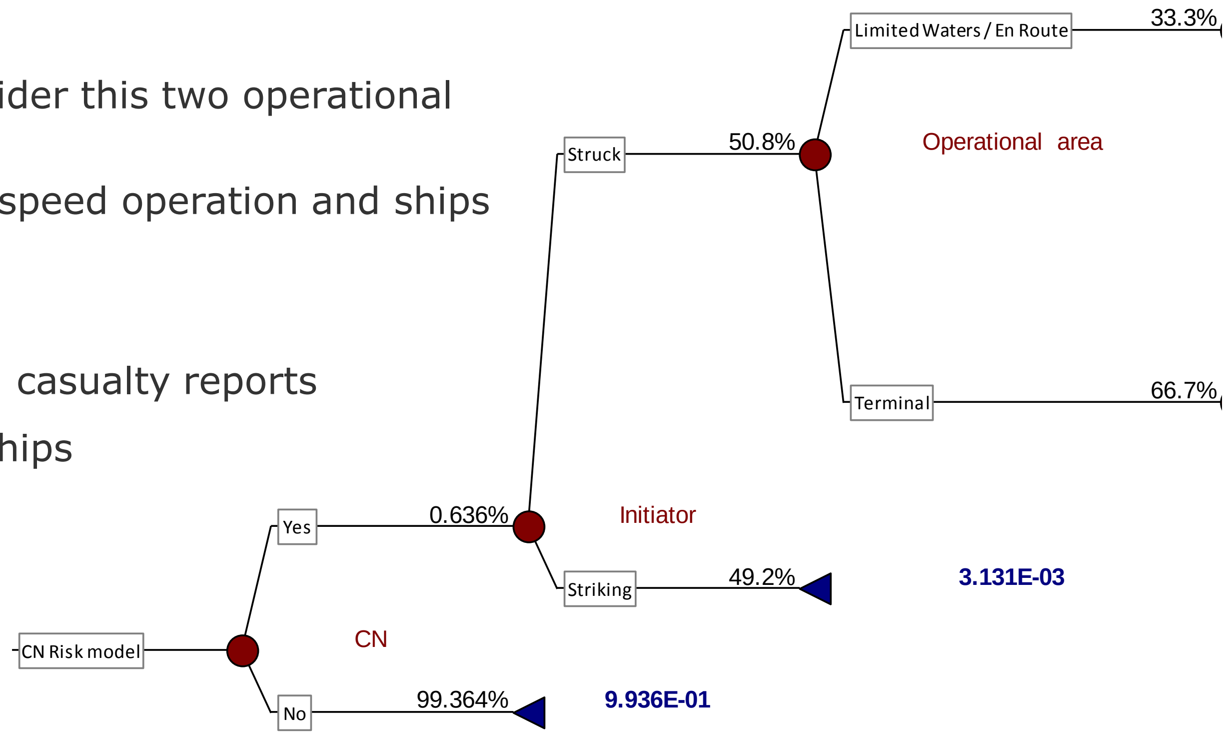
Risk Model: Quantification



- Operational area
  - Extent of hull damage heavily relates to impact energy which depends on ship speed and mass
  - In terminal area extent of hull damage is smaller than for collision in open sea or coastal waters
  - In order to adequately consider this two operational areas were distinguished
    - Terminal with typical low speed operation and ships berthed
    - All other areas
  - Quantification was based on casualty reports merging cruise and RoPax ships (33 reports)



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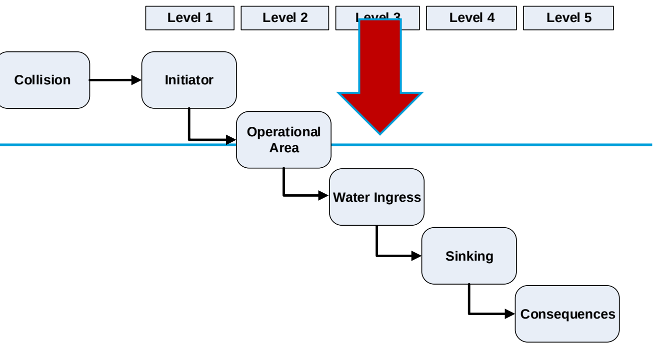
Risk Model: Quantification



- Water ingress
  - Depends on
    - Whether hull is penetrated in collision
    - Location of the breach, i.e. is water ingress possible

- By distinguishing two operational areas the model considers the differences between operation in terminal areas and others:
  - Probability of water ingress in terminal areas is about 7% (based on 14 casualty reports)
  - Probability of water ingress in other areas is about one third (based on six reports)
  - Quantification was based on casualty reports merging cruise and RoPax ships

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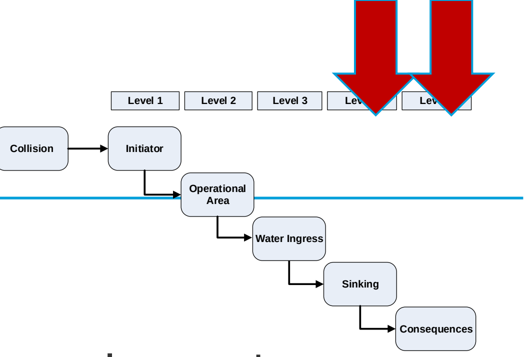
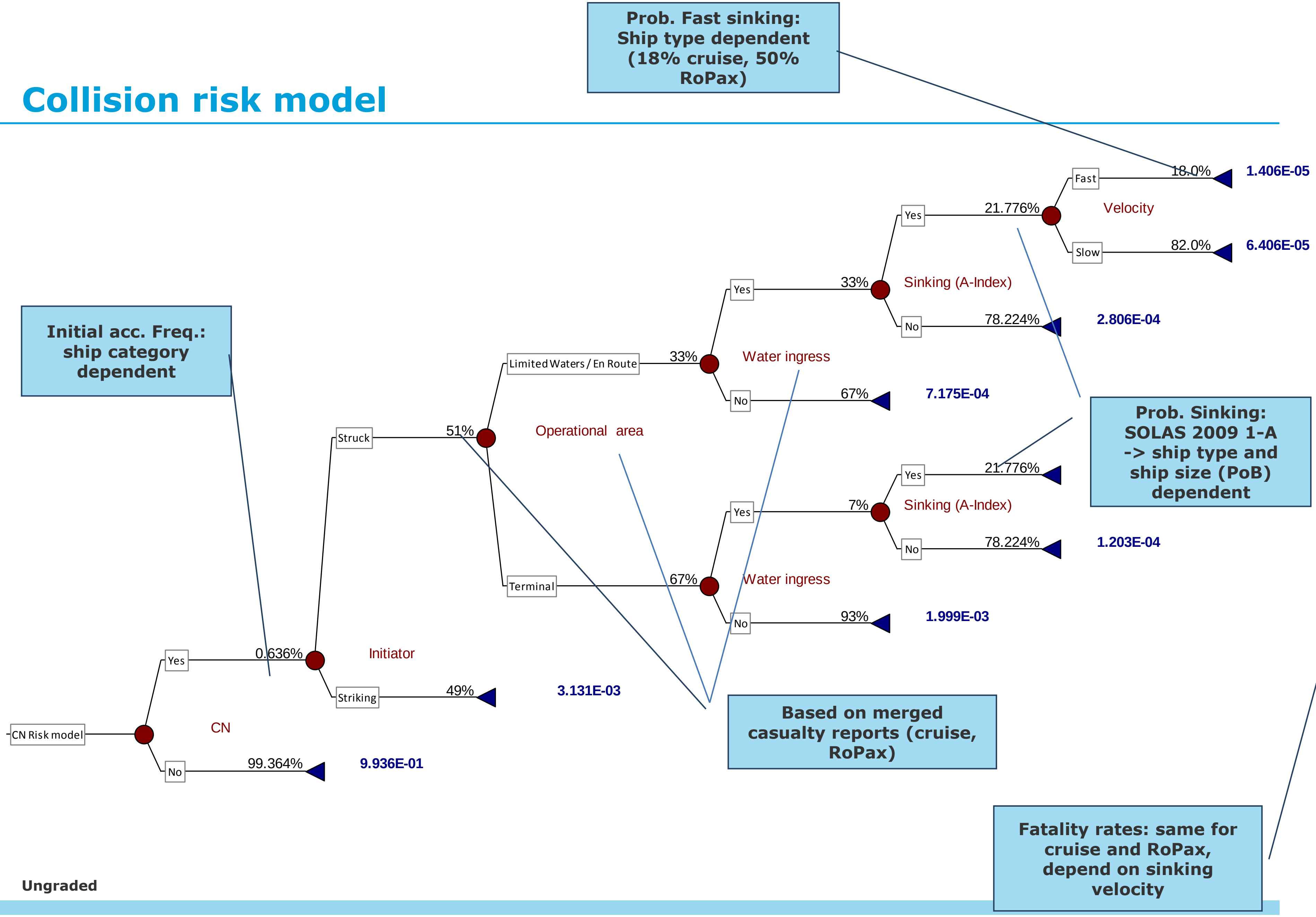
Risk Model: Quantification



- Probability of sinking
  - Is determined on basis of SOLAS 2009 damage stability requirements
  - Probability of sinking equal to 1 minus attained index (A-Index)

- Consequences
  - Related to persons on board (crew + passengers)
  - Considering occupancy of 90% for cruise, respectively seasonal occupancy for RoPax (100% for 12.5% of the year, 75% for 25% of the year and 50% for remaining time)
  - Two representative fatality rates used for the scenarios
    - Fast sinking/capsizing 80% of persons on board
    - Slow sinking 5% of persons on board
    - For sinking in terminal areas 5% fatality rate used for all scenarios
  - Probability of fast sinking depends on ship type (18% for cruise, 50% for RoPax)

Collision risk model



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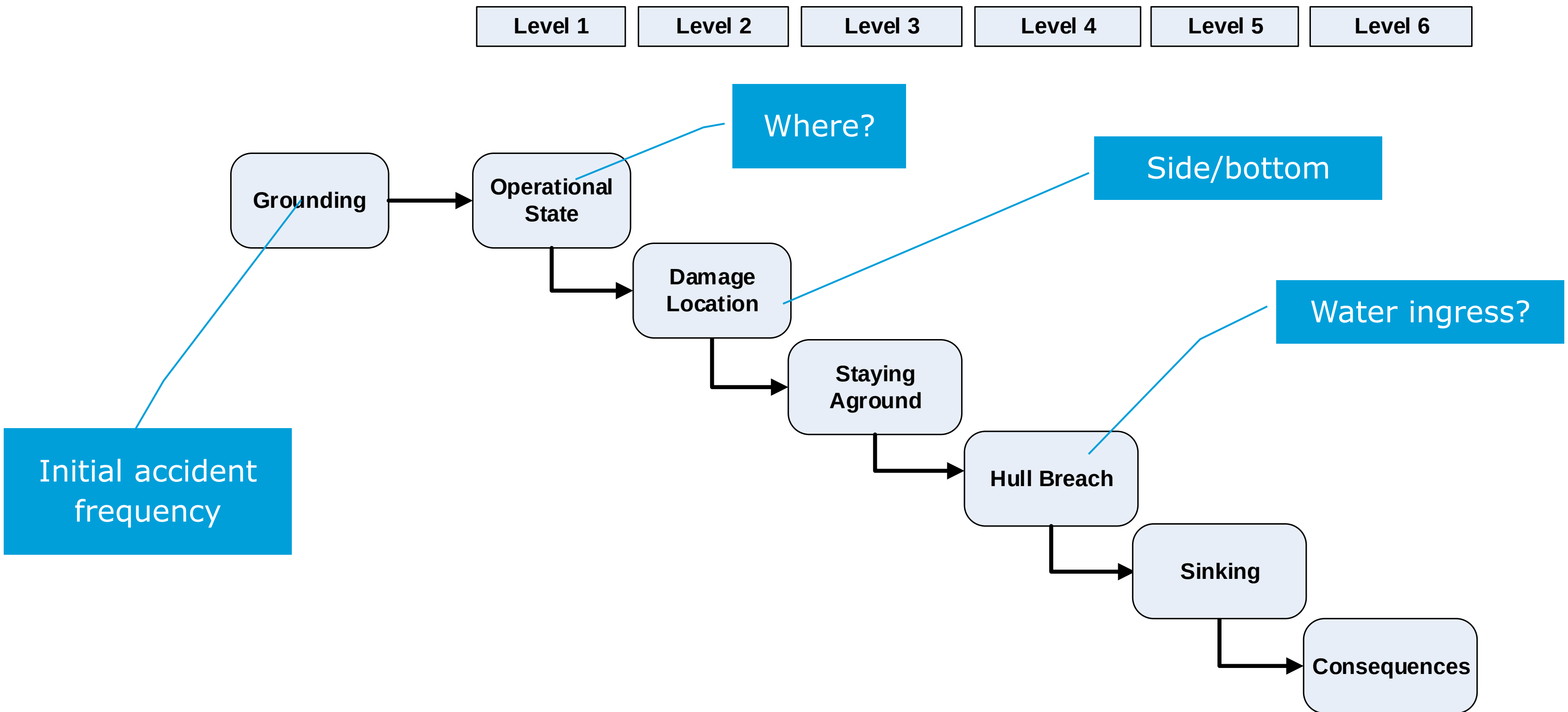
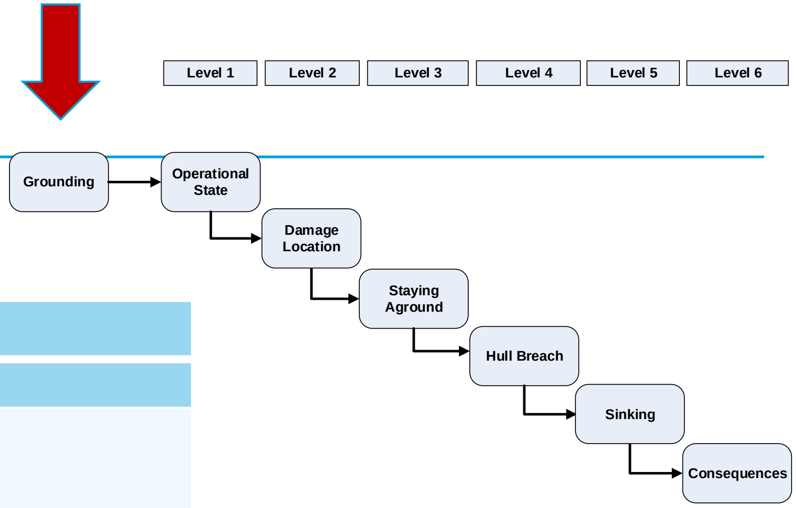
Risk Model: Grounding



- High-level event sequence for grounding and contact casualties of passenger ship
- Contact casualties with potential of penetrating hull and subsequent water ingress
- Only consequences with respect to persons on board are in focus

Risk Model: Quantification



- Initial accident frequency

Time Period	
2000 - 2012	
casualties	1/ship year
Cruise	
20 + 22	1.57E-02
RoPax	
27 + 86	2.12E-02

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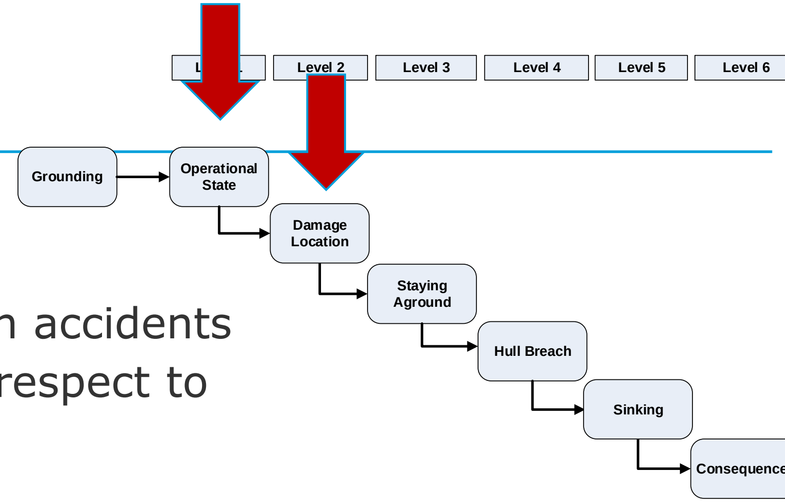
Risk Model: Quantification



- Operational state
  - Considering that scenarios will differ between accidents in terminal areas and other areas, e.g. with respect to possibility of rescue but also water depth
  - About 57% of accidents occurred in terminal areas (217 reports for period 1990 to 2012)
- Damage location
  - Distinguishing between side and bottom damage
  - For terminal areas about 92% are side damages (75 casualty reports)
  - For other areas about 51% are bottom damages (43 casualty reports)

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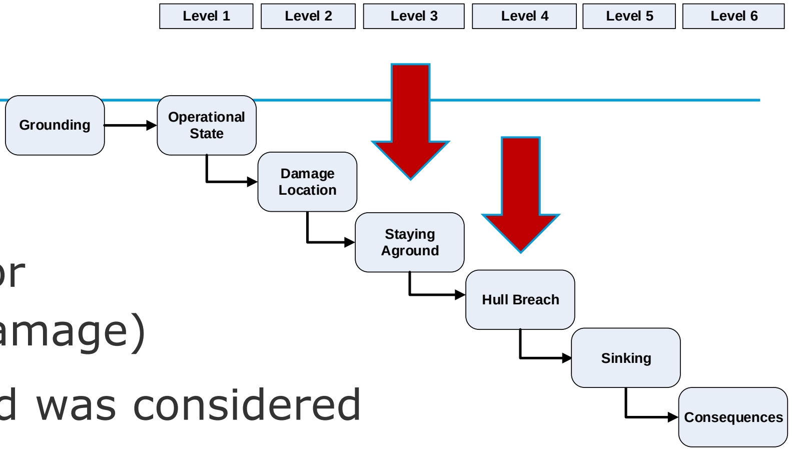
Risk Model: Quantification



- Nodes *staying aground* and *hull breach*
  - Consider influences like sea bed (soft/hard) or the general probability of hull breach (side damage)
  - Additionally, the possibility of staying aground was considered (= no possibility of sinking)

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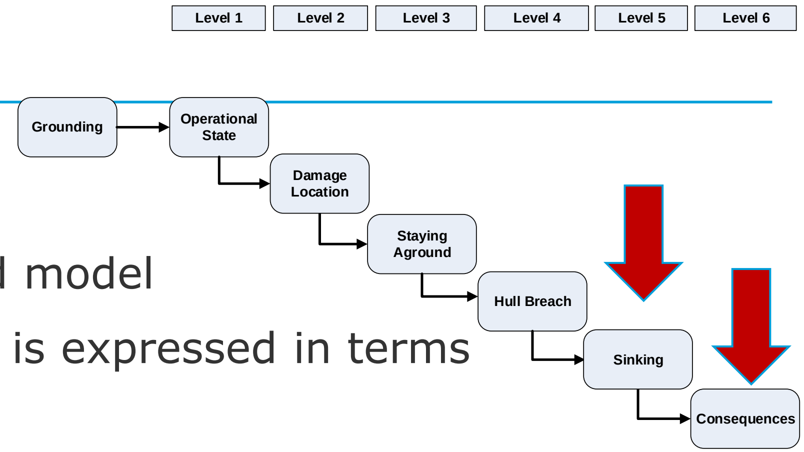
Risk Model: Quantification



- Probability of sinking
  - Is determined on basis of the new developed model
  - Similar to collision the probability of survival is expressed in terms of an index (A_{GR}-Index)
- Consequences
  - Related to persons on board (crew + passengers)
  - Considering occupancy of 90% for cruise, respectively seasonal occupancy for RoPax (100% for 12.5% of the year, 75% for 25% of the year and 50% for remaining time)
  - Two representative fatality rates used for the scenarios
    - Fast sinking/capsizing 80% of persons on board
    - Slow sinking 5% of persons on board
    - For sinking in terminal areas 5% fatality rate used for all scenarios
  - Probability of fast sinking depends on ship type (18% for cruise, 50% for RoPax)

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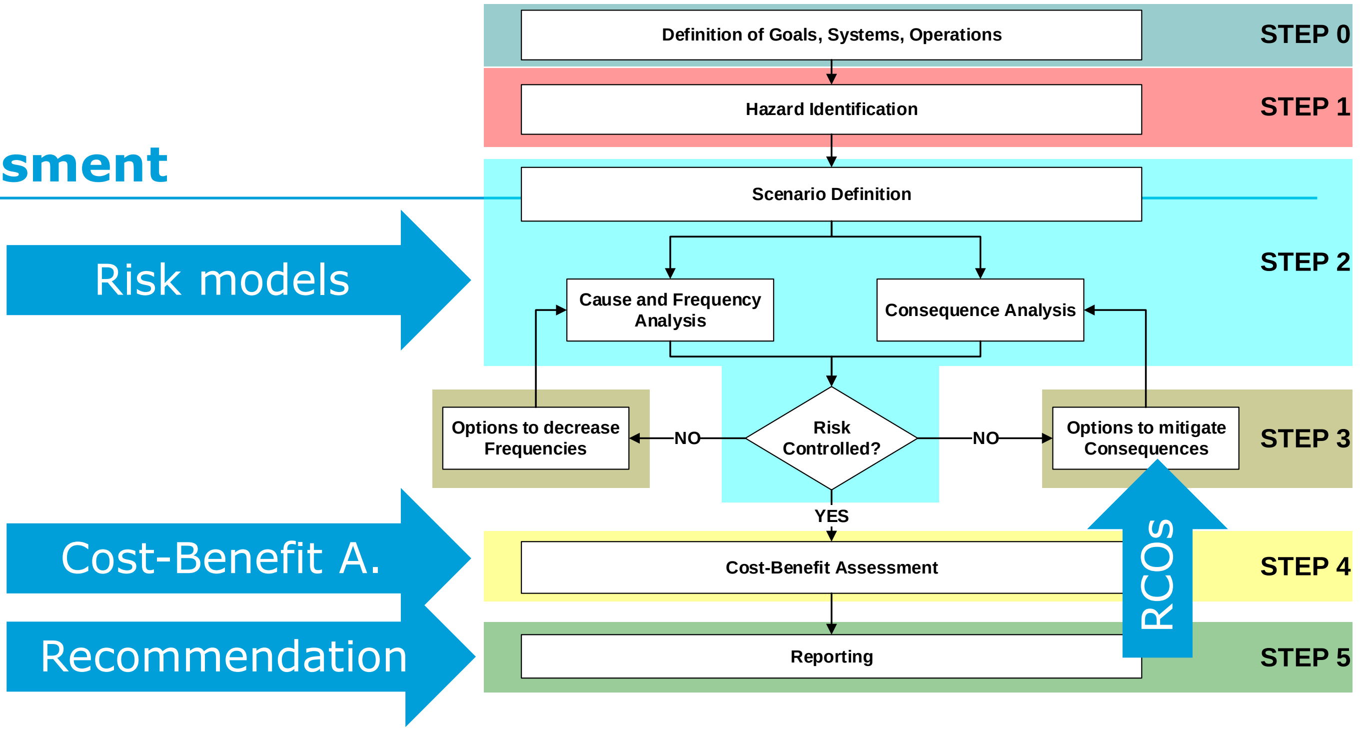
Cost-benefit assessment



- Risk models are used to determine risk reduction by increased damage stability
- Risk models are based on experience and numerical models
- For cost-benefit assessment so-called cost thresholds were calculated by means of risk models, i.e. calculating risk reduction (difference between A-Indices of reference and novel design) and monetary value per avoided fatality

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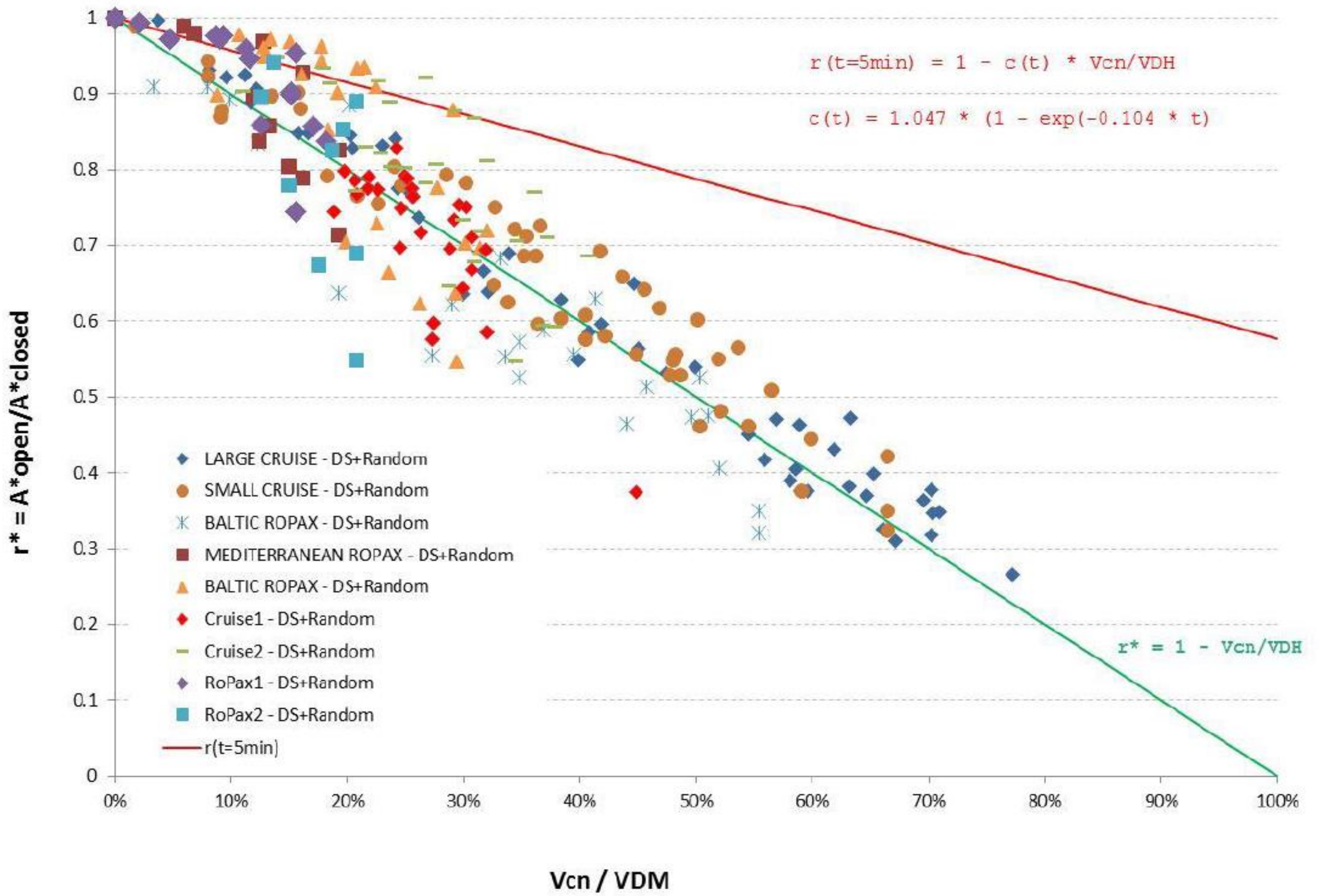
The effect of open watertight doors



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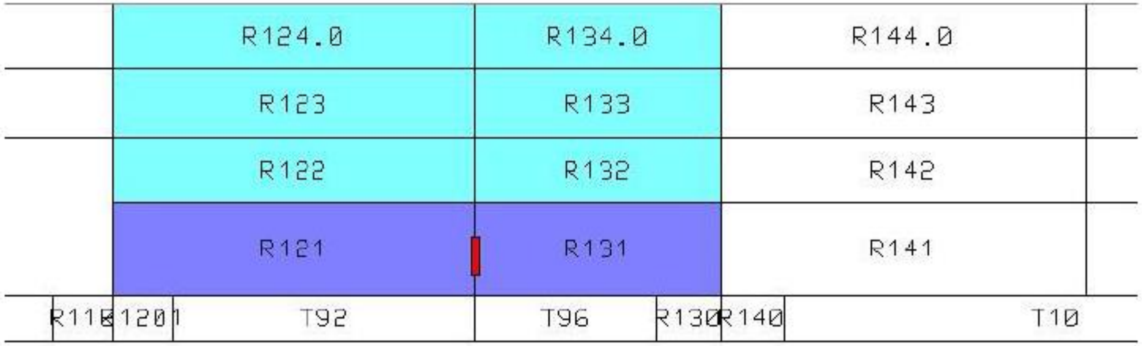
Methodologies for assessing risk from watertight doors

- A parametric model that can be used for assessing risk from watertight doors has been developed:

$$r^* = \frac{A^*_{opened}}{A^*_{closed}} = 1 - b * \frac{V_{cnall}}{V_{DH}}$$

$$b = \frac{\sum_{i=1}^{n_{door}} P_{WTD\,i} * c(t_i) * V_{cn\,i}}{\sum_{i=1}^{n_{door}} V_{cn\,i}}$$



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Categorisation of watertight doors

Door Category	Description of category	Probability that a door is open at a certain point of time $P_{WTD\ i}$	Time to close the door, t_i
A	Door permitted to stay open at sea	100%	5 minutes
B	Door which may be opened during work in the vicinity of the door	60%	3 minutes
C	Door which may be used to pass through	11%	1 minute
D	Door which is always closed – this is proposal of a new door category	0%	0 minute

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Methodology for assessing survivability from grounding

- Probabilistic method for grounding.pptx

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Sample ships, Risk Control Options and Cost Benefit Assessment

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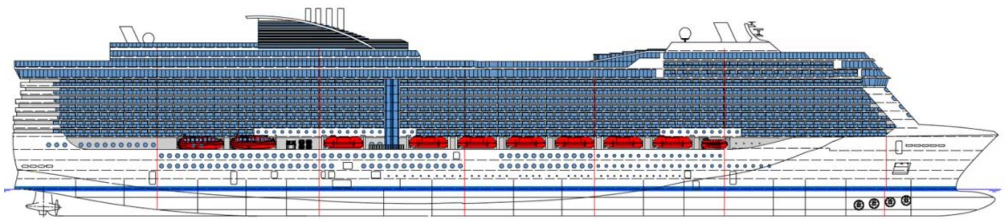
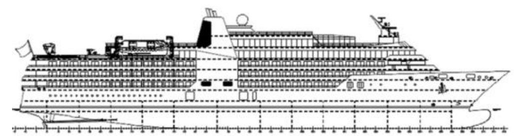
EMSA3 Sample ships and design teams

MEYER WERFT
PAPENBURG 1795



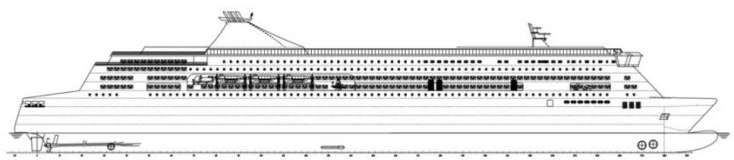
CARNIVAL
CORPORATION&PLC

FINCANTIERI S.p.A.



RoyalCaribbean
INTERNATIONAL

MEYER TURKU
SHIPYARD 1737



ColorLine

stx France

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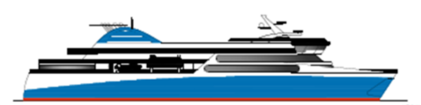
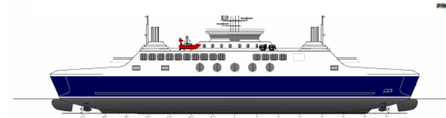
NAVAL ARCHITECTS DESIGNERS MARINE ENGINEERS
~Since 1937~





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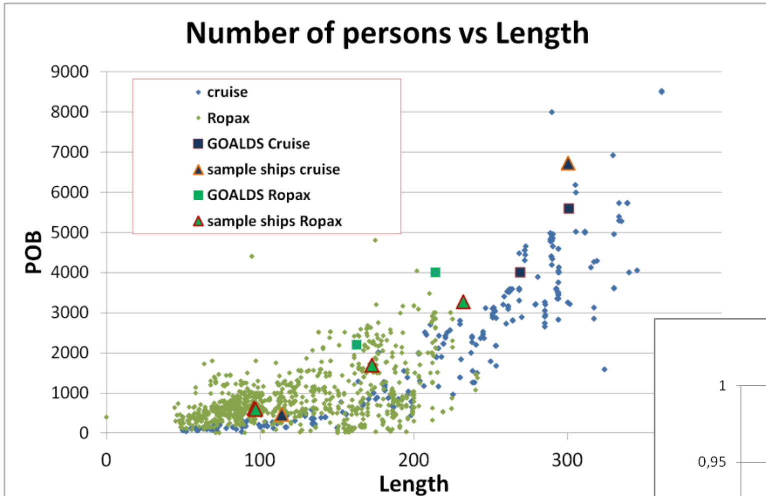
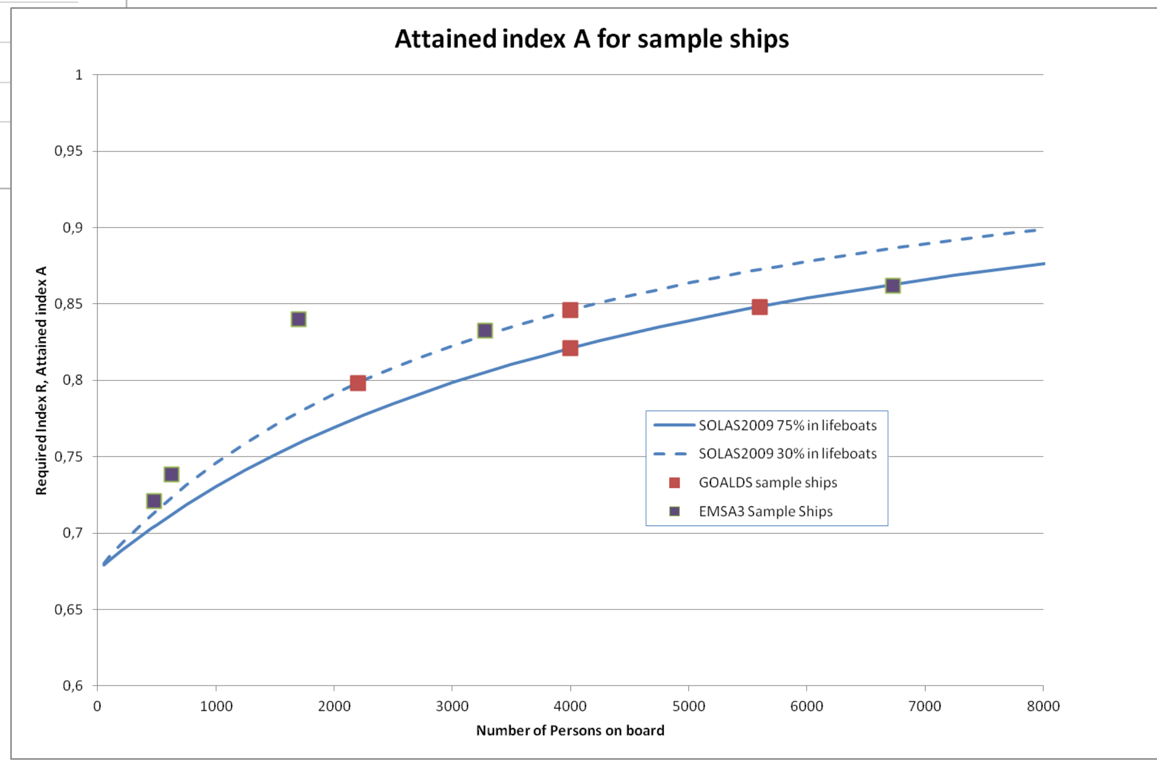
Overview EMSA III Sample ships

Yard/Designer	Type	Length bp (m)	B (m)	T (m)	GT	Number of persons
MW	Large cruise	294.6	40.8	8.75	153400	6730
Fincantieri	Small cruise	113.7	20.0	5.30	11800	478
Meyer Turku	Baltic RoPax	232.0	29.0	7.20	60000	3280
STX-France	Med RoPax	172.4	31.0	6.60	43000	1700
KEH	Small RoPax	95.5	20.2	4.90	7900	625
KEH	Double ender	96.8	17.6	4.30	6245	610

- Sample ships are suitable examples for state-of-the-art designs
- Basic design level
  - feasible realistic design to meet business model
  - No detailed layout of structure, architectual layout, piping and ducting

Overview EMSA III Sample ships





Attained index for Ropax based on SOLAS2009, impact of S-wod (SLF55) not shown

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Design variations

- For each sample ship design variations (RCOs) have been developed
- Following modifications have been applied in different combinations
  - Change of breadth and freeboard
  - Improvement of watertight subdivision
  - Different hull form
  - Buoyancy boxes on the car deck
  - Subdivided LLH
- For each RCO the change of A and costs have been calculated

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Calculation assumptions

- SOLAS2009 is used as calculation base
  - Assumptions as in Explanatory Notes
  - For RoPax additional new S-wod according SLF55 calculated
  - Draught range based on loading conditions
  - A-class boundaries considered in flooding stages
- Assumptions:
  - The business model is kept constant
    - No significant change of capacity (cargo, cabins)
    - Operational profile kept the same (distance, turn around time)
  - Same methodology to calculate weight and stability
  - Simplified but realistic cost estimations
  - GM limit curve defined based on loading conditions
  - Margins to GM curve are kept constant
- No detailed internal watertight integrity considered
  - Projects are on basic design level
  - No detailed routing of pipes and ducts

Ungraded

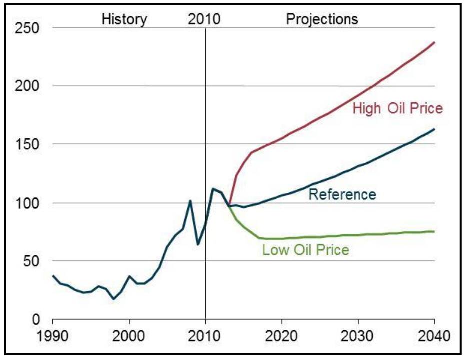
Cost-Benefit Assessment

- Cost Benefit Assessments for sample ships are based on:
  - **Investment Costs**
    - Building costs due to enlarged ship (steel, interior systems)
    - Cost impact due to changed equipment (engines, propulsion, thrusters etc)
    - Financing costs
  - **Operational costs**
    - Mainly fuel costs
    - Increased time in port may cause increased speed → higher fuel costs
    - Increased maintenance costs
  - **Revenue**
    - Small adjustments of income
    - Reduced probability of total loss results in less costs for scrap
- All costs are calculated in Euro and converted in USD based on exchange rate of 1.35 USD/Euro
- Changes of costs to the society or industry in general due to changed probability of large accidents have not been accounted for

Ungraded

Fuel oil price development

- Data published by EIA energy outlook have been used as basis for estimating the future trends.

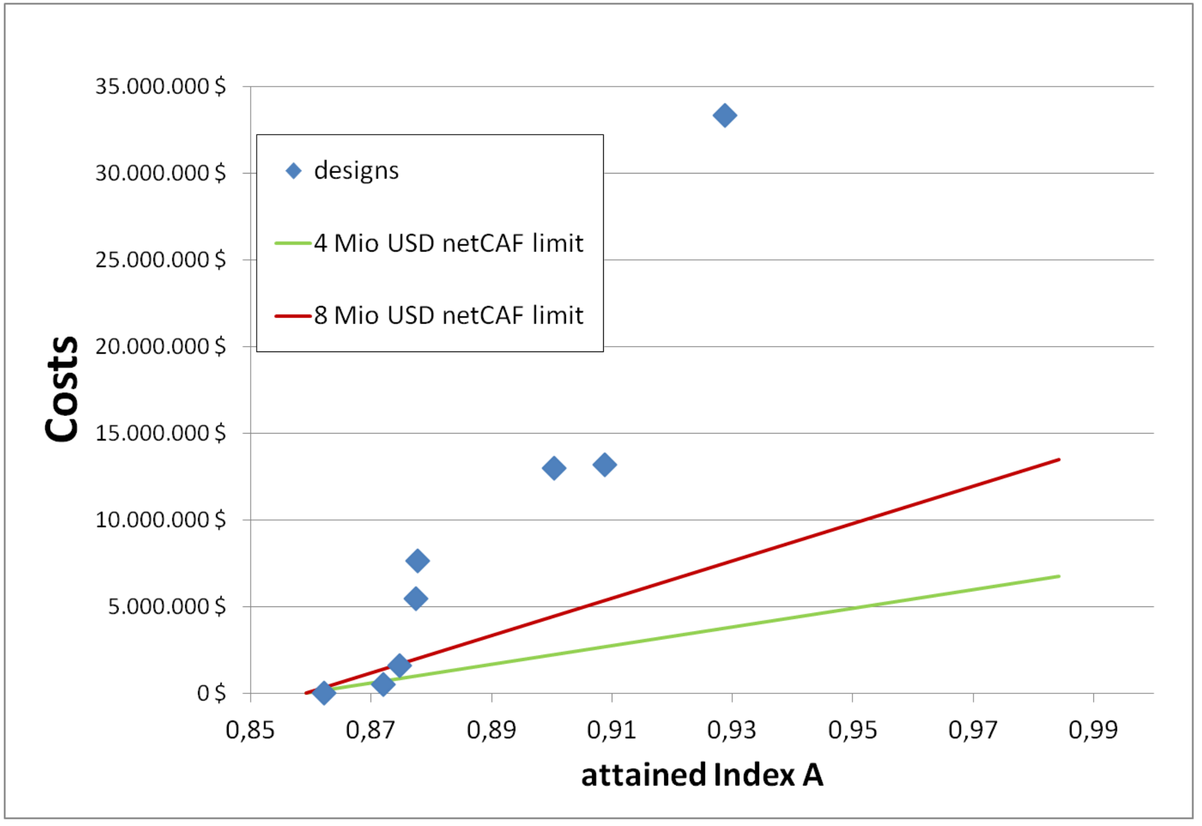


- The current prices for HFO and MGO; 600 USD/t and 900 USD/t, have been obtained using the average reported prices for 2013 and 2014 in Rotterdam using Clarkson Intelligence as a source.
- The price of LSHFO is obtained based on a 20/80 distribution of the HFO and MGO price. This is the distribution that is required in order to obtain a content of 0.5 % sulphur.
- Price of LNG is taken as 94.1% of the MGO cost. This is a standard assumption used in analysis based on the LNG supplier's standard way of pricing where it is referred to that the cost of the LNG should correspond to 80% of the use of MGO.
- The latest reduction of fuel prices (MGO 540 USD/t, HFO 300 USD/t) has not been accounted for.

Ungraded

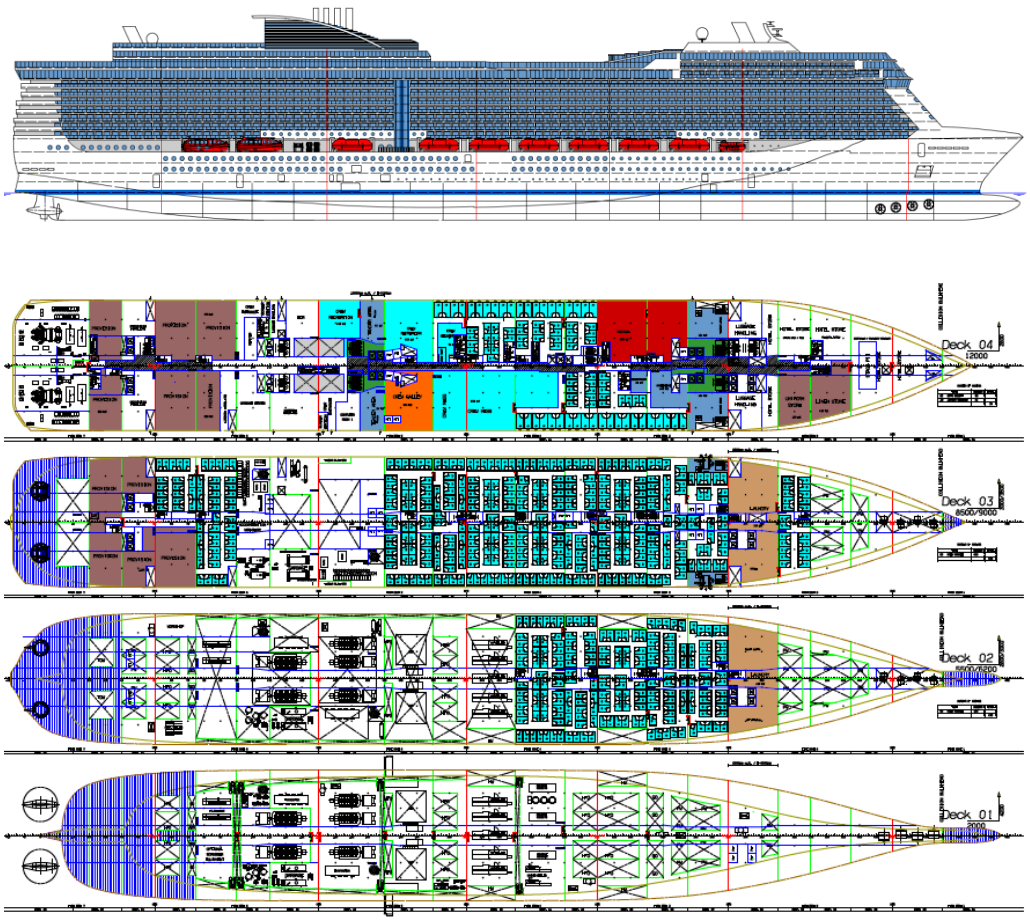
Cost Effectivness

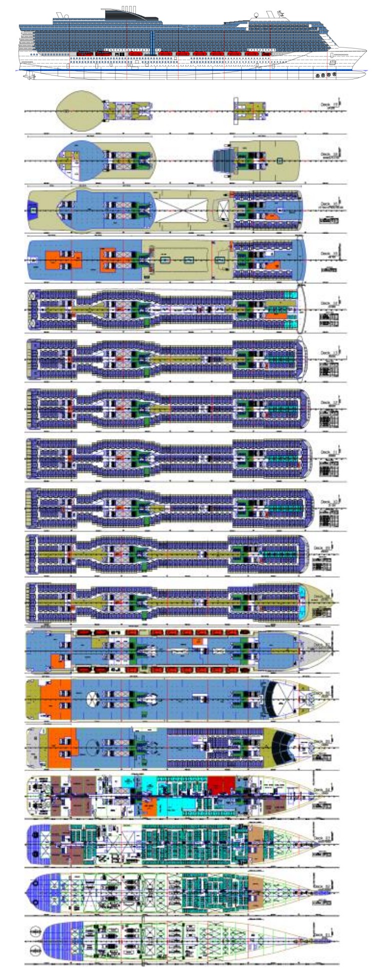
- For each ship the relation between ΔA and Δcosts created using the netCAF limits of 4Mio USD and 8Mio USD.
- This allows a simple check, if an RCO meets the criteria for cost effectiveness



Ungraded

Large cruise vessel – Meyer Werft & Carnival

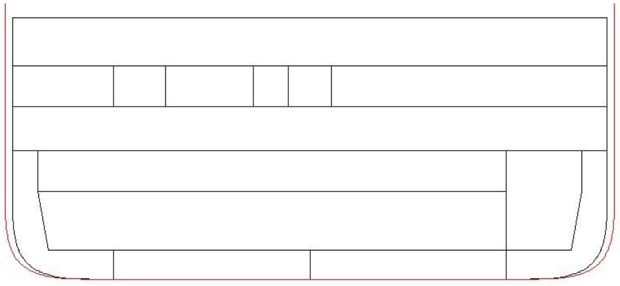


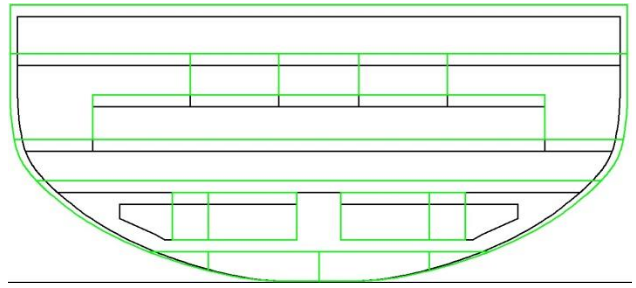


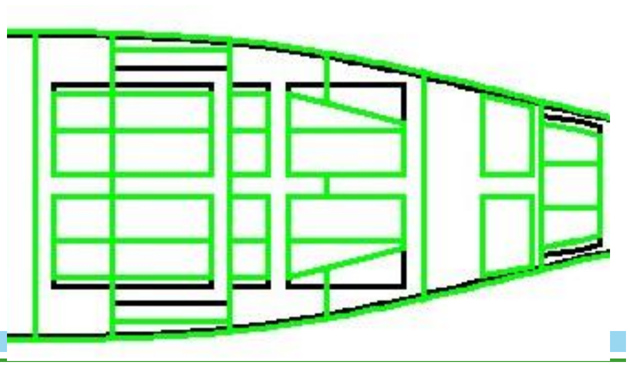
	Length bp (m)	B (m)	T (m)	GT	Number of persons
Ungraded	294.6	40.8	8.75	153400	6730

Large cruise vessel – Meyer Werft & Carnival

- Global changes (beam, freeboard)
- Local changes (internal subdivision)



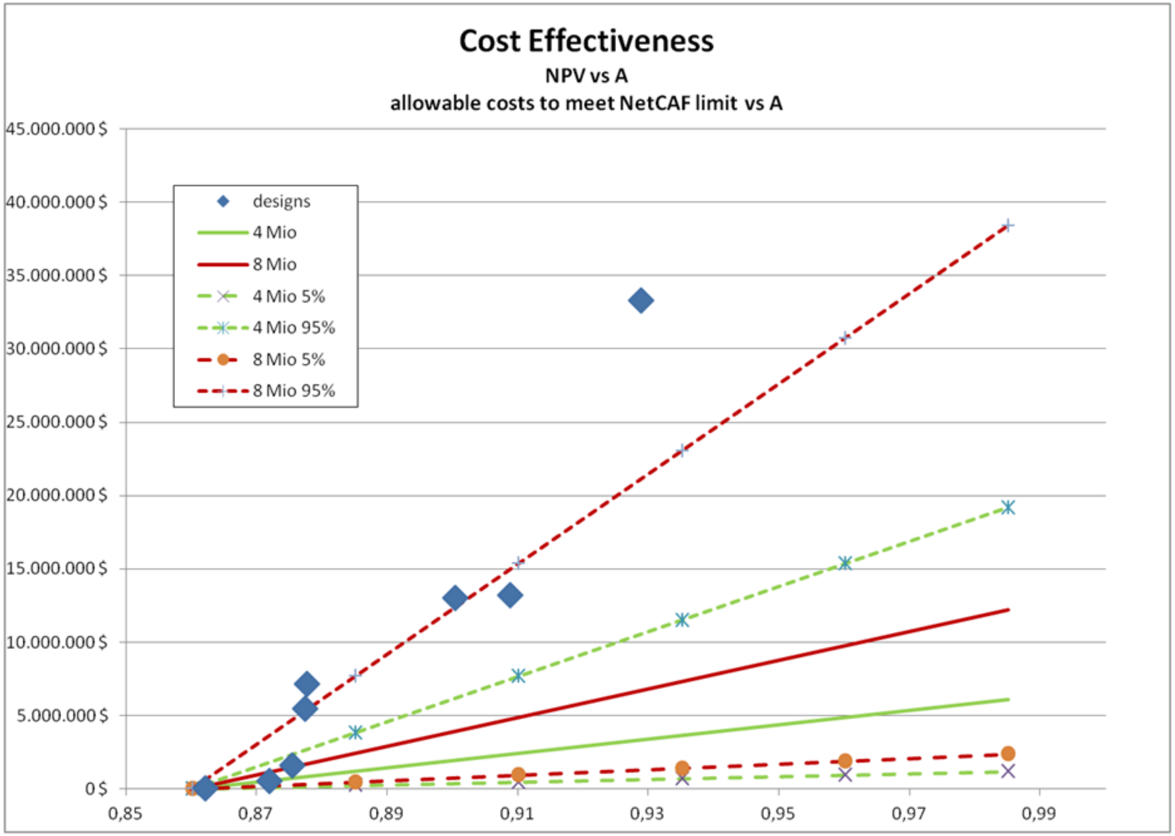




Version	Description
G2	Reference design
H4	Breadth increased by 1.0m
I3	Breadth increased by 1.0m Freeboard increased by 0.8m
J1	Breadth increased by 0.6m Freeboard increased by 0.2m
K1	change internal subdivision
K2	change internal subdivision as K1 part of bulkhead deck watertight
K3	change internal subdivision as K1 Freeboard increased by 0.4m
L1	change internal subdivision as K1 Breadth increased by 0.2m

Ungraded

Large cruise vessel – Meyer Werft & Carnival



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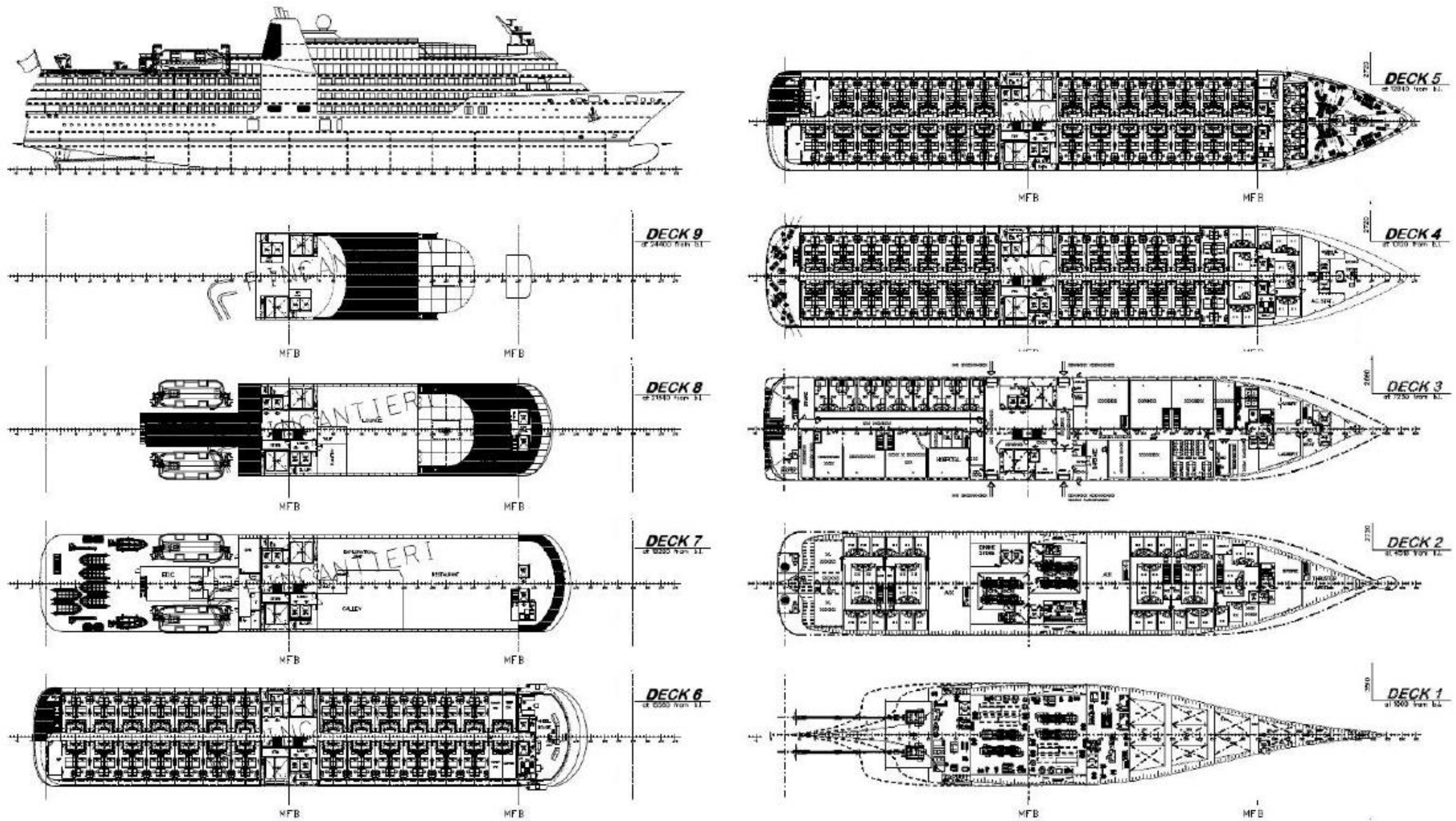
K2	change internal subdivision as K1 part of bulkhead deck watertight
K3	change internal subdivision as K1 Freeboard increased by 0.4m
L1	change internal subdivision as K1 Breadth increased by 0.2m

Version	G2	H4	I3	J1	K1	K2	K3	L1
required index R	0.8597	0.8597	0.8597	0.8597	0.8597	0.8597	0.8597	0.8597
attained index A	0.8621	0.9087	0.9288	0.9004	0.8719	0.8777	0.8754	0.8774
Change in A	0.0000	0.0466	0.0667	0.0383	0.0098	0.0156	0.0133	0.0153

Ungraded

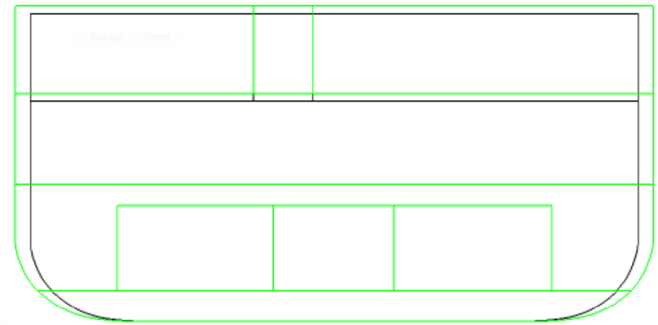
Small Cruise – Fincantieri & RCCL

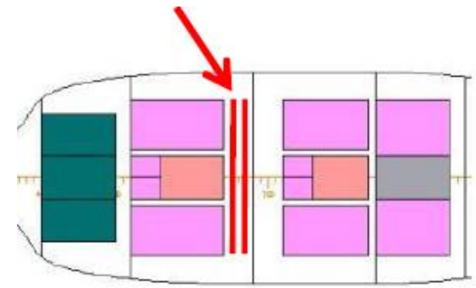


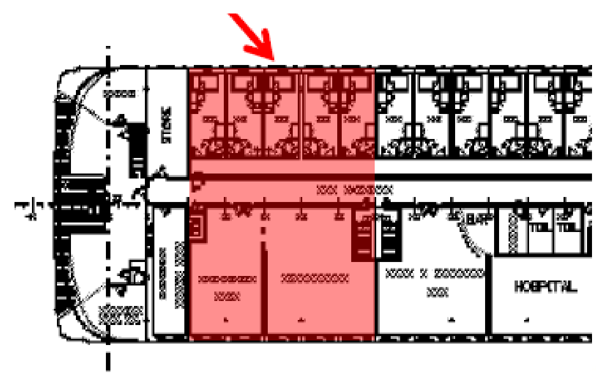
	Length bp (m)	B (m)	T (m)	GT	Number of persons
Ungraded	**113.7**	**20.0**	**5.30**	**11800**	**478**

Small Cruise – Fincantieri & RCCL

- Global changes (beam, freeboard)
- Local changes (internal subdivision, watertight decks)



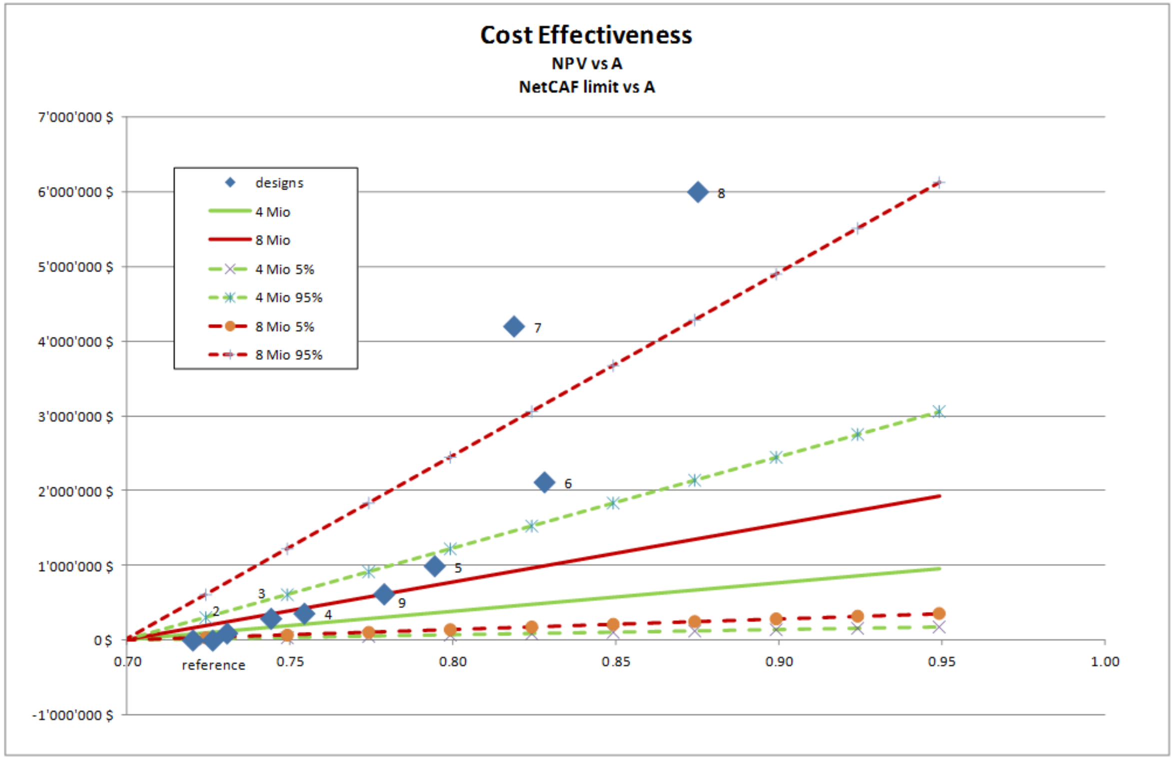




Version	Description
00	Reference design
01	Sill increased on external weathertight aft doors
02	Vs.01 + Deck 3 made wathertight for comp n.2 and n.3
03	Vs.02 + Cross flooding section within DB void spaces improved adding pipes
04	Vs.03 + Two weathertight door added and a watertight door added on BK deck
05	Vs.04 + Increased Beam by 0.2m (new B=20.2m)
06	Vs.04 + Increased Beam by 0.5m (new B=20.5m)
07	Vs.06 + Increased freeboard by 0.25m
08	Vs.07 + Increased Beam by 0.5m (new B=21m)
09	Vs.04 + Increased Beam by 0.1m (new B=20.1m)

Ungraded

Small Cruise – Fincantieri & RCCL



Version	Description
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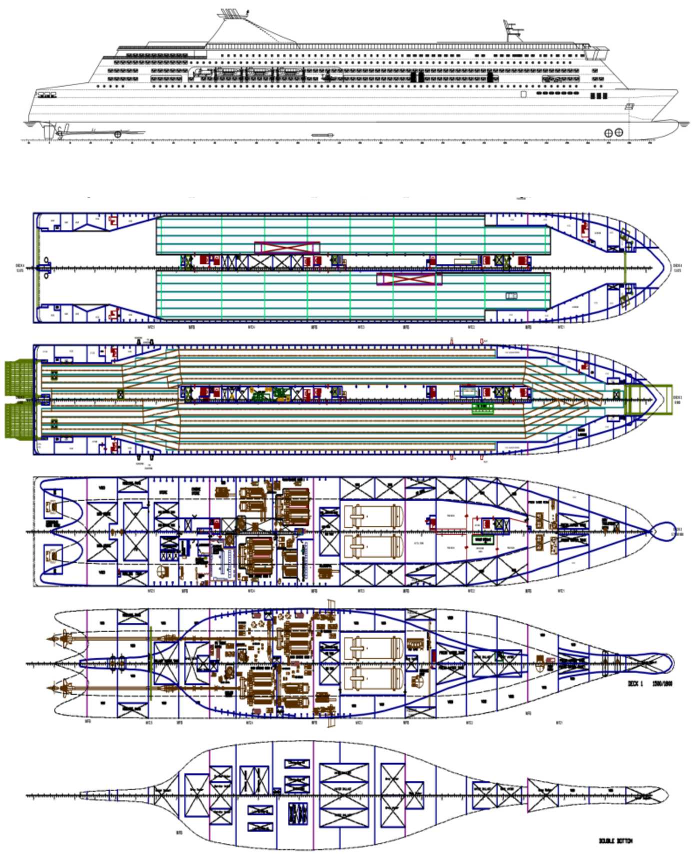
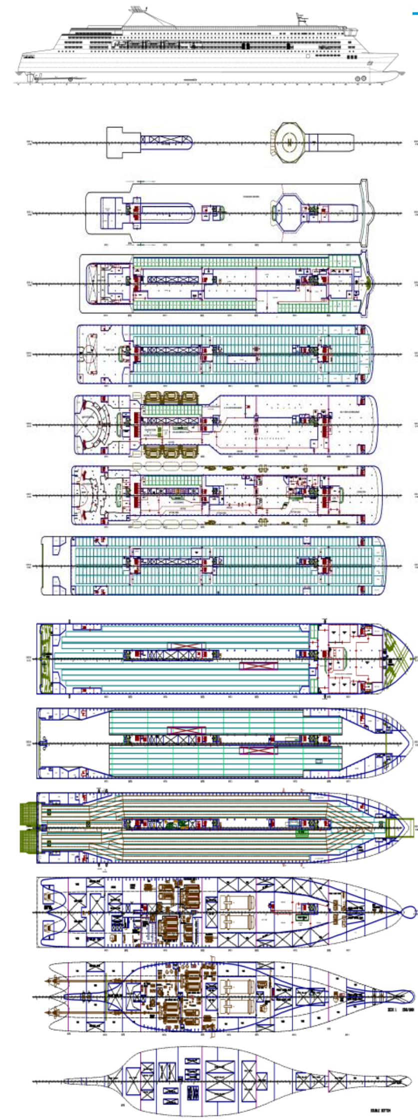
07	Vs.06 + Increased freeboard by 0.25m
08	Vs.07 + Increased Beam by 0.5m (new B=21m)
09	Vs.04 + Increased Beam by 0.1m (new B=20.1m)

Version	Ref.	01	02	03	04	05	06	07	08	09
required index R	0.6978	0.6978	0.6978	0.6978	0.6978	0.6978	0.6978	0.6978	0.6978	0.6978
attained index A	0.7202	0.7263	0.7307	0.7442	0.7544	0.7944	0.8281	0.8187	0.8752	0.7789
Change in A	0.0000	0.0061	0.0105	0.0240	0.0342	0.0742	0.1079	0.0985	0.1550	0.0587

Ungraded

Baltic RoPax – Meyer Turku & Color Line





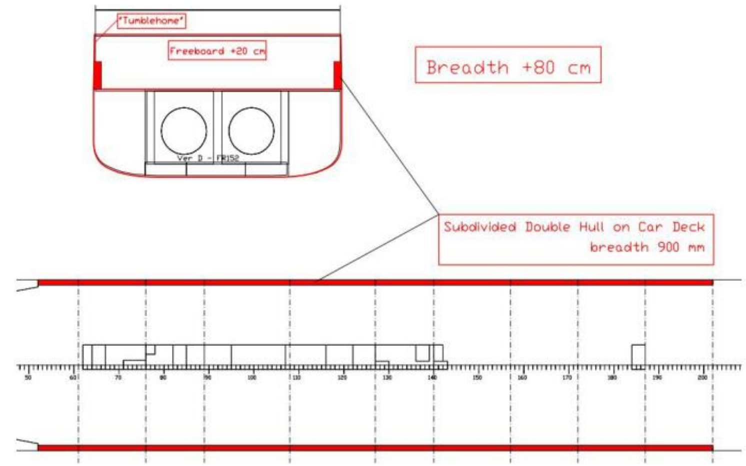
Ungraded

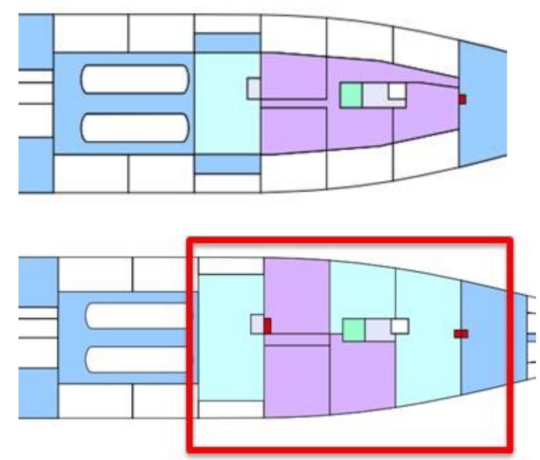
Length bp (m)	B (m)	T (m)	GT	Number of persons
232.0	29.0	7.20	60000	3280

Baltic RoPax – Meyer Turku & Color Line

- Global changes (beam, new hullform subdivided double hull on bulkhead deck)
- Effect of LLH

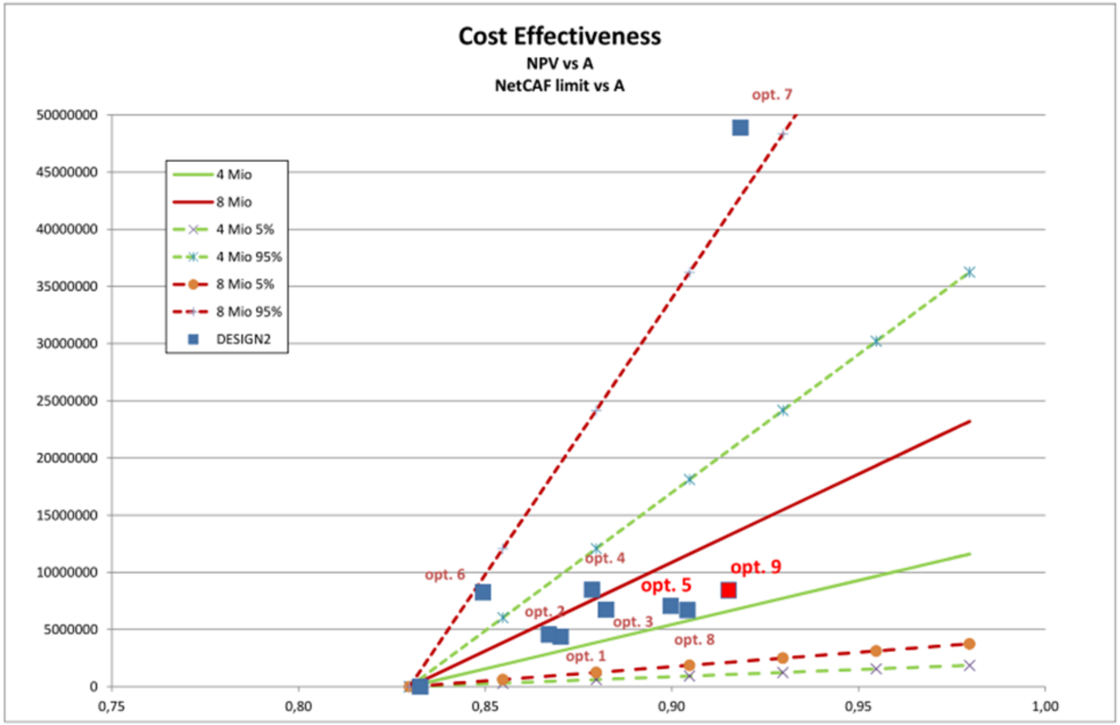
Phase	Version	Description
	A	Reference design
Phase 1	B (Option 1)	Breadth increased by 40 cm
Phase 1	C (Option 2)	Breadth increased by 20 cm Freeboard increased by 20 cm
Phase 1	D (Option 3)	Breadth increased by 40 cm Freeboard increased by 20 cm
Phase 1	E (Option 4)	Breadth increased by 40 cm Freeboard increased by 40 cm
Phase 2	F (Option 5)	As version D (opt. 3) subdivided double hull on bulkhead deck
Phase 3	I (Option 6)	As version F (opt. 5) impact of LLH
Phase 3	J (Option 7)	As version F (opt. 5) Subdivided Car Deck
Phase 3	K2 (Option 8)	As version F (opt. 5) No Lower Hold
Phase 4	L (Option 9)	As version F (opt. 5) + 40 cm more breadth = Breadth increased by 80 cm Freeboard increased by 20 cm subdivided double hull on bulkhead deck





Ungraded

Baltic RoPax – Meyer Turku & Color Line



Phase	Version	Description
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Phase 1	E (Option 4)	Breadth increased by 40 cm Freeboard increased by 40 cm
Phase 2	F (Option 5)	As version D (opt. 3) subdivided double hull on bulkhead deck
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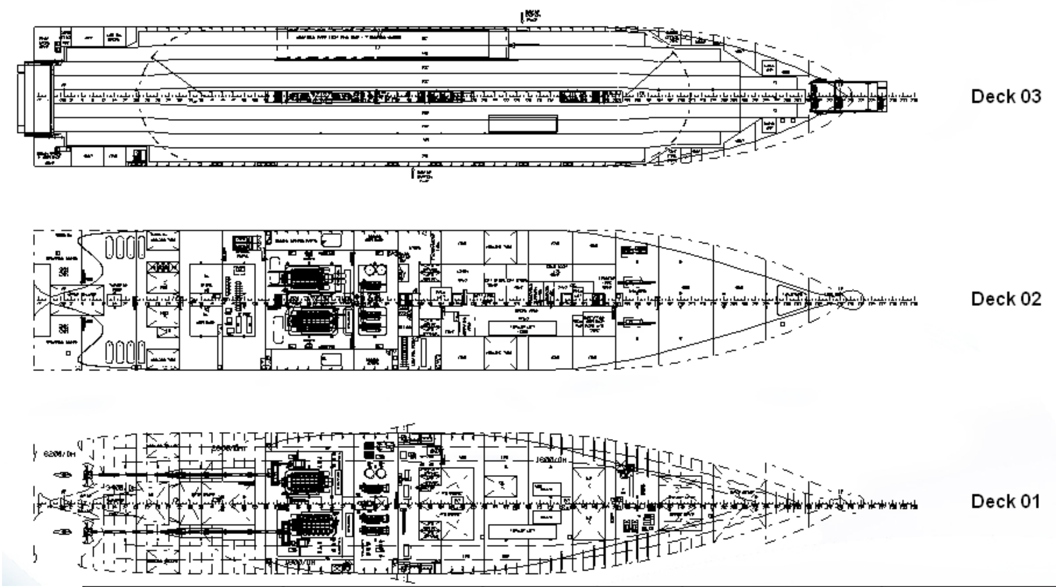
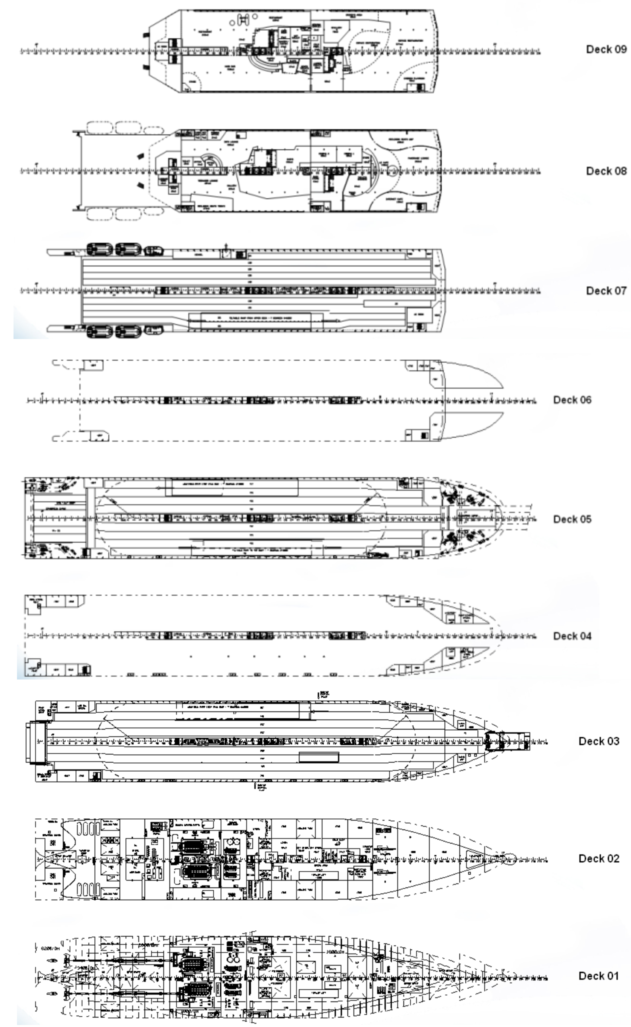
Phase 3	J (Option 7)	As version F (opt. 5) Subdivided Car Deck
Phase 3	K2 (Option 8)	As version F (opt. 5) No Lower Hold
Phase 4	L (Option 9)	As version F (opt. 5) + 40 cm more breadth = Breadth increased by 80 cm Freeboard increased by 20 cm subdivided double hull on bulkhead deck

Version	A	B opt 1	C opt 2	D opt 3	E opt 4	F opt 5	I opt 6	J opt 7	K2 opt 8	L opt 9
required index R	0.8300	0.8300	0.8300	0.8300	0.8300	0.8300	0.8300	0.8300	0.8300	0.8300
attained index A_{SLF55}	0.8326	0.8703	0.8670	0.8824	0.8786	**0.8997**	0.8494	0,.184	0.9042	**0.9152**
Change in A	0.0000	0.0377	0.0344	0.0498	0.0460	**0.0671**	0.0168	0.0858	0.0716	**0.0826**

Ungraded

Mediterranean Ropax – STX-France & Stena Line/Color Line

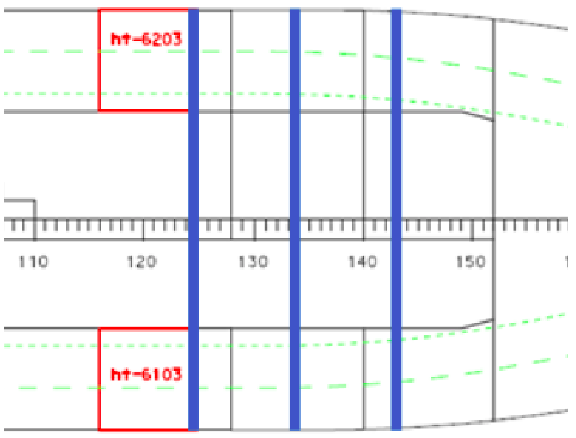




	Length bp (m)	B (m)	T (m)	GT	Number of persons
Ungraded	**172.4**	**31.0**	**6.60**	**43000**	**1700**

Mediterranean Ropax – STX-France & Stena Line/Color Line

- Internal subdivion
- Subdivided car deck
- Effect of LLH

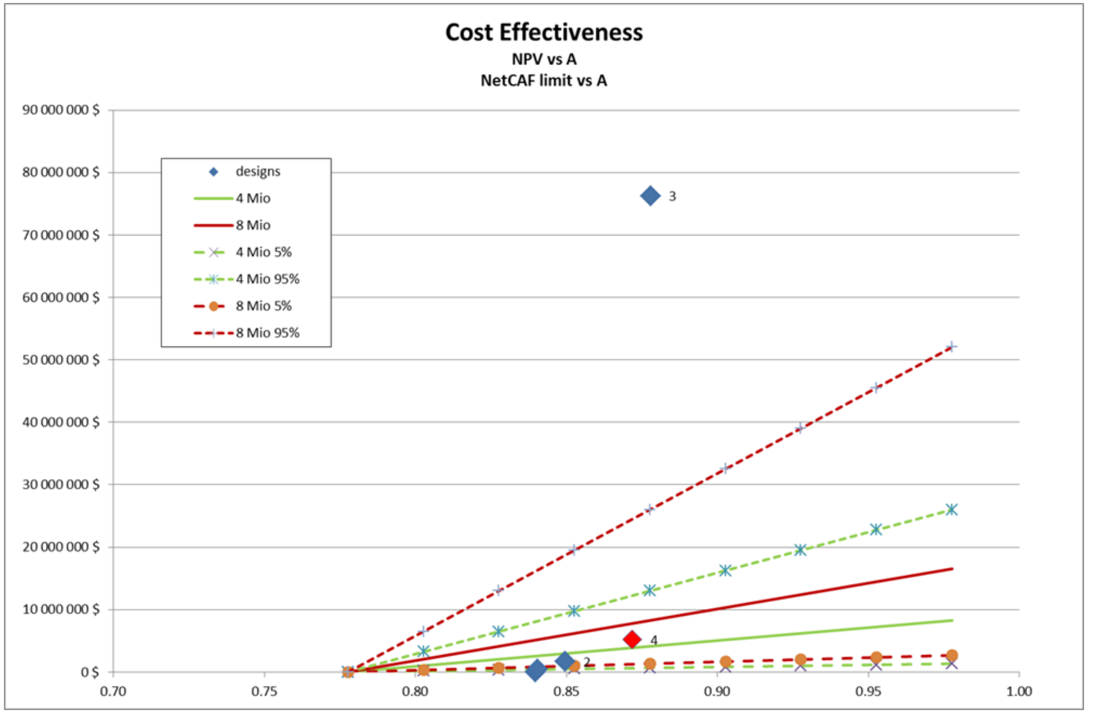


Version	Description
Initial design	
V0	New S Ropax (SLF55 formulation)
V1	Depth + 10cm
V12	Additional WT bulkheads below bulkhead deck
V21	Additional WT subdivisions above bulkhead deck
V13	Side casing based on V12*
V14	Increase in breadth + 20cm based on V12

*studied but not found to contribute significantly to raise A

Ungraded

Mediterranean Ropax – STX-France & Stena Line/Color Line



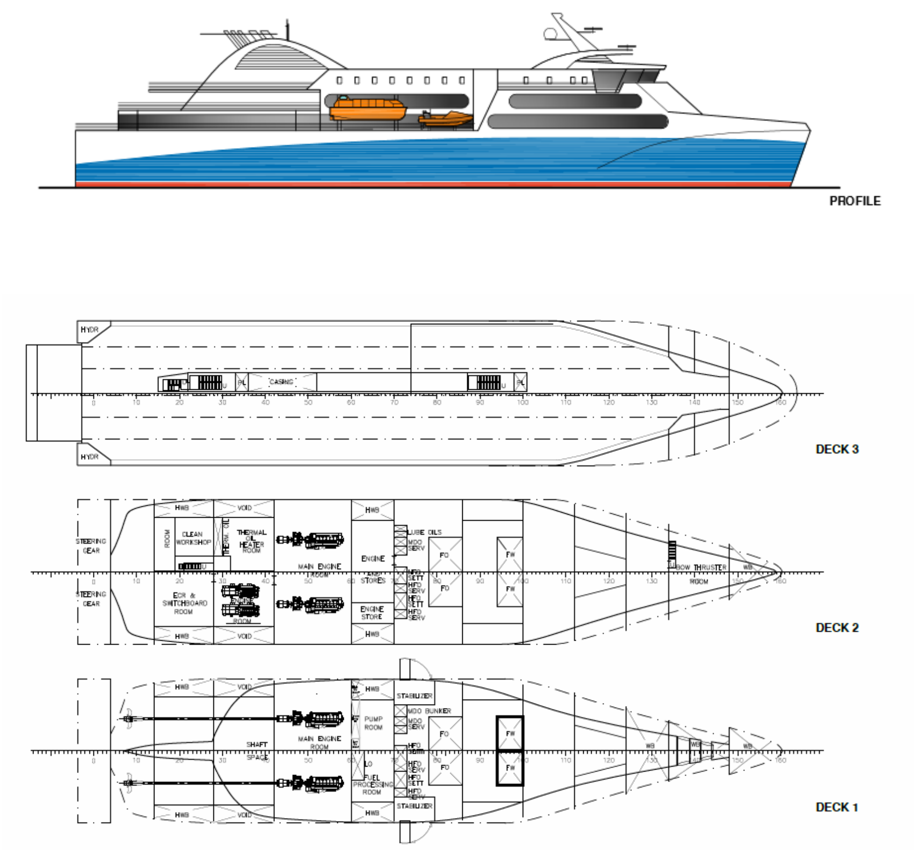
Version	Description
Initial design	
V0	New S Ropax (SLF55 formulation)
V1	Depth + 10cm
V12	Additional WT bulkheads below bulkhead deck
V21	Additional WT subdivisions above bulkhead deck
V13	Side casing based on V12*
V14	Increase in breadth + 20cm based on V12

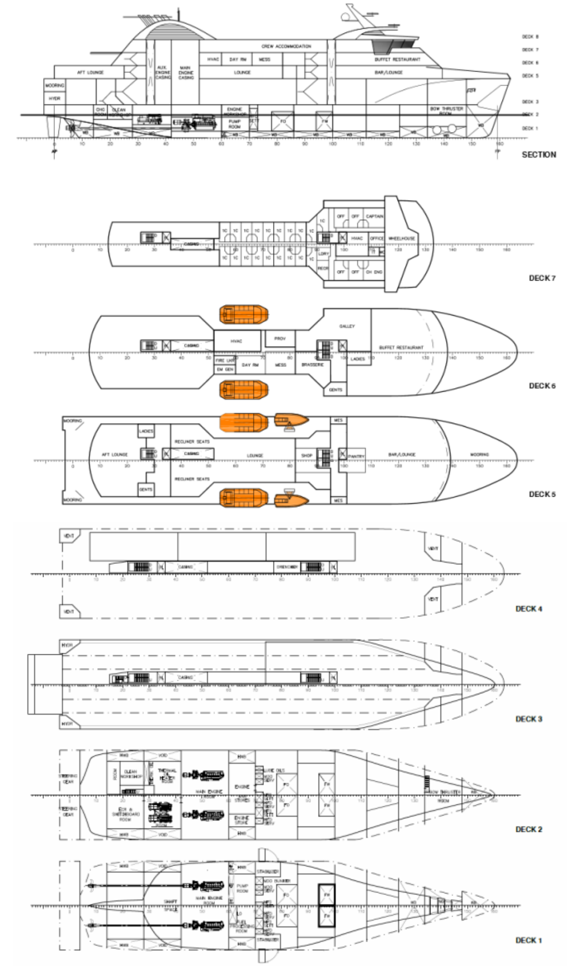
*studied but not found to contribute significantly to raise A

Version	reference design	1 design step	2nd design step	3rd design step	4th design step
Description		V1 - depth +10	V12 - Add bkds below BHD	V21 - Add bkds on car deck	V14 - Breadth increased
Required index R	0.7777	0.7777	0.7777	0.7777	0.7777
Attained index A	0.8398	0.8404	0.8496	0.8778	0.8718
Change in A	0.0000	0.0005	0.0097	0.0380	0.0319

Ungraded

Small RoPax – KEH & Stena Line





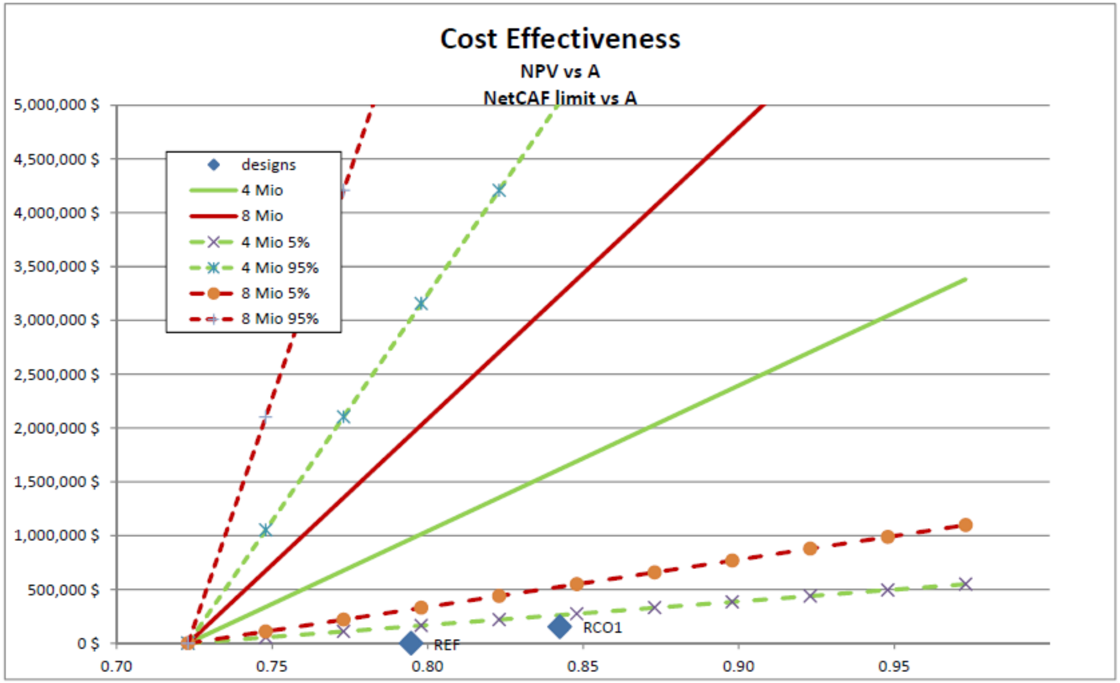
	Length bp (m)	B (m)	T (m)	GT	Number of persons
Ungraded	95.5	20.2	4.90	7900	625

Small RoPax – KEH & Stena Line

- Change of freeboard

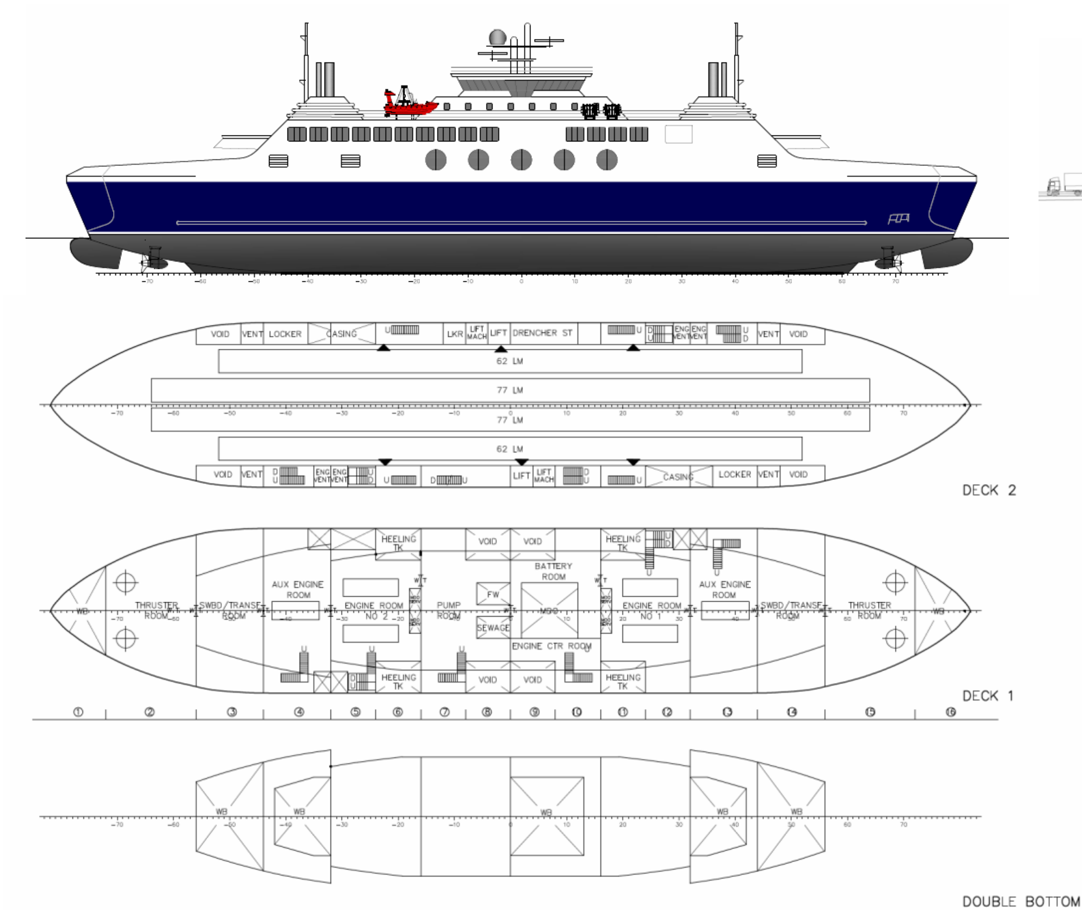
Version	Initial	RCO 1
Required index R	0.7214	0.7214
Attained index A	0.7947	0.8426
change A	0.0000	0.0479

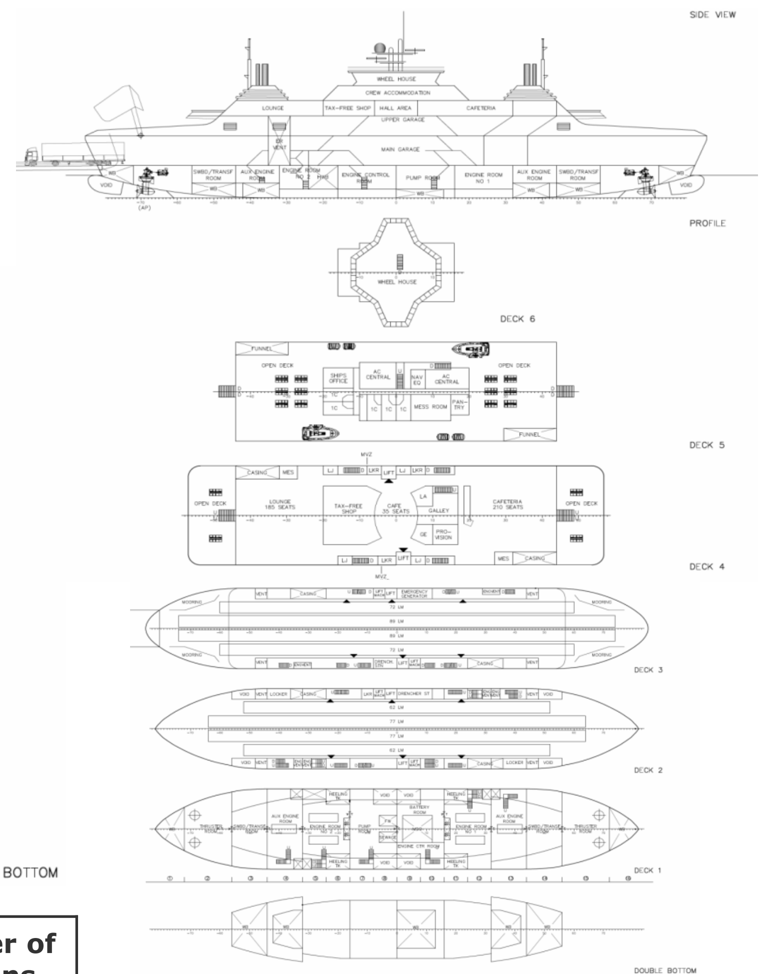
Version	Description
Initial design	
RCO1	Raise main deck + 30 cm



Ungraded

Double ender ferry – KEH & Stena Line





	Length bp (m)	B (m)	T (m)	GT	Number of persons
Ungraded	**96.8**	**17.6**	**4.30**	**6245**	**610**

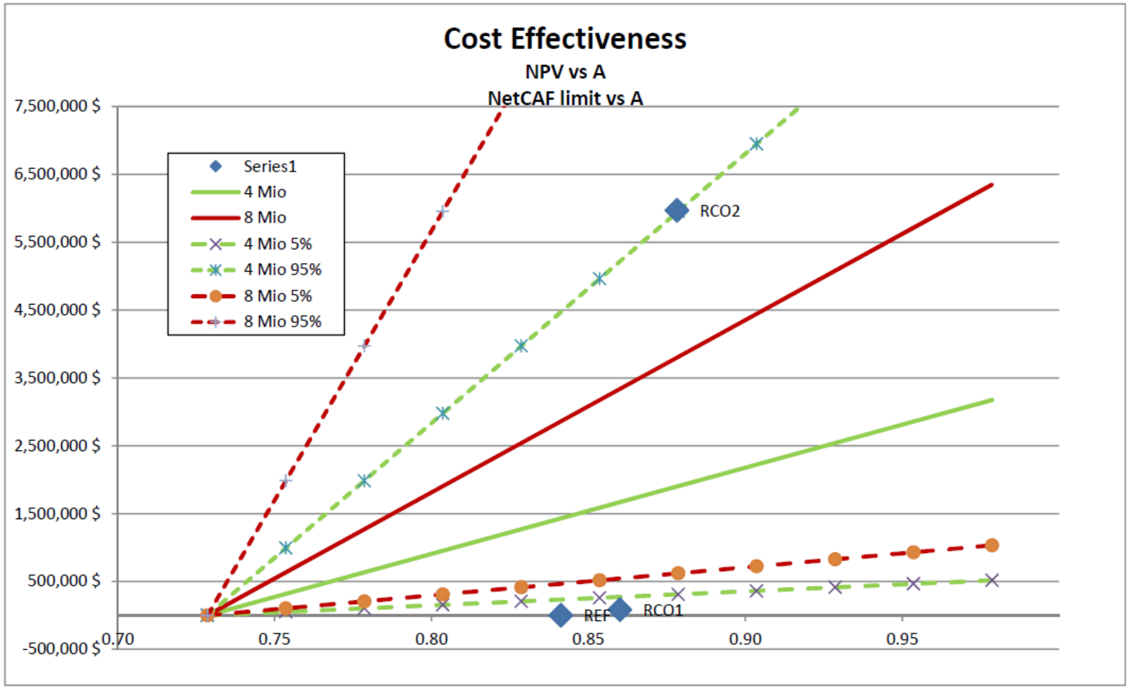
DNV·GL

Double ender ferry – KEH & Stena Line

- Change of freeboard

Version	Initial	RCO 1	RCO 2
Required index R	0.7279	0.7279	0.7279
Attained index A	0.8412	0.8601	0.8782
change A	0.0000	0.0189	0.037

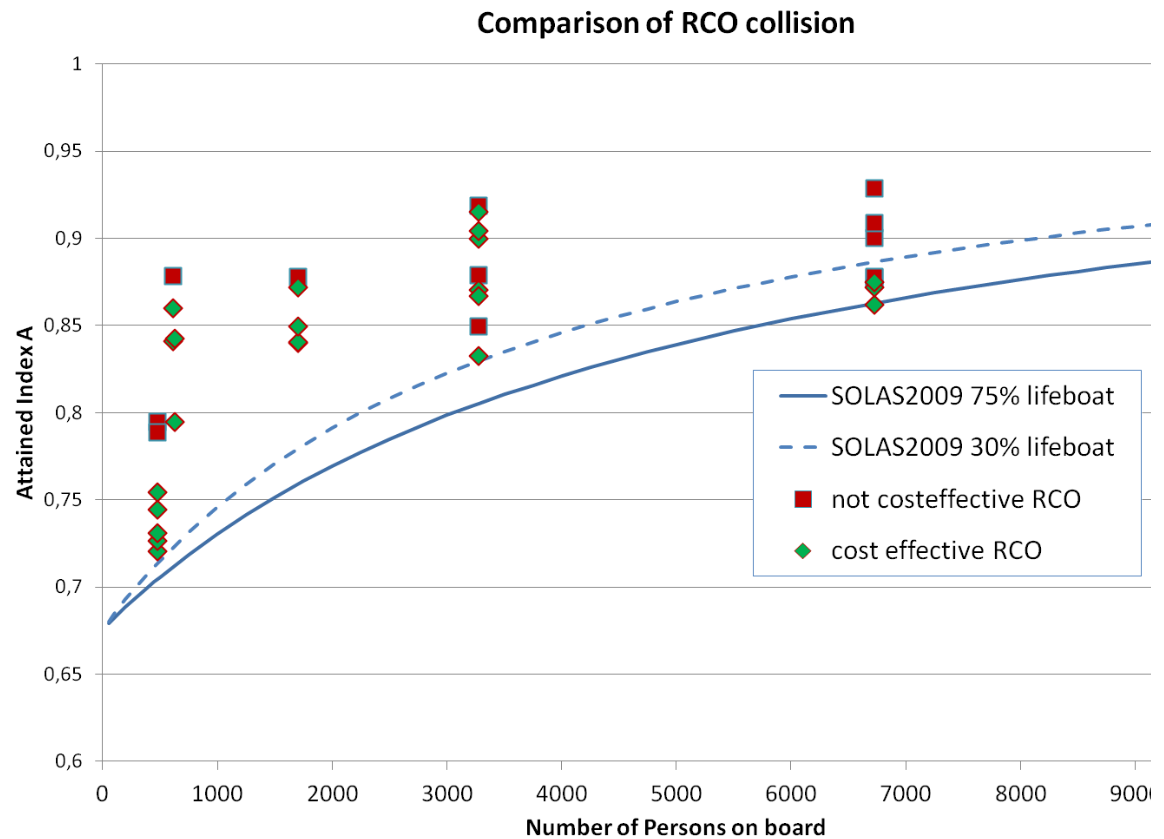
Version	Description
Initial design	
RCO1	Raise main deck + 30 cm
RCO2	Increase Beam +40 cm



Ungraded

Summary RCOs collision

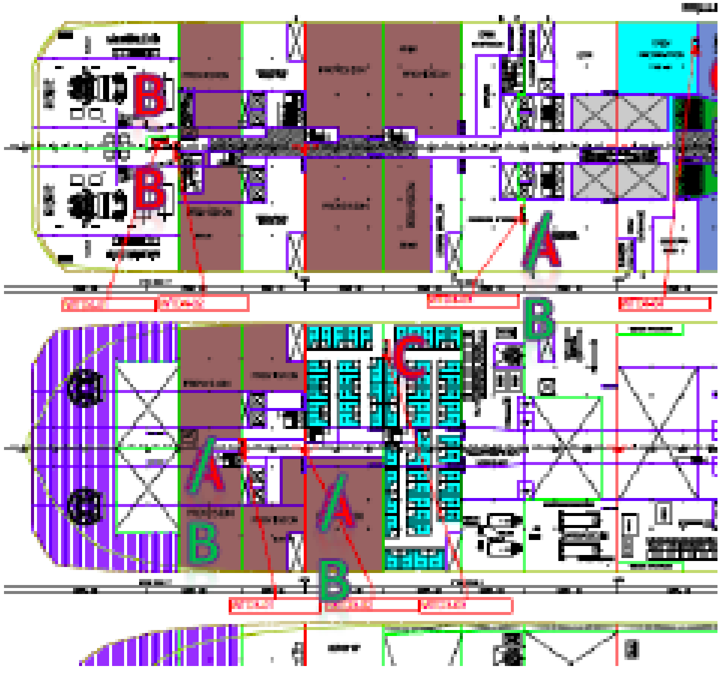
- High attained index possible
- For RoPax higher cost-effective RCOs can be found
- Large difference between RoPax and cruise



Ungraded

Watertight doors
Methodology

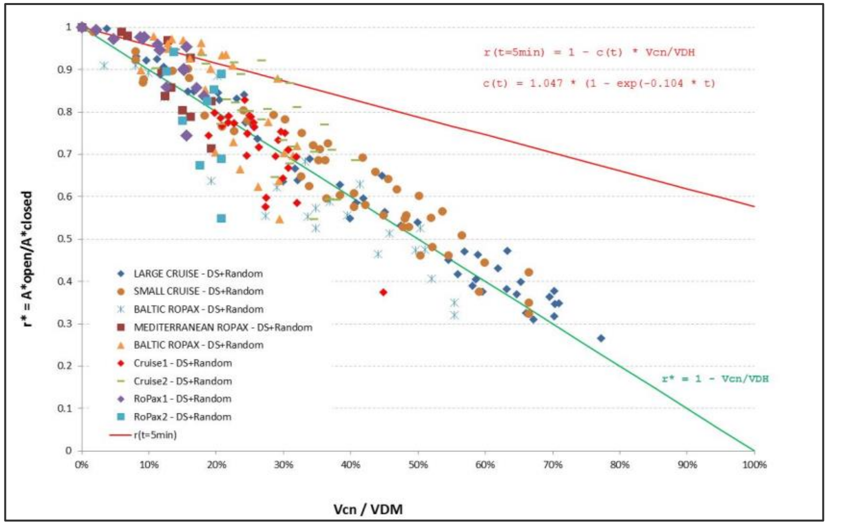
- Impact of open WTD calculated based on simplified collision attained index
  - Single door open
  - Multiple doors open, randomly selected
- Some RCO investigated
  - Category doors changed
  - Doors removed and replaced by additional stair cases
- Removal of doors sometime not cost effective
- Large variation of results between sample ships
- Taking into account the normal operation of WTD (normally closed, closing time 1 min.) there is no significant effect on attained index



Ungraded

DNV·GL

Watertight doors
Summary

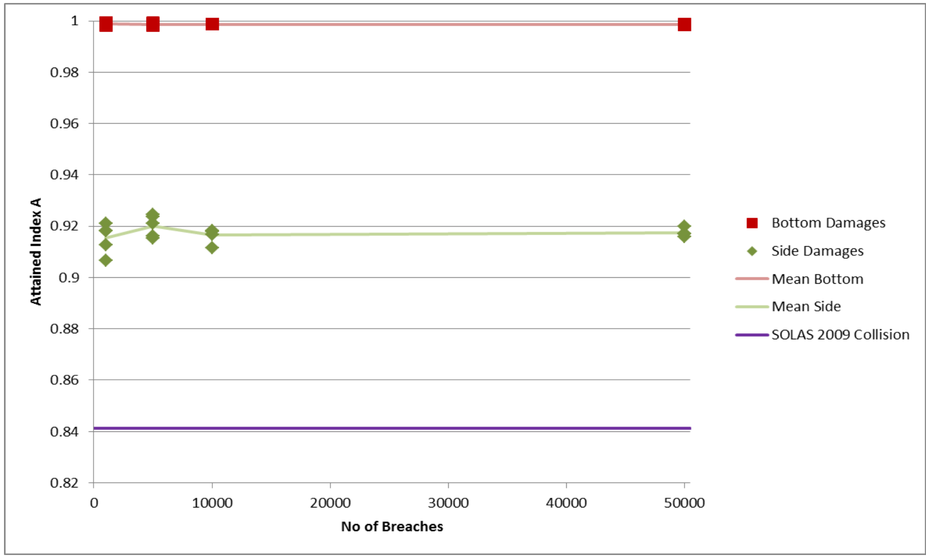


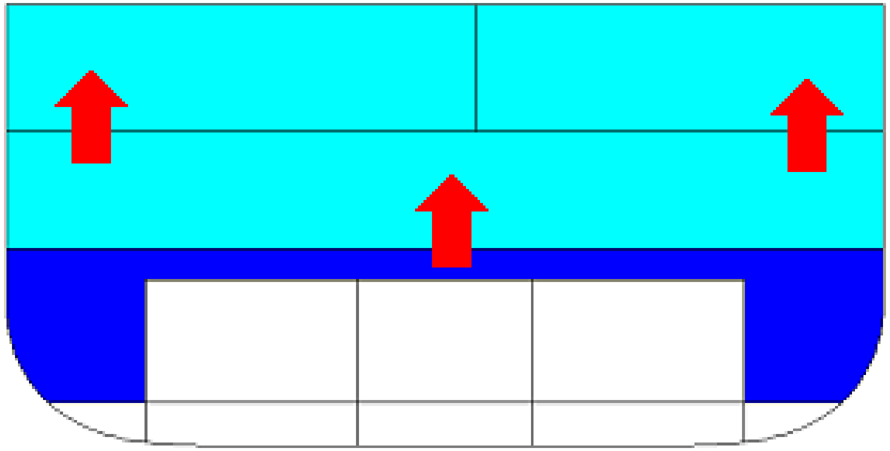
- Relation between connected volume and loss of index offers a great opportunity to increase awareness on board
  - Impact on safety level visible
  - Easy method, no damage stability calculation needed
  - May be used on board existing ships
- Designs without the need to operate WTD are possible for large ships
  - More restrictions for smaller ships
  - Difficult for ropax, as the WTD are needed to access spaces along the ship
- SDC2 decision to remove type A doors resolves much of the design problem

Ungraded

GROUNDING
Methodology

- Direct approach used
  - Bottom and side groundings
  - 5 repititions with 10000 breaches each
  - Good approximation of A
- Internal watertight integrity not fully considered
- Explicit RCOs investigated for large cruise and mediterranean ropax only
- For remaining sample ships only recalculation of reference version and one collision RCO.



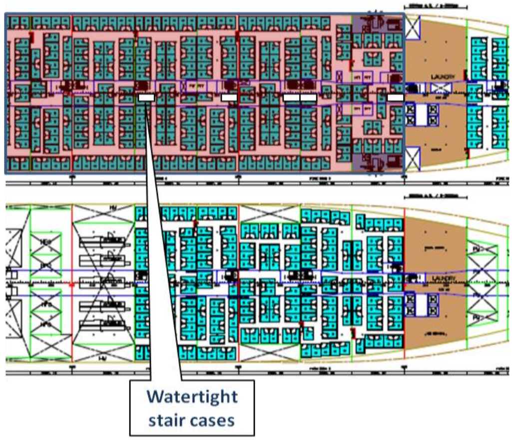


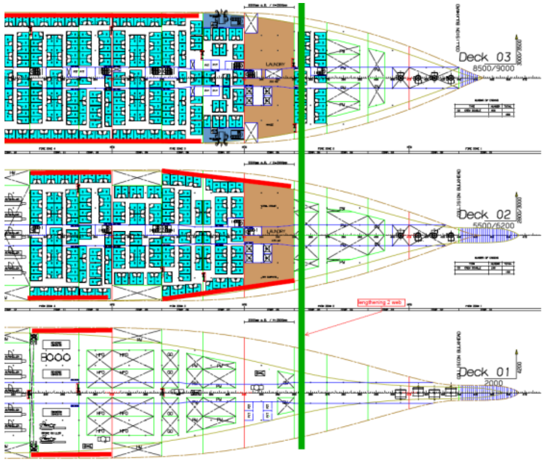
Ungraded

GROUNDING
Large cruise vessel – Meyer Werft & Carnival

- Global changes (beam, freeboard)
- Local changes (double hull, WT decks)

Version	Description
G2	Reference design
G3	as G2 with deck 3 made watertight as far as possible
K3	Selected optimized version for collision change internal subdivision as K1 Freeboard increased by 0.4m
K4	as K3 with deck 3 made watertight as far as possible
M1	double hull increased DB height lengthened by 1 web frame
M2	as M1 with deck 3 made watertight as far as possible
I3	Breadth increased by 1.0m Freeboard increased by 0.8m

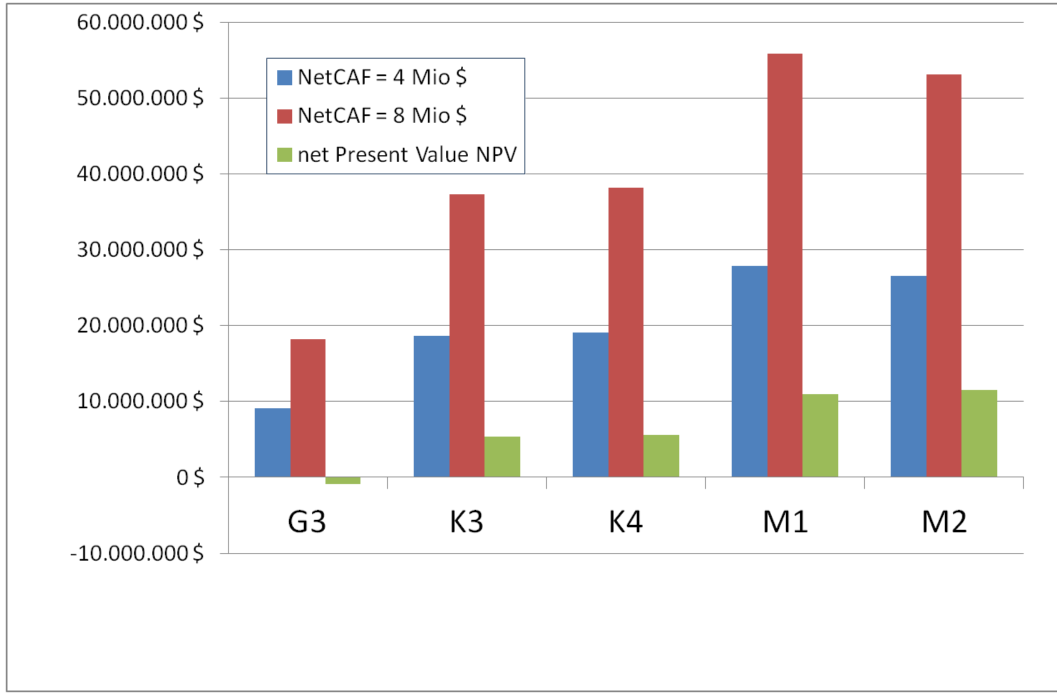




Ungraded

GROUNDING
Large cruise vessel – Meyer Werft & Carnival

- All grounding RCOs are cost effective
- some RCO do not comply with SOLAS2009 anymore



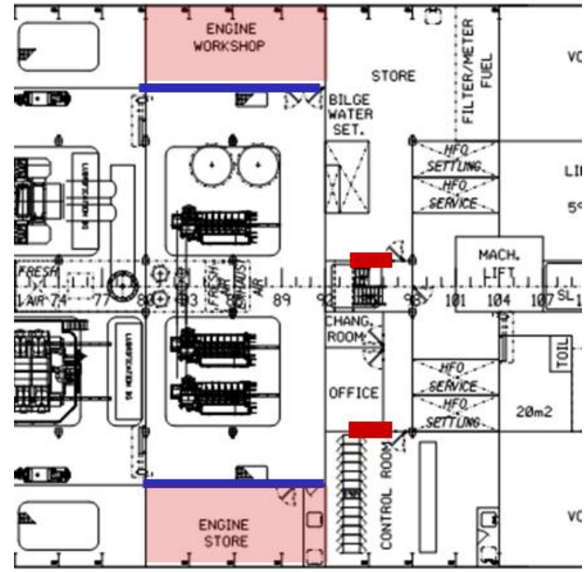
Version	G2	G3	K3	K4	M1	M2	I3
Description	reference version	as G2 with wt decks	opt. Version for collision	as K3 with wt decks	double hull increased DB height	as M1 with wt decks	Increased beam, increased freeboard
SOLAS2009	0.8626	0.8643	0.8754	0.8792	0.8529	0.8747	0.9288
A Grounding	0.9142	0.9336	0.9543	0.9551	0.9736	0.9707	0.9513

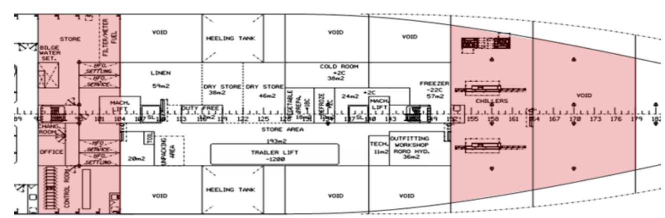
Ungraded

GROUNDING
Mediterranean RoPax – STX-France & Stena Line/Color Line

- Internal subdivision + beam increased
- WT decks + crossflooding

Version	Description
V0	original design
V14	Optimized for collision: Internal subdivision + Breadth increased
V15	Cross flooding devices + watertightness of longitudinal bulkheads
V16	Additional watertight parts of decks





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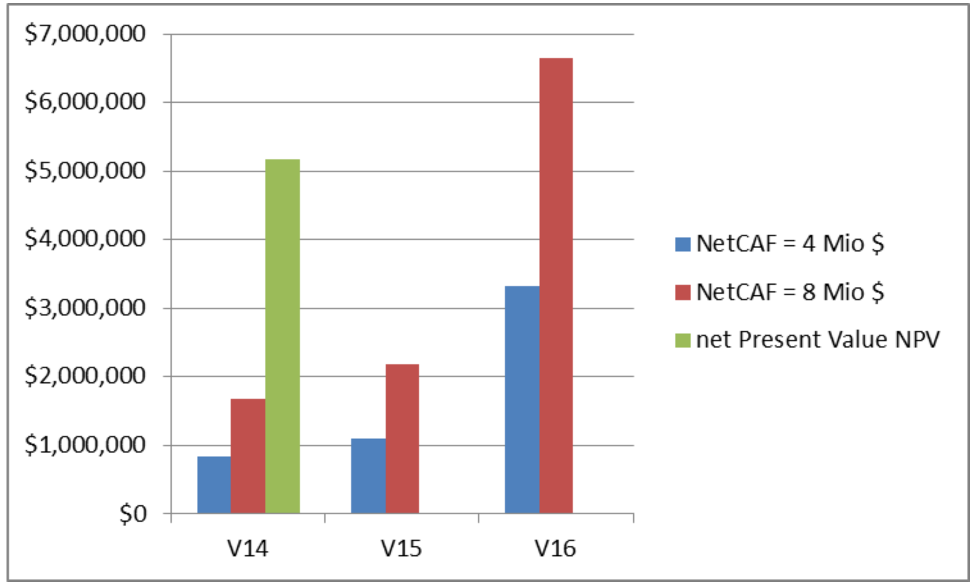
GROUNDING
Mediterranean RoPax – STX-France & Stena Line/Color Line

- Internal changes are cost effective
- Change of main parameters are not cost-effective



Version	V00	V14	V15	V16
	original design	Optimized for collision: Internal subdivision + Breadth increased	Cross flooding devices + watertightness of longitudinal bulkheads	Additional watertight parts of decks
Collision SOLAS2009 +SLF55	0.8398	0.8718	0.8717	0.880855
Mean attained index A grounding A_{GR}	0.954	0.958	0.963	0.973

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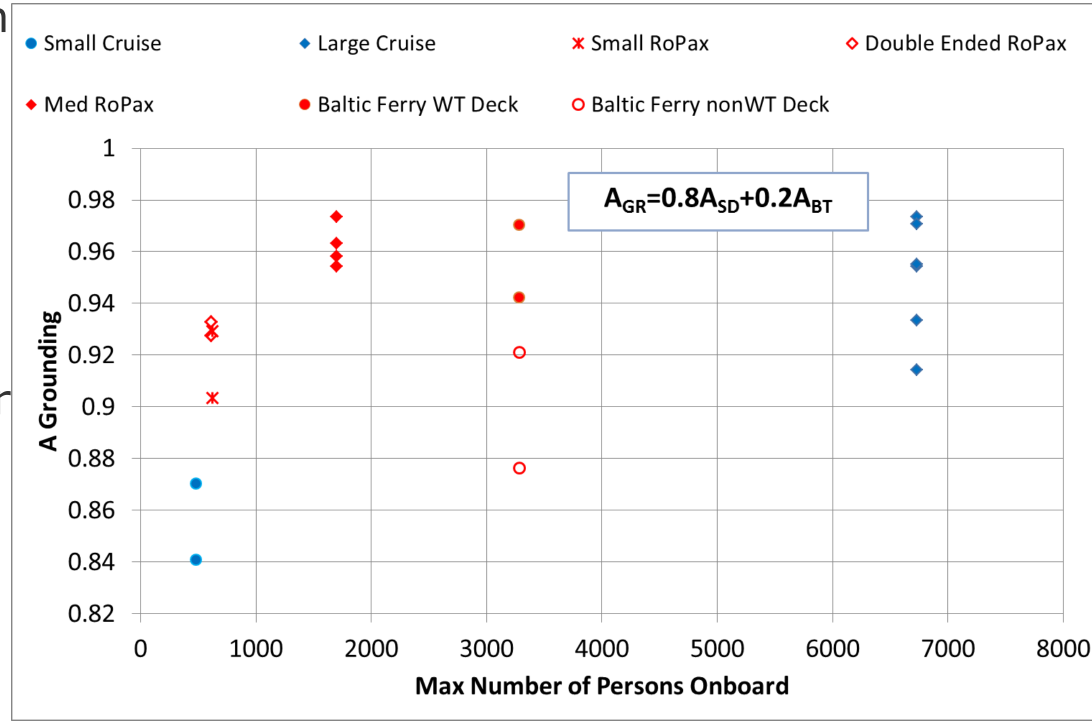
GROUNDING
Summary

- High index for grounding can be attained
- Direct approach is very time consuming but offers great potential to be used also for collision
- Methodology requires further validation and confirmation by IMO
- Some RCOs improve collision and grounding, other RCOs have adverse effects on collision or grounding
- Effect on detailed design and internal watertight integrity to be further analysed



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Sample ships, RCOs and CBA

- Introduction and overview of the EMSA III studies (Odd Olufsen)
- Formal Safety Assessment, Risk Models for collision and grounding (Rainer Hamann)
- Methodologies for assessing risk from watertight doors and risk from grounding (Odd Olufsen)
- Sample ships; design and risk control options (Henning Luhmann)
- Summary of results, recommendations for decision making (Odd Olufsen)

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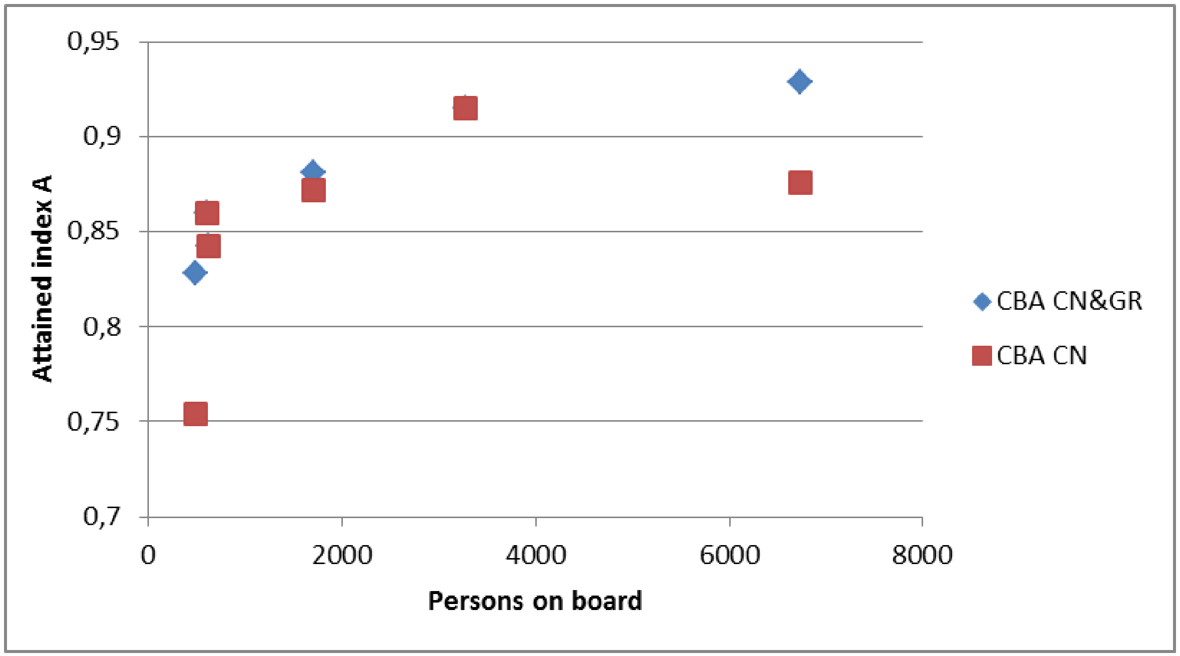
Effects of taking grounding into account in the CBA

Attained Index A (collision) for Risk control Options meeting the CAF criteria with and without including the effect from grounding.



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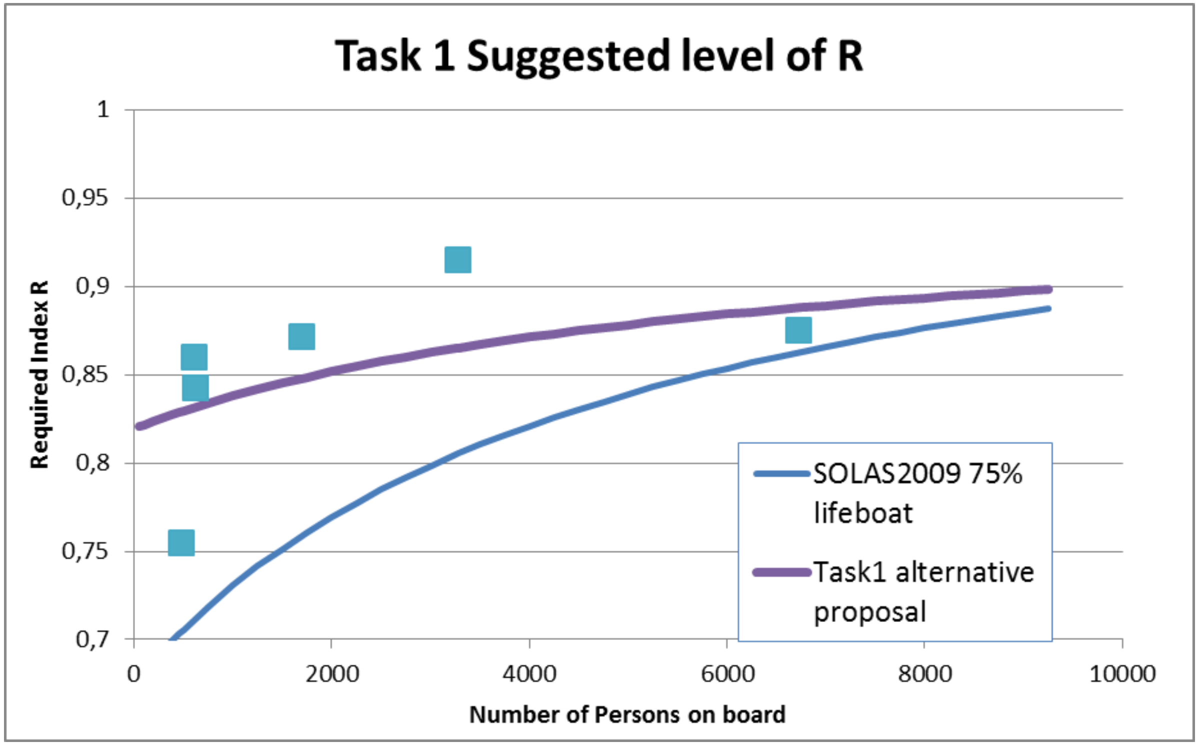
Suggested level of R if considering collision only



$$R = 1 - C1 * \frac{5000}{2,5 * N + 15225}$$

$$C1 = 0.8 - \frac{0.25}{10,000} * (10,000 - N)$$

N is the number of persons onboard without consideration of type of LSA

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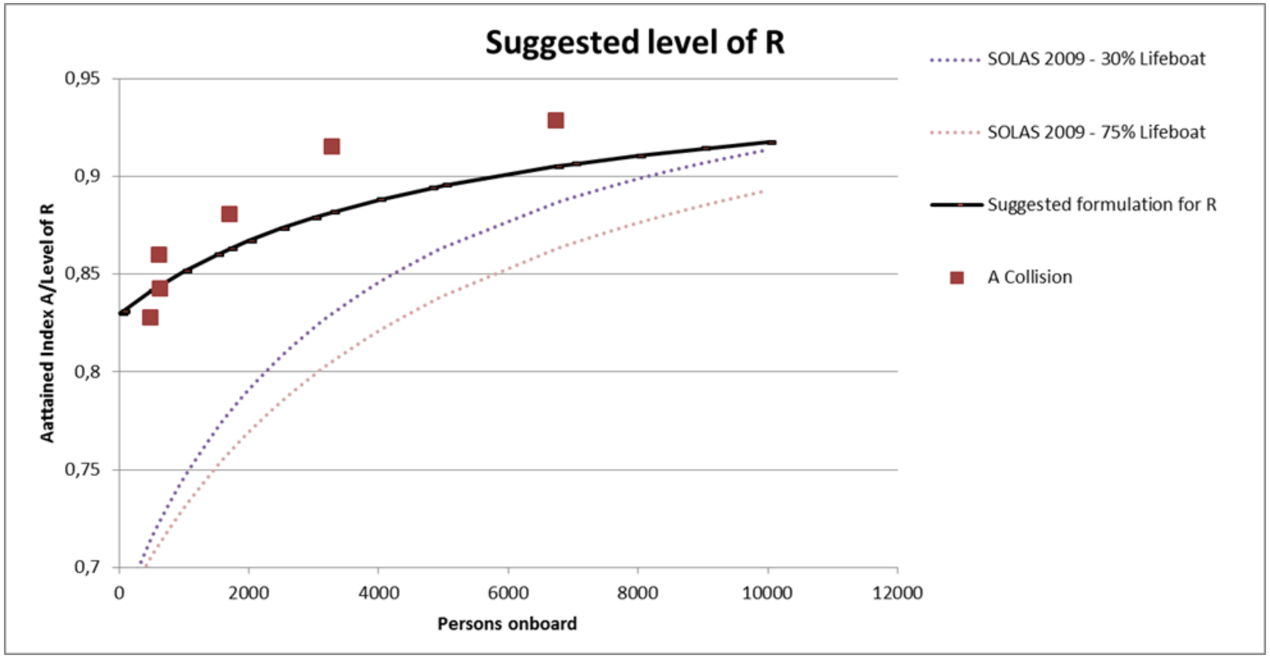
Alternative when grounding is accounted for in the CBA



$$R = 1 - \frac{C1 * 6200}{4 * N + 20000}$$

$$C1 = 0.8 - \frac{0.25}{10000} * (10000 - N)$$

N is the number of persons onboard without consideration of type of LSA

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Conclusions

- The project does not provide any data for RoPax and passenger ships carrying less than 400 persons onboard.
- There is no data available for RoPax having more than 3280 persons onboard.
- The Cost-Effectiveness Analysis performed in the project, supports raising the level of R for collision.
- For cruise ships, a number of RCOs have been investigated on 2 sample ships. When the assessment is based on benefits from collision only, the RCOs found to be cost effective show only limited improvement. Grounding represents a significantly higher risk than collision based on the calculations carried out in the project. There is a clear trend that RCOs improving the attained index A for collision would also improve the attained index A for grounding. When grounding is included in the risk assessment the CAF values are generally reduced and additional RCOs become cost-effective.
- Suggested levels of R are shown in two different formulations. Both formulations show a significant increase of safety level for small and medium sized ships and a moderate increase for very large ships. However, accounting for the additional cost-effective RCOs deriving from consideration of grounding (as explained above), it is concluded that the formulation with the higher level of R is deemed more appropriate, following closely the FSA process and methodology. *

* Some members of the consortium have expressed their reservation wrt. use of grounding in the CBA before the methods and assumptions have been further tested and validated.

Discussion points

- These include recommendations by the Project Partners as a Group of Experts and as Stakeholders of the maritime/marine industry beyond the EMSA III framework.
  - For large cruise ships, there is limited amount of information/data concerning their survivability in damaged conditions due to relatively small fleet and (luckily) small number of casualties, thus not attracting research focus. The limited amount that does exist indicates that the current formulation of the s-factor in SOLAS 2009 tends to underestimate the survivability of cruise ships. This, in turn, influences ΔPLL and cost-effectiveness.
  - By contrast, there are significantly more published validation results available for damage stability of RoPax ships (s-factor) than for cruise ships, e.g., North-West European Project for Damage Stability of Ro-Ro Passenger Ships (the basis for Stockholm Agreement) and the EC-funded projects HARDER and GOALDS.
  - The results of EMSA III show that grounding is the dominant risk. It certainly represents a significantly higher risk than collision. However, further validation and testing is required in order to develop specific proposals.
  - Presentation to and familiarisation by industry outside the consortium is also recommended before suggesting requirements such as combined collision and grounding to IMO.
  - Method and software for calculation of A for collision should be developed based on the non-zonal approach as was done in the EMSA III project for grounding.

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Thank you for your kind attention

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