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Risk acceptance criteria and risk based damage stability. Second interim report.

European Maritime Safety Agency

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Task and objective: This report includes a review of HAZIDs for passenger ships previously carried out, an updated collision risk model including uncertainty and sensitivity analysis and the presentation of 5 sample ships that will be used in the furthe studies.

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Reference to part of this report which may lead to misinterpretation is not permissible.

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0	2014-09-26	First issue			
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APPENDICES

1 PREFACE

This report is a deliverable according to the Framework Service Contract Number EMSA/OP/10/2013. This is the third study commissioned by EMSA related to the damage stability of passenger ships. The previous studies focused on ro-ro passenger ships.

This study aims at further investigating the damage stability in an FSA framework in order to cover the knowledge gaps that have been identified after the finalization of the previous EMSA studies and the GOALDS project.

The project is separated in to 6 studies:

- Identification and evaluation of risk acceptance and cost-benefit criteria and application to risk based collision damage stability
- Evaluation of risk from watertight doors and risk based mitigating measures
- Evaluation of raking damages due to groundings and possible amendments to the damage stability framework
- Assessment of cost effectiveness or previous parts, FSA compilation and recommendations for decision making
- Impact assessment compilation
- Updating of the results obtained from the GOALDS project according to the latest development in IMO.

The project is managed by DNV-GL and is established as a joint project which includes the following organisations:

Shipyards/designer:

Euroyards representing: Meyer Werft, STX-Finland, STX-France and Fincantieri

Knud E. Hansen AS

Operators:

Royal Caribbean Cruises

Carnival Cruises

Color Line

Stena Line

Universities:

National Technical University of Athens

University of Strathclyde

University of Trieste

Consultants:

Safety at Sea

Software manufacturer:

Napa OY

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2 ABBREVIATIONS

A: Attained index calculated in accordance with SOLAS 2009. Ch.II-1

ALARP: As Low As Reasonable Practicable

CN: Collision

CT: Contact

FD: Foundering

FSA: Formal Safety Assessment

FX: Fire/Explosion

GOALDS: **GOAL** based **D**amage **S**tability

GR: Grounding

GT: Gross tonnage

IACS: International Association of Classification Societies

IMO: International Maritime Organisation

LMIU: Lloyds Maritime Investigation Unit

POB: Persons on board

R: Required Subdivision Index in accordance with SOLAS 2009. Ch.II-1

SAFEDOR: Design, Operation and Regulation for Safety (EU FP6 project)

WOD: Water on deck

3 EXECUTIVE SUMMARY

Section 7 includes the results from a review of FSAs previously carried out in the SAFEDOR project for cruise and Ropax in addition to the FSA carried out for safety of navigation NAV49/INF.2. In addition, examination of data on accidents that have occurred since 2005, have been carried out focusing on collision and grounding. The sources for this additional investigation are the IHS-SeaWeb, IMO GISIS and EMSA's "Accident Investigation" summary reports. Analysis of causes and contrasting with causes included in the HAZIDs have been carried out when possible, however this has only been possible for a limited number of accidents. It is concluded that the causes included in the HAZIDS cover a much wider range of possibilities than which can be extracted from the accidents that have occurred. It is concluded that the causes of the accidents occurred are also covered by the three HAZIDs that were carried out.

Section 8 includes the description of the updated collision risk model. In the first interim report of Task 1 of the EMSA/OP/10/2013, the total risk for ship types cruise and RoPax was estimated using the risk models for the relevant accident categories of both ship types available from the FSAs on both ship types (MSC 85/INF.2 and MSC 85/INF.3) as well as of GOALDS project. Casualty reports for collision accidents are further analysed and subsequently the collision risk model updated. Furthermore, databases are used for estimating the uncertainty in parameter values of the risk model and the risk model modified to deal with these uncertainties, i.e. calculate confidence interval for risk in terms of PLL as well as for the input generated for cost-benefit assessment of novel ship designs. In section 7 the updated risk model for accident category collision is described. The updated risk model is realised in EXCEL using the software packages PrecisionTree© and @Risk©.

Section 9 includes the description of the sample ship developed to give the best possible distribution considering the world fleet of cruise/passenger ships and Ropax ships and the standards set forth by the current regulations. There is now one large cruise vessel, one small cruise ship, one large Ropax intended for operation in the Baltics, one smaller Ropax intended for operations in the Mediterranean, a smaller Ropax and finally a double ender ferry intended for operation on short international voyages.

4 ABSTRACT

This report consists of three parts. The first part includes a review of FSAs previously carried out in the SAFEDOR project for cruise and Ropax in addition to the FSA carried out for safety of navigation NAV49/INF.2. In addition, examination of data on accidents occurred since 2005 have been carried out focusing on collision and grounding. The sources for this additional investigation are the IHS-SeaWeb, IMO GISIS and EMSA's "Accident Investigation" summary reports. Analysis of causes and contrasting with causes included in the HAZIDs have been carried out when possible, however this has only been possible for a limited number of accidents. It is concluded that the causes included in the HAZIDS cover a much wider range of possibilities than which can be extracted from the accidents that have occurred. It is concluded that the causes of the accidents occurred are also covered by the three HAZIDs that were carried out.

The second part includes an updated collision risk model. The risk model has been updated in comparison with the model used in GOALDS. Updated frequencies for collision have been derived from analysis of casualty reports in the period of 2000 to 2012. For dependent probabilities such as struck/striking, operational state and probability for water ingress the data for cruise and passenger ships have been merged. The fatality rate for the event of sinking in "terminal area" has been adjusted to account for shallower water. For all dependent probabilities uncertainties have been taken into account and the assumptions behind the probability distributions are described.

The third and last part of the report includes descriptions of the samples ships developed within the EMSA III studies and which forms the basis for the further studies on design modifications. There is now one large cruise vessel, one small cruise ship, one large Ropax intended for operation in the Baltics, one smaller Ropax intended for operations in the Mediterranean, a smaller Ropax and finally a double ender ferry intended for operation on short international voyages.

5 INTRODUCTION

This report is the second interim report prepared in accordance with the tender specification and the project proposal. This report covers subtasks 2. (a), 2 (b) and 2.(c) of the Task 1 on “Risk acceptance criteria and risk based damage stability”

Included in this report is a review of the Hazids carried out in the SAFEDOR project as well as NAV.49/Inf.2. Records of accidents that have taken place since these studies were carried out are investigated to confirm the validity of the identified causes for accidents, primarily focusing on collision and grounding.

In the first interim report of Task 1 of the EMSA/OP/10/2013, the total risk for ship types cruise and RoPax was estimated using the risk models for the relevant accident categories of both ships types available from the FSAs on both ship types (MSC 85/INF.2 and MSC 85/INF.3) as well as of GOALDS project. The risk estimated in this task was evaluated deploying updated criteria for F-N diagram (societal risk) as well as by means of risk dimensions applied in other industries, e.g. fatalities per billion passenger kilometre. Following this investigation major risk contributors are the accident categories collision and grounding which are also in focus when discussing the damage stability criterion.

Casualty reports for collision accidents are further analysed and subsequently the collision risk model updated. The collision risk model is ship size dependent with respect to the calculation of the dependent probability for sinking and considers ship size dependent number of people on board. Other parameter values of the risk model like probability for struck/striking or initial accident frequency are independent of ship size. It would be preferable to develop a full ship size dependent risk model, however, the limited number casualty reports and spread in the range of ship sizes (Cruise 19; RoPax 55) does not allow such investigation. The data basis is used for estimating the uncertainty in parameter values of the risk model and the risk model is modified to deal with these uncertainties, i.e. calculate confidence interval for risk in terms of PLL as well as for the input generated for the cost-benefit assessment of novel ship designs. The updated risk model is realised in EXCEL using the software packages PrecisionTree© and @Risk©. This report describes the updated collision risk model.

Finally, in accordnace with the subtask description 2.(c), 5 new sample ships that have been developed are presented.

6 REVIEW AND UPDATE OF SAFEDOR HAZID

According to the project description; subtask 2(a) objectives are to:

- Review HAZIDs carried out for cruise ships and for RoPax as part of the activities of the SAFEDOR project, as well as the HAZID carried out for the Navigation Safety of Large Passenger Ships project (NAV49/INF.2).
- Examine data and information of accidents occurred since carrying out these HAZIDs with a view to take onboard any relevant information and confirm the validity of the HAZID studies.

Review of HAZIDs

The purpose of the SAFEDOR HAZIDs was to establish, at a high-level, the main risks related to cruise and RoPax ship operation and design, and as such, they include hazards relating to all types of incidents.

On the other hand, the purpose of the NAV49/INF.2 HAZID was to identify hazards to safe navigation to be implemented for large passenger ships, and as such, mainly focusing on collision and grounding incidents.

For each hazard identified, causes, consequences, current safeguards and recommendations for potential future safeguards are included in detailed risk registers. A review of the main findings of the three HAZID studies mentioned is included in this part of the report.

SAFEDOR Cruise Ship HAZID

This HAZID is reported in SAFEDOR deliverable "SAFEDOR-D-04.01.01-2005-10-31-DNV-HAZID". The purpose of the HAZID was to establish, at a high-level, the main risks related to cruise ship operation and design. Two brainstorming workshops were organised by gathering panels of different cruise industry experts, as follows:

- The first workshop, held on 21-22 March 2005, focused on the daily operation of cruise ships. The workshop was moderated and recorded by DNV risk experts. The experts' team comprised 5 members, and included technical and operational directors of maritime affairs, marine safety manager and first engineer officer, as well as a risk analyst from Carnival and P&O Cruises. A total of 84 hazards were identified relevant to cruise ship operations, distinguished in the following phases: planning of voyage (18 hazards); arrival/departure to/from port (10 hazards); voyage at open sea (13 hazards); tender operations (15 hazards); emergency operations (19 hazards); common for all modes of operation (6 hazards); other (3 hazards).
- The second workshop, held on 13-14 September 2005, focused on cruise ship design. This workshop was also moderated and recorded by DNV risk experts. The experts' team comprised 5 members and was more design-focused, and included technical risk analysts from Carnival, a flag state representative (MCA), an expert from the ship safety department of a shipyard (Fincantieri) and a cruise/design and regulatory

expert from DNV. A total of ***34 hazards*** were identified focusing in particular on flooding and structural integrity, split in the following categories: collision (13 hazards); fire/explosion (13 hazards); contact (7 hazards); grounding (1 hazard).

The first workshop focused on high-frequency and low-consequence incidents (i.e., occupational incidents, tender operations, etc.), while the second workshop focused on low-frequency and high-consequence incidents (collision, grounding, etc.). It should be mentioned, as highlighted in the HAZID report that collision, grounding and fire/explosion hazards identified in the first workshop, were re-visited and further analysed in the second workshop.

The experts participating in the second workshop provided their assessment of the importance of the hazards identified, which resulted in a ranking of the most important collision/grounding and fire/explosion hazards. Ranking of hazards was carried out using the standard 7 x 4 risk matrix proposed in the IMO FSA guidelines.

The following are the ***five major collision/grounding hazards*** identified by the experts:

1. Officer on-duty not watch-keeping
2. Failure of critical navigational aids (in fog)
3. Severe loss of functionality (e.g. loss of rudder/steering at full speed; failure of shaft bearings)
4. Lack of knowledge of navigating procedures
5. Misinterpretation of bridge information

A list of the next five hazards (*with lower risk*) was also provided:

- Collision between two ships (cruise-other) where cruise ship is not at fault
- Wrong pilot intervention
- Lack of interpersonal communication on bridge
- Severe loss of functionality (e.g. loss of power, blackout, etc.)
- Contamination of fuel tanks

The following are the ***five major fire/explosion hazards*** identified by the experts:

1. Arson – deliberate act resulting in a fire (could be anywhere, anytime)
2. Galley – deep fat fryers, greasy cooking appliances catching fire (due to overheating)
3. Engine room – flammable fluids on hot surfaces
4. Laundry – lint from tumble driers catching fire
5. Cabins – fire starts in cabin (cigarettes, candles, electrical equipment failure, etc.)

A list of the next five hazards (with lower risk) was also provided:

- Hot work procedures (including engine room)
- Mooring deck (mooring ropes catch fire)
- Bunkering – leakage whilst bunkering, ignition through sparks, etc.

- Theatre (front stage and backstage) – hot lights and flammable materials
- Storage areas – self ignition (chemical reactions)

SAFEDOR RoPax HAZID

This HAZID is reported in SAFEDOR deliverable "SAFEDOR-D-04.02.01-2005-10-31-LMG-HAZID". The purpose of the HAZID was to establish, at a high-level, the main risks related to RoPax ship operation and design.

A brainstorming workshop was organised for this purpose on 13-14 June 2005. The workshop was chaired by an experienced risk analyst from LMG Marin and moderated by personnel from the Ship Stability Research Centre and Safety at Sea. The experts' team comprised 8 members covering a wide spectrum of required expertise: naval architect from the basic design office of a shipyard (FSG), a principal surveyor from a class society (DNV), an FSA expert from a flag state (MCA) and five personnel from a RoPax operator, Color Line (new building director, safety manager, naval architect, superintendent, quality assurance/safety superintendent). Specific sessions of the workshop were also attended by further three Color Line personnel (technical director, captain and chief officer), as their expertise was required.

The workshop comprised a series of separate sessions to facilitate identification of hazards occurring during distinct phases of RoPax operation. The eight phases of operation considered are the following, with the associated number of hazards identified: loading (7 hazards); departing quay (8 hazards); transit and navigation in coastal waters (12 hazards); transit in open sea (6 hazards); arriving in port, mooring and preparing for unloading (6 hazards); unloading (6 hazards); bunkering and treatment of fluid and solid garbage (3 hazards); emergency evacuation and drills (8 hazards); other and ordinary hazards (6 hazards).

A total of 62 hazards were identified, with their causes, consequences, current safeguards and potential mitigating measures recorded in a risk register. The HAZID has been conducted based on generic characteristics and features of RoPax ships.

The experts participating in the workshop provided their assessment of the importance of the hazards identified, in terms of their anticipated frequencies and consequences, which resulted in a ranking of the most important hazards. Ranking of hazards was carried out using the standard 7 x 4 risk matrix proposed in the IMO FSA guidelines.

The ***top-ranked high-consequence hazards*** are the following:

1. Failure of evacuation equipment during an emergency
2. Fire in accommodation while in open sea or navigating in coastal waters
3. Human error and/or lack of training during an evacuation
4. Collision with other ships while in open sea or navigating in coastal waters
5. Fire on vehicle deck while unloading due to accumulation of fuel spills during journey
6. Fire in machinery spaces while in open sea or navigating in coastal waters
7. Evacuation arrangements and plans not as effective as designed for
8. No or reduced visibility and high toxicity due to smoke during evacuation

9. Evacuating following a fire or explosion
10. Grounding while navigating in coastal waters

A list of top-ranked high-frequency hazards were also produced, which, however, is not included in this review as the focus of this project is on collision and grounding.

Navigation Safety of Large Passenger Ships (NAV49/INF.2) HAZID

This HAZID was part of an FSA study on the navigation safety of large passenger ships sponsored by the Norwegian Shipowners Association, the Norwegian Maritime Directorate, Kongsberg Maritime Ship Systems and DNV with an objective to identify risk control options related to safe navigation to be implemented for large passenger ships.

The HAZID workshop took place on 20-22 November 2002. The workshop was facilitated and recorded by experienced DNV personnel, and the experts' team comprised 6 members covering a wide spectrum of required expertise: officer on large cruise ships (from RCCL); expert on marine electronics equipment (from Kongsberg Maritime Ship Systems); two DNV nautical surveyors with previous experience as navigator and deck officer, both educated in marine engineering and nautical science; a senior and a principal nautical surveyor from the Norwegian Maritime Directorate, with previous experience as ship masters.

A total of 45 hazards were identified during brainstorming, classified under five main issues determinant for performance on the bridge of a large passenger ship regarding navigation safety, namely: company culture (11 hazards); navigator (7 hazards); procedures, rules and regulations (9 hazards); technical systems (11 hazards); user interface (6 hazards); other (1 hazard).

For each of these identified hazards causes, consequences, current safeguards and recommendations for potential future safeguards were made. The focus was kept on powered grounding, collision and grounding accident scenarios.

The experts contributed their ranking of the most important/critical of the hazards identified. The following list is the hazards ranked as most important to the industry:

1. Level of destruction when the OOW is performing his/her tasks
2. INS/IBS (Integrated Navigational System / Integrated Bridge System) failure (including software)
3. Poor bridge design and physical work conditions
4. Misjudgement of traffic situations
5. OOW unfamiliar with vessel/bridge

Review Comments

The main conclusions from this review are the following:

- All three HAZIDs followed the well-established SWIFT (Structured What IF Technique) approach, a structured form of identifying hazards, their causes, consequences, current and potential future safeguards. At the start of all HAZIDs the participants decided on the sessions required for the HAZID (for example, for the cruise ships and RoPax, the HAZIDs were divided in sessions corresponding to phases of operation; for the Navigation Safety study, the HAZID was divided in sessions corresponding to areas of importance for navigational safety). This resulted in well-organised and structured brainstorming sessions.

- The duration of the brainstorming sessions, number of experts and complementarity of their expertise, facilitation and recording are considered to be satisfactory and adequate for the purpose intended.
- The HAZIDs on cruise ships and RoPax are done at a high-level addressing the needs of the high-level SAFEDOR FSA studies that were part of. This reflects on the hazards identified which mainly associate with consequences of accidents and their mitigation. On the other hand, the HAZID on navigation safety of large passenger ship, as having very specific focus, resulted in hazards mostly related to prevention of accidents relating to navigation safety. In this respect, the risk registers of the three studies can be considered as complementary to each other. Evidence of this are the similarities of hazards identified as most important in the three studies, as reviewed above.

Updating of HAZIDs

The second objective of subtask 2(a) is to examine data and information of accidents occurred since carrying out these HAZIDs with a view to take onboard any relevant information and confirm the validity of the HAZID studies.

The current project deals with hazards associated with collision, grounding and contact. Since the earlier HAZIDs cover experience until the end of 2005, the updating of HAZIDs will be carried out with the use of information from accidents occurred from the beginning of 2006 and onwards.

For this purpose, the relevant subset of accident data of subtask 2(b) of the project is utilised, namely, in carrying out an analysis of causes of total losses and serious accidents classified as collisions, groundings, and contacts involving cruise ships and RoPax from the beginning of 2005 and onwards to verify the validity of the HAZIDs undertaken.

Approach Adopted

The approach adopted in carrying out this work comprises of the following steps:

- Examine data and information of accidents occurred since carrying out these HAZIDs in 2005 with a view to take onboard any relevant information and confirm the validity of the HAZID studies.
- Focus is placed on collision and grounding incidents, as this is the objective of the EMSA III project.
- Contrast and compare causes, consequences and safeguards of collision and grounding incidents occurred from 2005 and onwards with the causes, consequences and

safeguards, as included and documented in the two HAZIDs of the SAFEDOR project and the NAV49/INF.2 HAZID.

For this purpose, the accident dataset of the risk analysis work of Task 1 of this project is used. The following sources of accident details and descriptions are utilised:

- IHS-SeaWeb (www.sea-web.com)
- IMO's GISIS (Global Integrated Shipping Information System) database
- EMSA's "Accident Investigation" summary reports from accident investigations carried out by National Authorities, as published in EMSA's website (www.emsa.europa.eu)

EMSA III Task 1 Dataset

The dataset contains the number of collisions and groundings (2005 onwards) as shown in the below Table 6-1:

Table 6-1 EMSA III accident dataset

Ship Type	Collisions	Groundings
Cruise Ships	20	17
Passenger Ships	0	2
Passenger/Cruise Ships	1	3
	21	**22**
Passenger-RoRo Ships (Vehicles)	5	8
RoPax Ships	50	24
RoPaxRail Ships	2	0
	57	**32**

IHS-SeaWeb Records – Analysis

Appendix A includes details of the records for all accidents as included in the dataset. It is noted that in the descriptions only high level causes and consequences are included. For example, the description for the Costa Concordia grounding is as follows:

"

Visible only for internal review.

Visible only for internal review.

With reference to the causes of accidents, the following is the information which can be retrieved from these records:

- Ship status: moored/anchored; manoeuvring; manoeuvring without assistance; on voyage
- Weather: good visibility and good weather; calm weather/seas; heavy weather (wind, waves); hurricane, etc.; fog, mist, poor visibility; freezing conditions
- Location: in port, harbour or dock, at quay; estuary/river; canal; restricted waters; shipyard, dry dock; at sea

It is noted that for a very limited number of records, there is mention of mechanical/electrical failure of equipment as contributing cause to the incident.

Regarding accident consequences, the following details are mentioned in the records:

- Number of people injured, fatalities
- Structural damage to the ship and location of damage (in some records also mentioning if the damage was above or below the waterline)
- Occurrence of flooding
- Environmental pollution (in some records also mentioning amount and type of oil spilled)
- Severity of damage – assistance given (by tugs or other ships), need for repairs, time out of service, total loss
- Some evacuation process details
- Recovery and salvage operations

In conclusion, causes included in IHS-SeaWeb are at a very high-level, only location and status of the ship at the time of incident and the weather conditions are recorded systematically. The following are specific comments in contrasting the HAZIDs with the information included in the IHS-SeaWeb database:

- The HAZIDs include a very wide array of accident causes; the causes mentioned in the IHS-SeaWeb records have been examined in sessions comprising the HAZID workshops, as operational phases.
- There is no mention of the effects of the human factor in the IHS-SeaWeb records.
- The IHS-SeaWeb records are more complete with reference to consequences, as included in the HAZIDs risk registers.

GISIS and EMSA Records

In order to obtain more detailed information in relation to detailed causes of the accidents being reviewed, particularly with reference to the effect of the human factor, additional relevant information is reviewed.

The IMO (GISIS Global Integrated Shipping Information System) database and records retrieved from the EMSA website are used in order to obtain a more comprehensive overview of the causes of the collisions and grounding occurred after 2005.

The GISIS database contains only a limited number of incidents, as shown in the below Table 6-2 :

Table 6-2 IMO GISIS database

Ship Type	Collisions	Groundings
Cruise Ships	0	3
Passenger Ships	0	1
Passenger/Cruise Ships	0	0
	0	**4**
Passenger-RoRo Ships (Vehicles)	1	1
RoPax Ships	10	5
RoPaxRail Ships	1	0
	12	**6**

Additional details (summary reports from accident investigations carried out by National Authorities) obtained from EMSA's website for 6 of the collisions and 1 grounding for RoPax are also used.

Details of Analysis

The following tables 6-3 through 6-7 include w? the accidents for which the causes are contrasted with causes as included in the three HAZIDs under review.

Table 6-3 Accidents - *Cruise Ships*

Ship Name	Incident	Remarks
Sea Diamond	Grounding, 05/04/2007	No mention of causes
Astor	Grounding, 15/05/2009	
Costa Concordia	Grounding, 13/01/2012	

Table 6-4 Accidents - *Passenger Ship*

Ship Name	Incident	Remarks
Ocean Nova	Grounding, 17/02/2009	No mention of causes

Table 6-5 Accidents - *Passenger-RoRo Ships (Vehicles)*

Ship Name	Incident	Remarks
Nuraghes	Collision, 21/06/2006	No mention of causes
Ile de Groix	Grounding, 28/07/2008	no mention of causes

Table 6-6 Accidents - *RoPax Ships*

Ship Name	Incident	Remarks
Panstar Dream	Collision, 03/11/2005	No mention of causes
Finnsailor	Collision, 13/11/2005	
Olympia Palace	Collision, 07/12/2005	No mention of causes
Mercandia IV	Collision, 11/09/2006	EMSA summary report
Pride of Bruges	Collision, 13/11/2007	EMSA summary report
Skania	Collision, 17/02/2009	EMSA summary report
Gotland	Collision, 23/07/2009	No mention of causes
Scottish Viking	Collision, 05/08/2010	
Stena Feronia	Collision, 07/03/2012	EMSA summary report
Nils Holgersson	Collision, 03/05/2012	EMSA summary report
Hamnavoe	Grounding, 16/05/2006	
Stena Danica	Grounding, 10/01/2008	No mention of causes
Pride of Canterbury	Grounding, 31/01/2008	EMSA summary report
Princess of the Stars	Grounding, 21/06/2008	No mention of causes
Isle of Arran	Grounding, 28/03/2009	

Table 6-7 Accidents - *RoPaxRail Ships*

Ship Name	Incident	Remarks
Schleswig-Holstein	Collision, 24/08/2009	EMSA summary report

Appendix B contains all the details of the reports available from the IMO GISIS database and also the additional information obtained from EMSA's "Accident Investigation" summary reports. Appendix B also contains full details of the contrasting between the causes of the accidents and possible causes included in the HAZIDs.

As an example, Table 6-8 below shows the contrasting of the causes of the Costa Concordia incidents with causes included in the HAZIDs.

Table 6-8 Costa Concordia causes vs causes included in HAZIDs

Causes of Costa Concordia Incident Extracts from IMO GISIS Record	Causes included in HAZIDs
• Illusion of control • Distraction caused by presence of additional persons on the bridge and a mobile telephone call • Insufficient bridge resource management • Lack of appropriate large-scaled chart • Insufficient position monitoring	SAFEDOR Cruise HAZID, Workshop II risk register. Hazard on "Grounding" – ship at full speed hitting hard sea-bottom (rock), as causes the following are mentioned: navigational equipment, updated and appropriate sea-charts, trained and competent officer on watch. Another section of the SAFEDOR Cruise HAZID is on "Emergency Operations" with hazards included 5.1 "crew ability/training", 5.3 "crew behaviour/reaction/emergency handling", 5.7 "knowledge of emergency procedures", 5.14 "ship movement (list/trim)"; etc.
	Hazards included in NAV49/INF.2 • No. 1 – "OOW distractions", one of the causes mentioned is "human: telephone calls, other crew members, passengers" • No. 10 – "poor company policy/culture" • No. 19 – "communication between navigators, misunderstandings" • No. 32 – "large vessels, difficult to manoeuvre" A number of hazards relating to use of bridge equipment: No. 15 "incorrect use of equipment", No. 29 "poor quality of equipment"
Some passengers jumped into the water and swam to safety, but there were delays in getting others into life boats, especially as the vessel had by then rolled over onto her side and many of the lifeboats were inaccessible	Hazards 8-1 and 8-2 of the SAFEDOR RoPax HAZID refer to emergency evacuations when the ship is trimmed and heeled and to evacuation equipment failure. It should be highlighted that hazard 8-2 was the top-ranked hazard in this HAZID. The causes for these hazards included in the HAZID are: difficulties in launching lifeboat and MES; slow reaction/awareness by passengers; inappropriate assistance to passengers from crew; lack of plans, training and experience; poor maintenance; lack of training; faulty equipment; too extreme heel and trim; human error.
Some reports indicated that the ship had also suffered a major electrical fault	NAV49/INF.2 – Hazard No. 30 "technical failure of power supply" SAFEDOR Cruise HAZID –under the "planning, departure/arrival & voyage" section, HAZARD A is "black-out"
• Error in judgement; Inappropriate choice of route • Insufficient risk assessment and passage planning	The SAFEDOR Cruise HAZID includes a whole section for hazards relating to Voyage Planning. We can highlight the following hazards included: 1.4 – navigational failure with causes mentioned "unreliable electronic charts" 1.8 – crew resource management 3.7 – humar error – two of causes included are inappropriate watch changeover and complacency

On the basis of the analysis carried out, we can derive the following conclusions:

- Analysis of causes and contrasting with causes included in the HAZIDs only possible for a very limited number of accidents (2 cruise ship groundings; 8 RoPax collisions; and 3 RoPax groundings).
- Causes included in HAZIDs, as the result of brainstorming, cover a much wider range of possibilities when compared with the causes of accidents occurred.
- Due to the very little data available, quantitative analysis of causes cannot be performed, hence it is not possible to make exact comparisons with the ranking of hazards included in the HAZIDs. In any case, the rankings provided in the HAZIDs appear to be appropriate and corresponding to the nature of causes analysed in this subtask.
- From this analysis, it can be concluded that the causes of the accidents occurred are included as causes in the three HAZIDs reviewed, hence the latter can still be considered valid.

7 COLLISION DAMAGE RISK ANALYSIS

The collision risk model developed in GOALDS is herein revisited in order to incorporate newly collected information, which was identified when updating the casualty database developed within GOALDS as well as responding to the conclusions drawn from the risk quantification carried out in Task 1c of this project.

The risk model used in GOALDS and Task 1c of this project is shown in Figure 7-1. As shown both scenarios for collision "en route" and "limited waters" consider the same dependent probabilities and also consequences assigned to these scenarios. Therefore, both branches of the event tree are merged. Probability of flooding of accidents in "terminal" areas is and will be lower than for other areas and therefore this branch is kept in the risk model. In this context "terminal" area is the berth and the entrance ways to ports used for manoeuvring.

Another aspect discussed is the possibility of capsizing in "terminal" area[1]. In this discussion the potential scenarios are discussed considering in particular water depth and ships' main dimensions. For instance, the investigation of ship's beam for three ship size categories[2] (small Figure 7-2, medium Figure 7-3, large Figure 7-4) showed for the majority of ships that ship's beam is larger than 20 m and it is concluded this will have an influence on ship capsizing/sinking scenario and its consequences, when occurring in relatively shallow waters, i.e. a ship with a beam of 20 m capsizing in water depth of 10 m cannot be fully flooded. The effect of limited water depth was clearly shown in the accident of **Herald of Free Enterprise** that capsized outside the port of Zeebrugge but was only partly flooded. Water depth in "terminal" area varies and no statistics for harbours called by Cruise and RoPax is available. With respect to the RoPax, project partners provided the information that typically the water depth in "terminal" areas is below 10 m.

Furthermore, in this discussion it is also mentioned that harbour infrastructure will enable immediate activation of emergency response forces, which is expected to reduce the number of "second-stage-fatalities", i.e. fatalities after leaving the ship for instance by drowning or hypothermia.. Therefore, the percentage of fatalities for sinking in "terminal" area is assumed to be lower than for other operational areas.

Based on this discussion the event sequence for collision in "terminal" area is updated and considers ship sinking with a representative percentage of fatalities of 5%.

For the scenarios other than in operational state "terminal" different probabilities for capsizing and slow sinking are used for ship categories Cruise and RoPax.

[1] Definition of Operational State:
En route: operation in Open Sea (≥ 12 nm from the coast, archipelagos).
Limited waters: operation in coastal waters (< 12 nm), restricted waters, rivers, canals, inland waters.
Terminal areas: operation in port, anchorage, port approach, at berth.

[2] Ship size categories specified in terms of passenger capacity

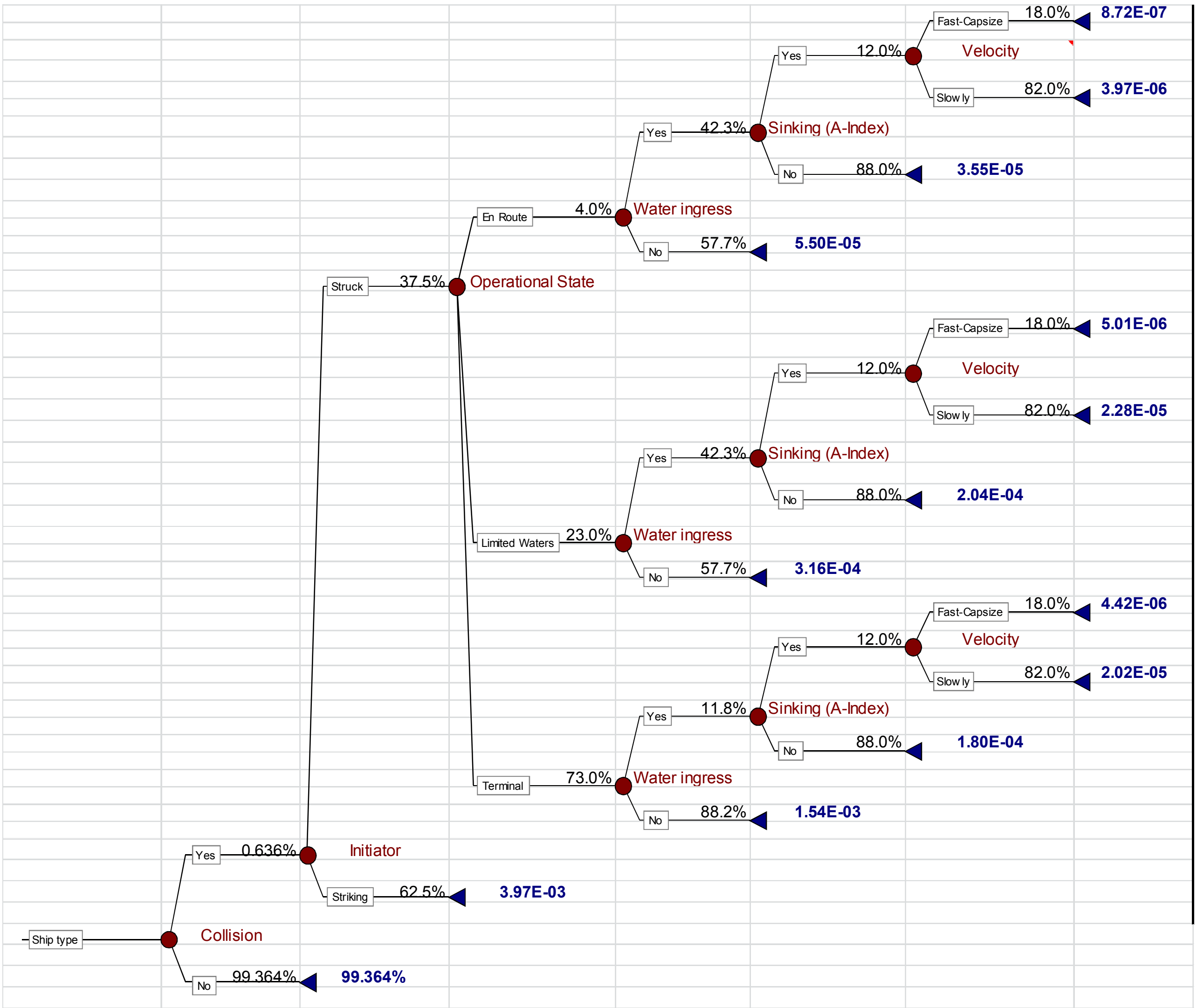


Figure 7-1 Collision risk model for ship type cruise of Task 1c.

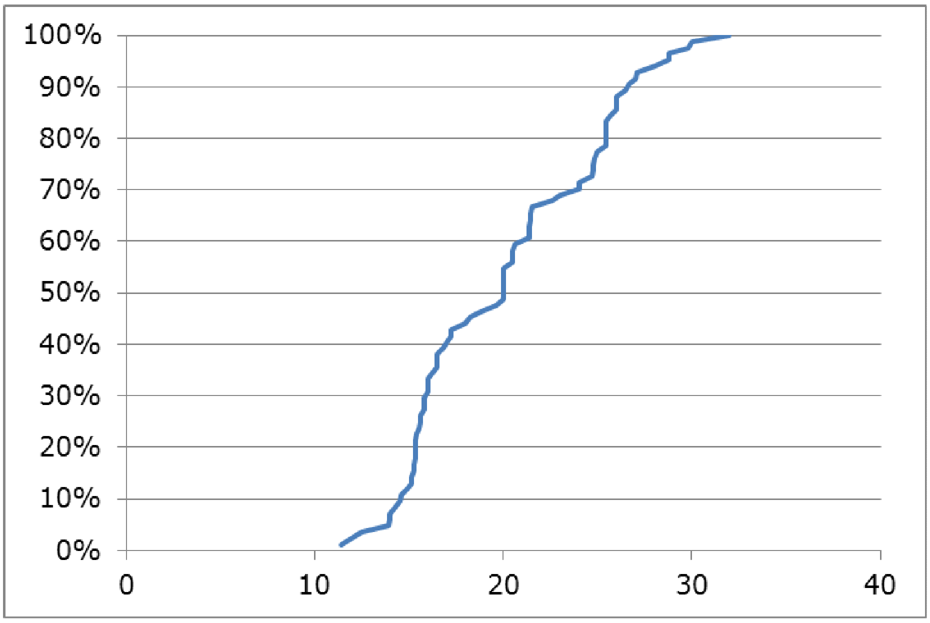


Figure 7-2 Cumulative distribution of ship beam for small cruise ships with less than 800 passengers.

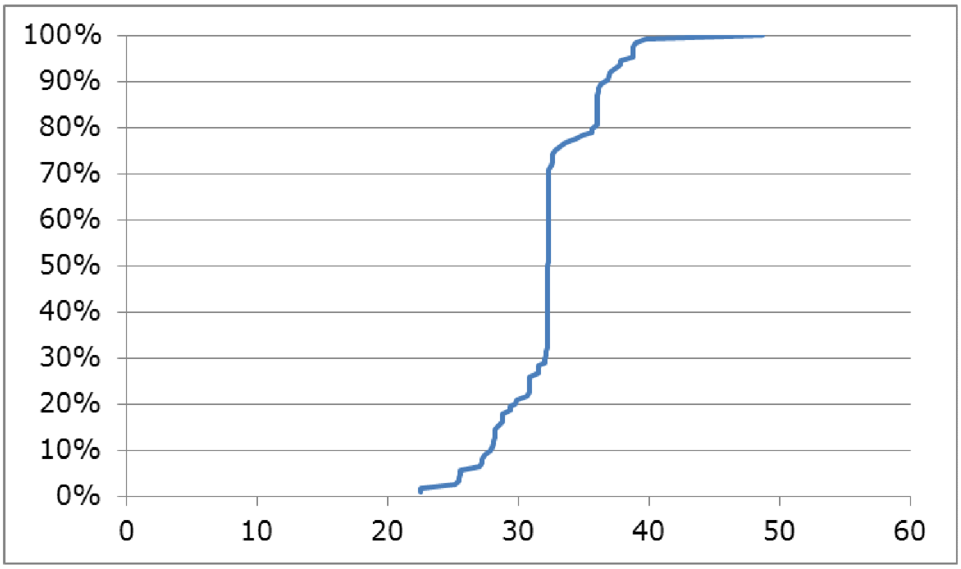


Figure 7-3 Cumulative distribution of ship beam for medium cruise ships with passenger capacity between 800 and 3000.

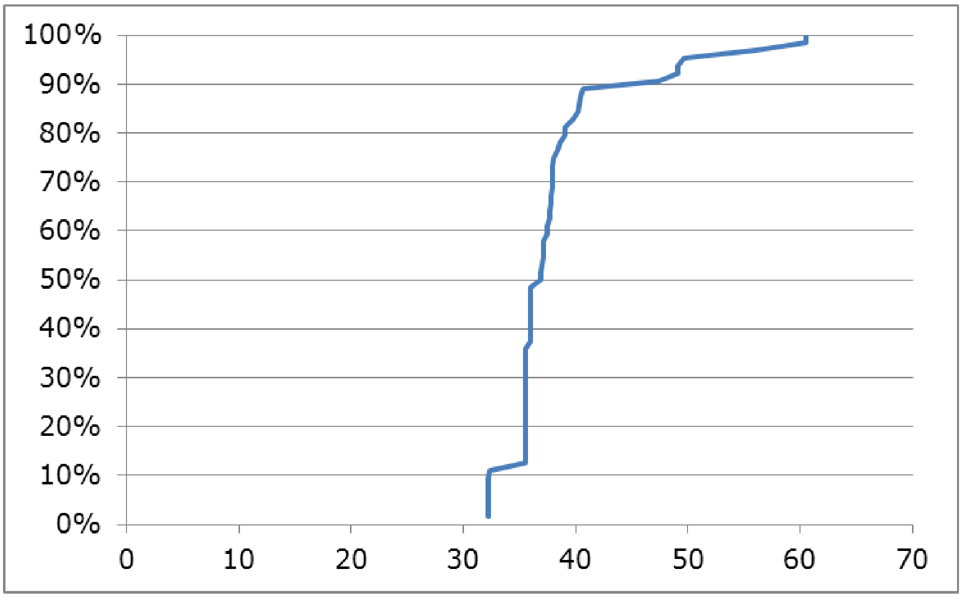


Figure 7-4 Cumulated distributionof ship beam for small cruise ships with more than or equal to 3000 passengers.

Already in the GOALDS project the limited number of casualties and the influence on the confidence of the risk analysis were discussed, i.e. the effect of parameter uncertainty on cost-benefit assessment. That time it was mentioned that consideration of parameter uncertainty and calculation of confidence intervals would improve the quality of results. This idea is considered in the update of collision risk model.

In the collision risk model dependent probabilities for events "initiator"; "operational state" and "water ingress" (Figure 7-1) are estimated by means of casualty reports. In total 74 casualty reports for Cruise and RoPax are available for 1994 to 2012 after the review plus 1 accident from the time before. Typically, casualty reports do not contain all information needed to quantify the above mentioned dependent probabilities, e.g. for "initiator" 65 reports contain relevant information (1990 to 2012) only, where the reports are unequally distributed over both ship categories with smaller numbers for Cruise. In order to reduce uncertainty in the dependent probabilities for the three events it is suggested to merge the information for both ship categories.

The updated risk model for Cruise is shown in Figure 7-5 highlighting also which parts of the collision risk model that are ship category dependent.

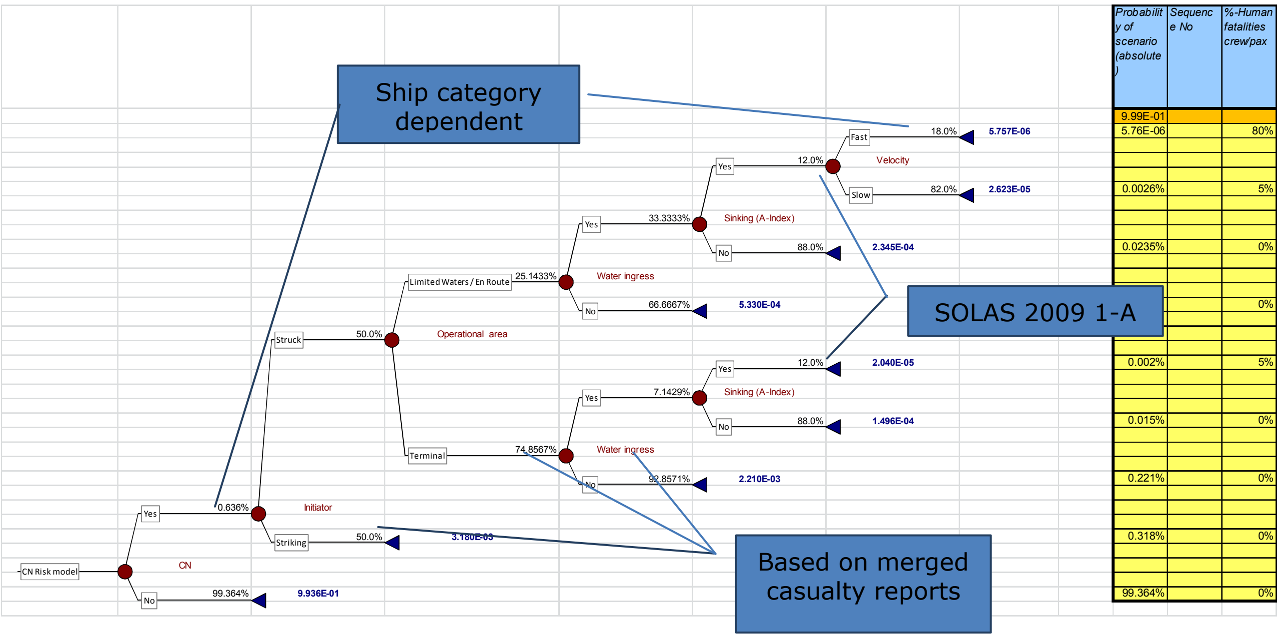


Figure 7-5: CN risk model for cruise ship (draft).

The small number of casualty reports prohibits also the development of a full ship size dependent risk model. The current model considers the ship size in the calculation of the dependent probability for sinking and the number of people on board. Table 7-1 shows a summary of the casualty reports for both ship categories and ship size categories.

Table 7-1 Collision casualty reports for ship categories Cruise and RoPax and size categories, time period 2000-2012

Cruise ships - Ship size acc. to GT	
Small (<20,000 GT)	2 (struck 0)
Medium (GT: 20,000 -100,000)	14 (struck 5)
Large (≥ 100,000)	1 (struck 1)
RoPax ships - Ship size acc. to Loa	
Small (Loa <140m)	22 (struck 11)
Medium (Loa: 140 - 200)	24 (struck 9)
Large (Loa ≥200m)	7 (struck 3)

In the following the parameter values for the updated risk model are explained.

Initial accident frequency

Initial accident frequency is exclusively determined using the casualty reports considered in the enhanced GOALDS database and number of ship years. For the period 2000 to 2012 17 collision accidents were reported for cruise ships, respectively 53 for RoPax. The fleet at risk operating in this period corresponds to 2,673 ship years (cruise) and 5,328 for RoPax. Therefore, initial accident frequency for calculated to 6.36E-03 (cruise) and 9.95E-03 (RoPax).

The *confidence* interval for this estimation is calculated using the approach by Engelhardt (1994) and the assumption that collision accidents are *Poisson* distributed. For the collision of cruise ships the respective 90% confidence interval has the boundaries [4E-03; 9.5E-03].

As shown by the characteristic values (6.36E-03 and [4E-03; 9.5E-03]), determined using the approach by Engelhardt, the distribution is not symmetric to the mean value and therefore for approximation of the confidence interval the *Log-Normal* distribution is selected for considering the *uncertainty* in initial accident frequency. For the Log-*Normal* distribution the standard deviation σ is calculated by means of the limits for the confidence interval and the mean value. However, it is not possible to meet exactly the characteristic values given above. The approximation for cruise ships is shown in Figure 7-6. As shown the distribution is an approximation which deviates slightly from the values estimated by Engelhardt with respect to the bounds of the 90% confidence interval.

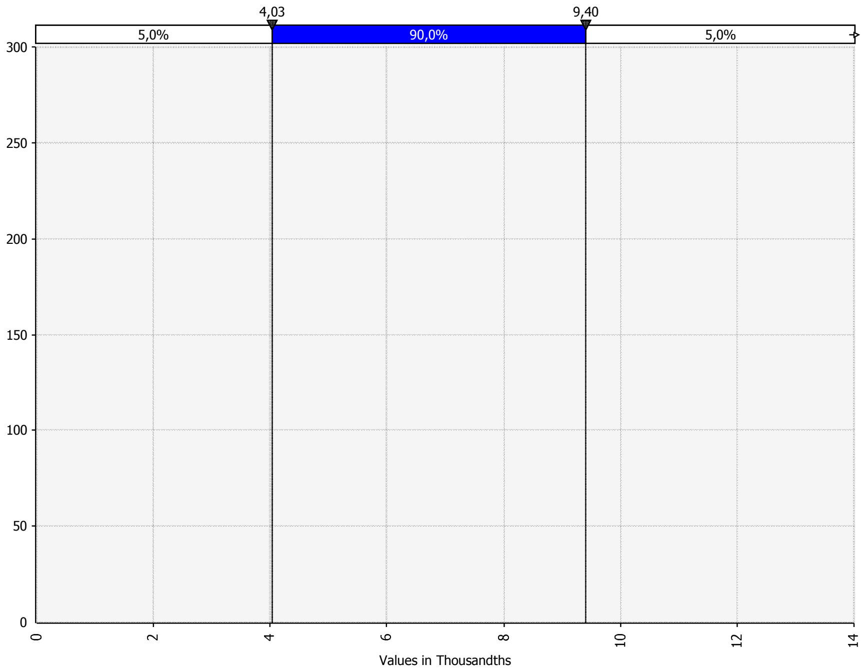


Figure 7-6 Gauss-Normal distribution for initial accident frequency (cruise) with 90% confidence interval.

Struck/Striking

For the event "initiator", 65 casualty reports form basis for estimation of dependent probability (33 struck; 32 striking). In the updated model, the probability of being struck is now ~50%. In GOALDS, the dependent probability for struck was ~38% for Cruise and 68%

for RoPax. Using the updated sample of casualty reports for both ship categories separately yields 44% (Cruise) and 53% (RoPax), which means both values are approaching the value used in the model, namely 50%.

For estimating the confidence interval, struck/striking is regarded as an experiment with two possible results for a ship having a collision; either it is striking or it is struck which is a typical binominal experiment, or the number of events is distributed over the ship years (probability of being struck). In the latter case the limits of the 90% confidence interval can be calculated with the approach mentioned above [2.2E-03/ship year; 4.1E-03/ship year]. These boundaries are calculated with the number of ship years yielding an interval of 24 to 44 struck ships for 1990 to 2012 which is equivalent to a dependent probability between 0.37 and 0.68. It is assumed that the probability of a vessel being struck can be approximated by a truncated Gauss-Normal distribution as shown in Figure 7-7. The process of estimating the characteristics is the same as for the initial accident frequency leading to some deviation in the confidence interval.

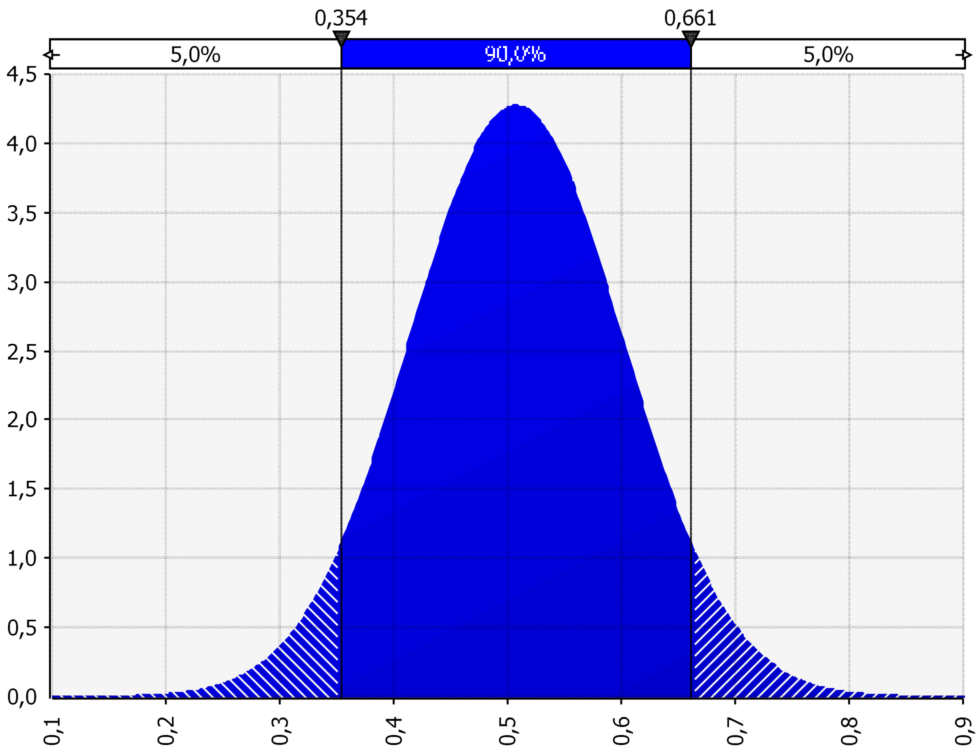


Figure 7-7 Gauss-Normal distribution for ship being struck with 90% confidence interval.

Operational Status

Similar to struck/striking the probability distribution for the operational status "terminal" is determined. The 90% confidence interval for having a collision in "terminal" area is [1.4E-03/ship year; 2.9E-03/ship year] which is equivalent to 15 to 32 collision events between 1990 and 2012. The truncated Gauss-Normal distribution is shown in Figure 7-8. With ~66% the mean value is lower than that used in Task 1c of EMSA III project (75%) and GOALDS (73%).

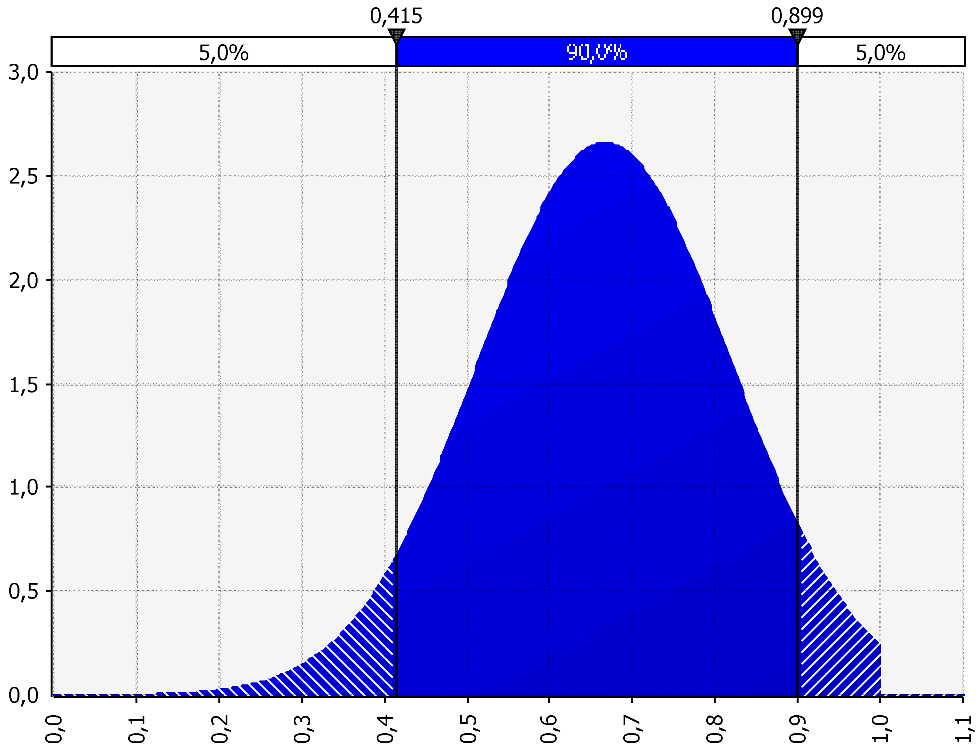


Figure 7-8 Gauss-Normal distribution for collision in "terminal" area with 90% confidence interval.

Water Ingress

Two distributions for the probability of water ingress due to collision in operational areas "terminal" and "limited waters/en route" are calculated using the approach explained above. The Gauss-Normal distributions are shown in Figure 7-9 and Figure 7-10. The mean values for the dependent probabilities are 7% ("terminal") and 33% ("limited waters/ en route") respectively.

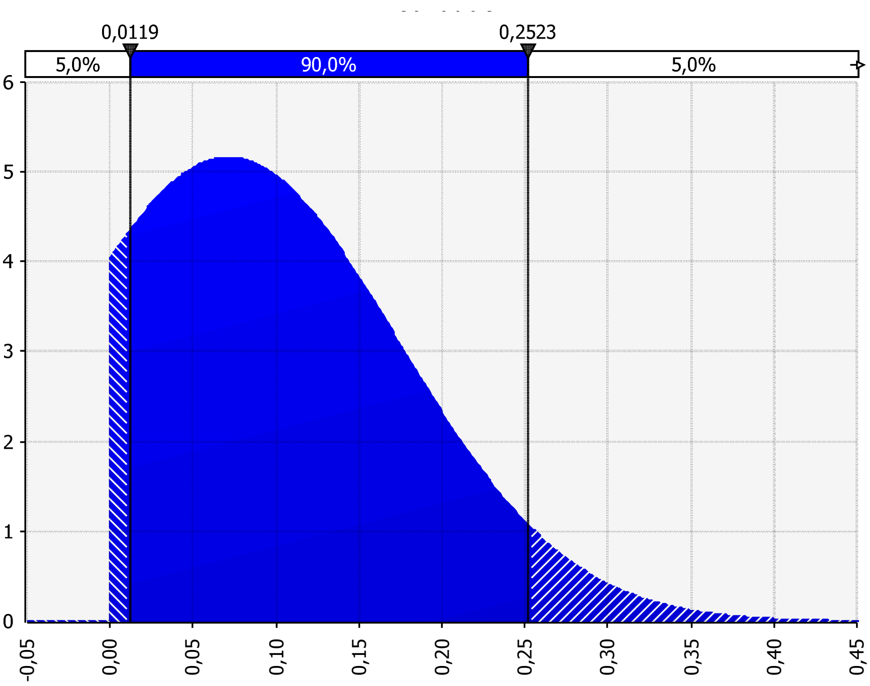


Figure 7-9 Gauss-Normal distribution for water ingress after collision in "terminal" area with 90% confidence interval.

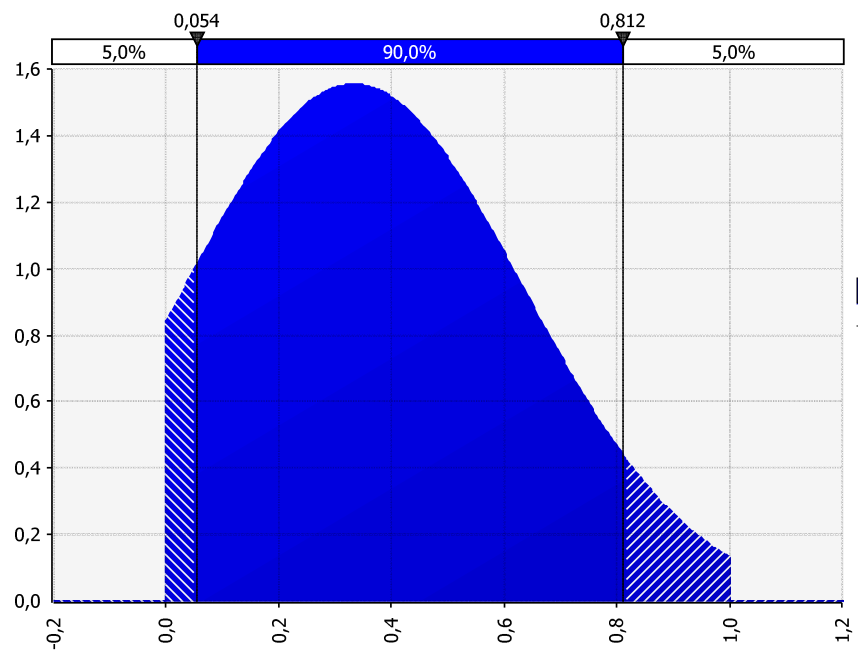


Figure 7-10 Gauss-Normal distribution for water ingress after collision in "lmited waters/en route" area with 90% confidence interval.

Sinking

The dependent probability of sinking is estimated using the SOLAS 2009 damage stability requirement assuming that the R-Index represents the dependent probability for a ship surviving a collision damage that leads to water ingress (breach of hull). According to SOLAS

2009 damage stability the R-Index depends on ship's length, the number of POB and the total lifeboat capacity, i.e. percentages of passengers that can be evacuated by lifeboat. For the calculations in the context of the cost-benefit assessment a lifeboat capacity of 75% for cruise and 30% for RoPax is used.

Typically, ships are designed so that the attained index (A-Index) is slightly higher than the R-Index in order to provide some buffer for later changes in the design, which may reduce the attained index. Like in GOALDS, EMSA III is considering damage stability requirements and therefore the minimum required index, which is the standard value to which a ship is specified to be built and this is considered in the risk model. The probabilities for fast and slow sinking are used as in the GOALDS model, as no new information is available giving reason to change these values. Only for sinking in "terminal" areas both categories are merged as explained below. For both dependent probabilities no uncertainty analysis was conducted.

Fatalities

It is obvious that the assumed fatality rate (percentage of fatalities given that a scenario occurs) has a significant influence on the collision risk of both ship types. For example, the current collision risk model leads to, for the large cruise ship with a maximum 6,730 persons (assuming year-round 90% occupancy) on board, a PLL of 5E-02 fat/ship year using the assumption that 5% fatalities occur in slow sinking and 80% in fast (capsizing/sinking). Reducing the fatality rate for fast sinking to 60%s would decrease the overall risk by 13%. Similar effect would be seen from changes in the year-round occupancy rates, which are highly market, seasonal and ship type/category dependent.

The fatality rates represent average (representative) consequences for the scenarios slow and fast sinking. The rates were specified in GOALDS project by expert judgement considering casualty reports, observation in model tests as well as numerical investigations (including simulations) on the stability behaviour of ships after water ingress. Representative consequences mean that all possible outcomes are merged into one, i.e. all possible fatality rates for ship sinking after collision are merged into the scenarios slow and fast sinking.

In this project additional information with respect to fatality rates were collected considering *all accident* categories (summarised section 7.3.4) and investigated with respect to reviewing or providing data supporting currently used fatality rates. Information is collected for the period 1990 to 2012 for Cruise and RoPax built after 1980. It is not surprising that the number of reported accidents and their fatality rates are small, i.e. 24 total losses and 19 serious accidents. Most of accidents with fatalities are reported for fire & explosion (15) and foundering (12). For collision, no total loss is reported, whereas they were seven serious accidents. Details of the collision accidents with respect to scenarios leading to fatalities are not available and therefore no conclusions can be drawn for the relation between this data and scenarios in the risk model. Available data for accidents leading to a loss of ship shows higher fatality rates than for serious accidents. In particular, the collected foundering accidents lead to either low (< 20%) or high (> 20%) fatality rates. When grouping the fatality rates in two subsets using 20% as a boundary, the average fatality rates are 4% and 60%. Foundering accidents are always interpreted as loss of ship accidents (sinking) and it may be concluded that fatality rate in such accidents is low, if time for evacuation was sufficient, and vice versa high if sinking fast. However, this means neglecting the effect the weather conditions, which are typically bad in foundering accidents, have on evacuation. Focusing only on the fact that the ship sinks and neglecting the effect of weather, the information shows that if things went good average fatality rate is about 4% if not the average rate is about 60%.

The present analysis shows that available information is limited and therefore does not allow a more granular consideration the consequences, i.e. various fatality rates for fast and slow sinking. Likewise to other FSAs the assigned fatality rates are representative values for all possible outcomes.

Based on this discussion and the information summarised below the values for fatality rates in the risk model are kept unchanged with respect to the GOALDS project, i.e. 5% and 80 %. For consideration of the various probabilities in fatality rates Gauss-Normal distribution is used (Figure 7-11). The characteristic values for the distribution are estimated using the fatality rates discussed in section 7.3.4 (Figure 7-12).

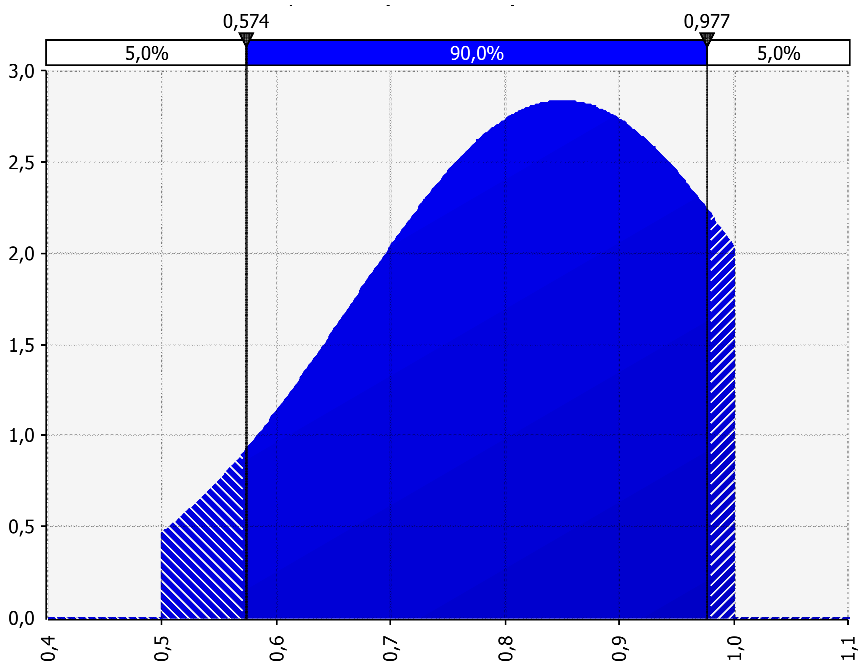


Figure 7-11 Gauss-Normal distribution (truncated) used for the probability of fatality rate for fast sinking.

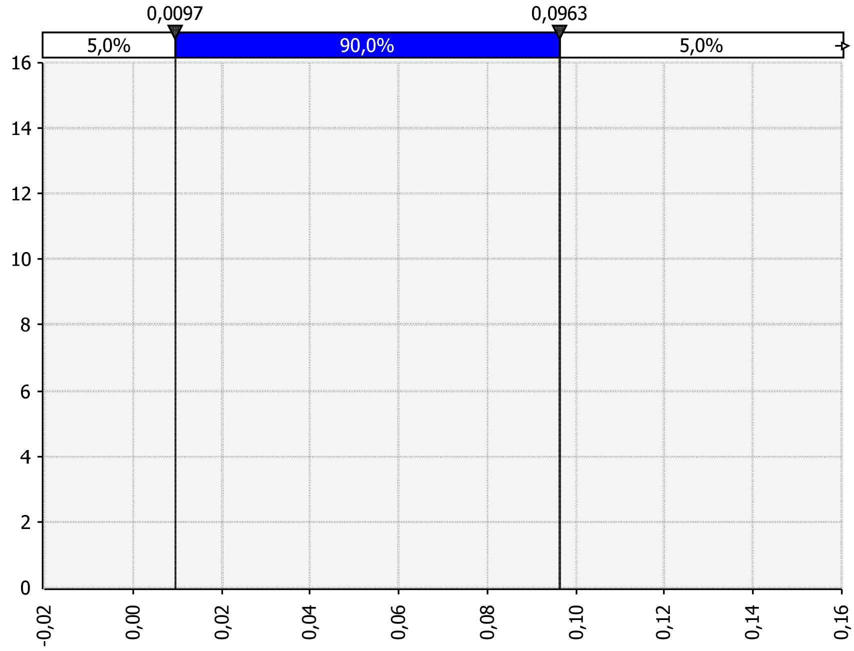


Figure 7-12 Gauss-Normal distribution (truncated) used for the probability of fatality rate for slow sinking.

7.1 Updated Collision Risk Model

The updated collision risk model is shown for cruise ship in Figure 7-13 (large) and for RoPax in Figure 7-14 (large).

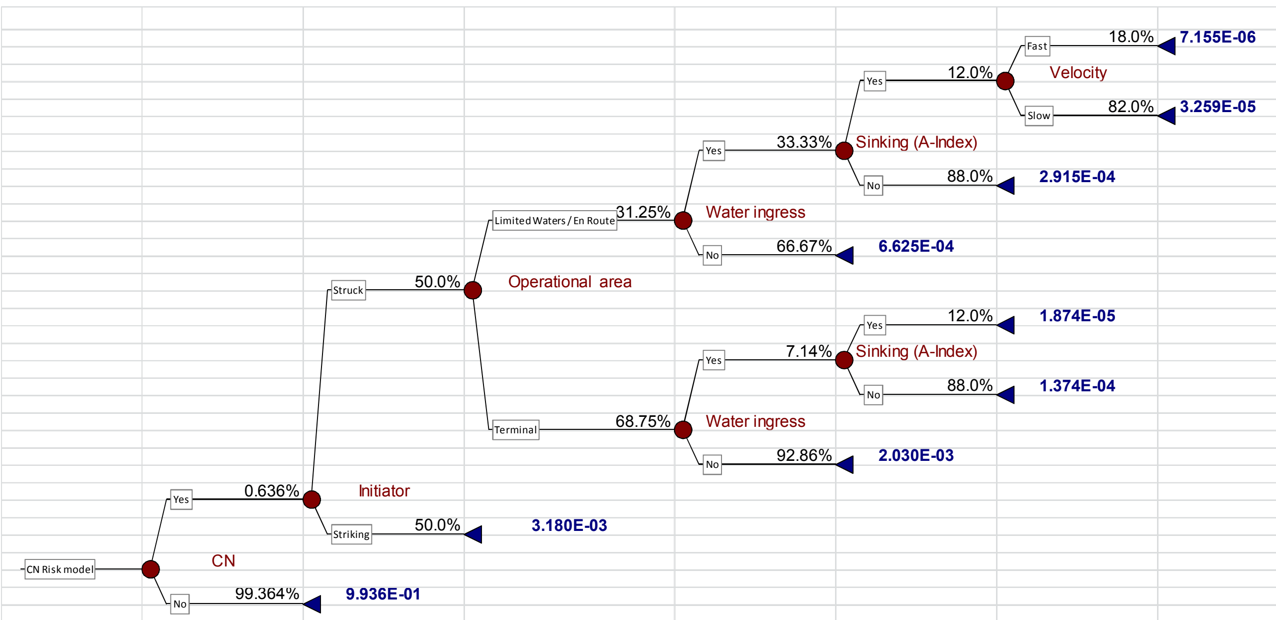


Figure 7-13 Collision risk model for cruise ship (large) developed as Event Tree. Probabilities/frequencies are mean values.

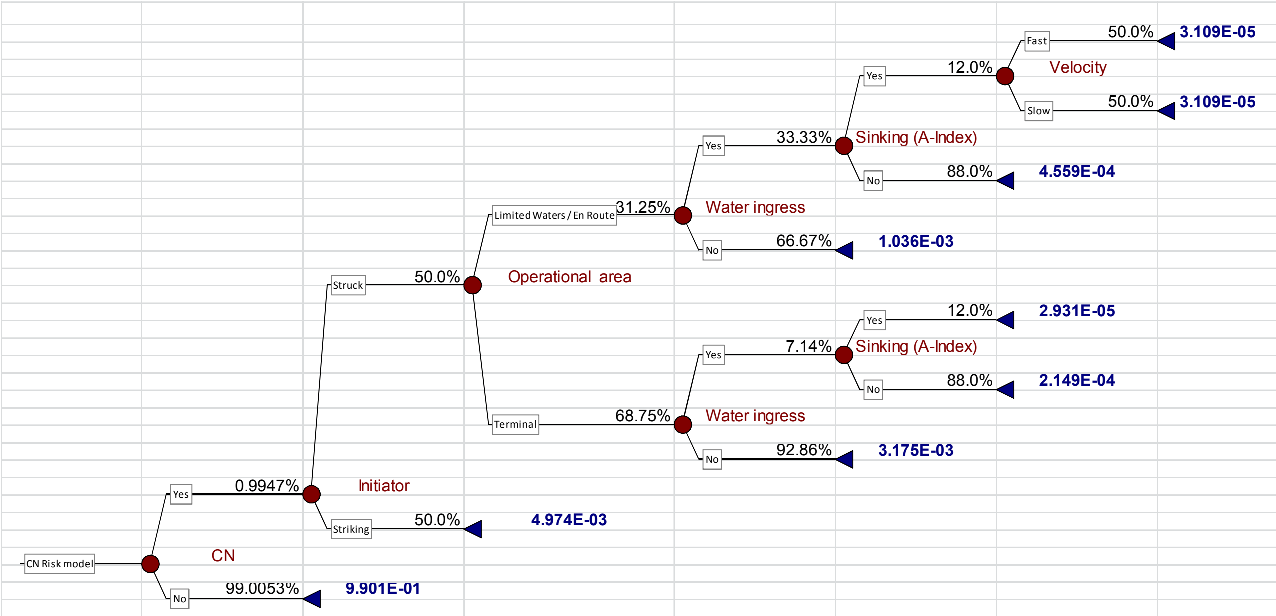


Figure 7-14 Collision risk model for RoPax ship (large) developed as Event Tree. Probabilities/frequencies are mean values.

Using this risk model, the PLL is calculated (Monte Carlo Simulation) in terms of a distribution as shown in the following for the three cruise ship size categories small (Figure 7-15), medium (Figure 7-16) and large (Figure 7-17). The figures also show the characteristic values like mean, standard deviation and 90% confidence interval. For example for the medium cruise ship the mean PLL is 5.6E-02 per ship year, which is higher than the value calculated using the static values (mean values for the nodes in the event tree), namely 4.4E-02. As shown the 90% confidence interval is large stretching from 8.2E-03 per ship year to 1.5E-01 per ship year.

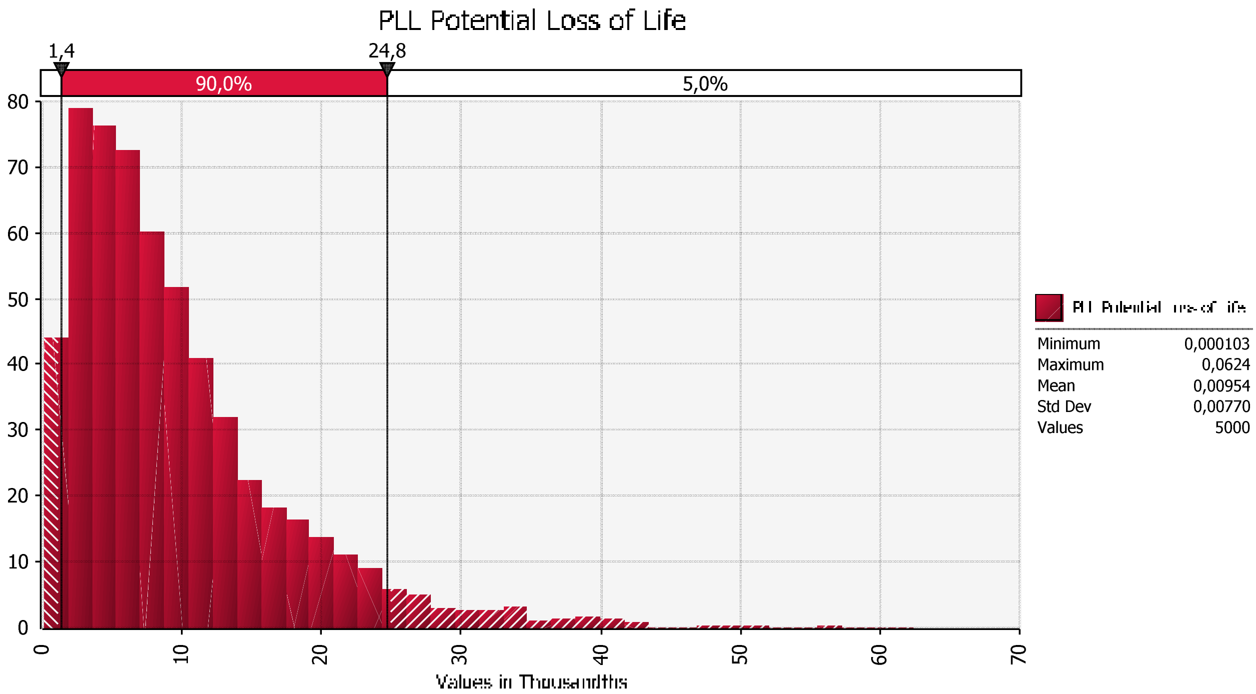


Figure 7-15 PLL distribution for small cruise ship with maximum capacity of 400 persons and 90% occupancy.

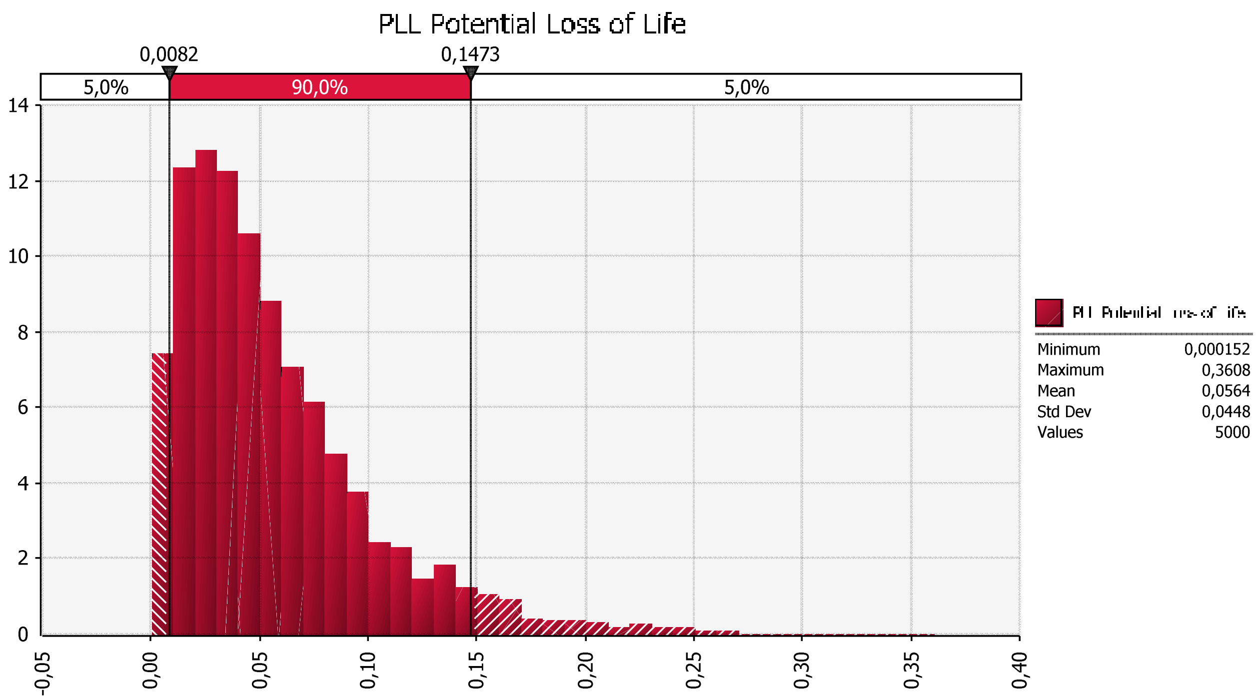


Figure 7-16 PLL distribution for medium cruise ship with maximum capacity of 4,000 persons and 90% occupancy.

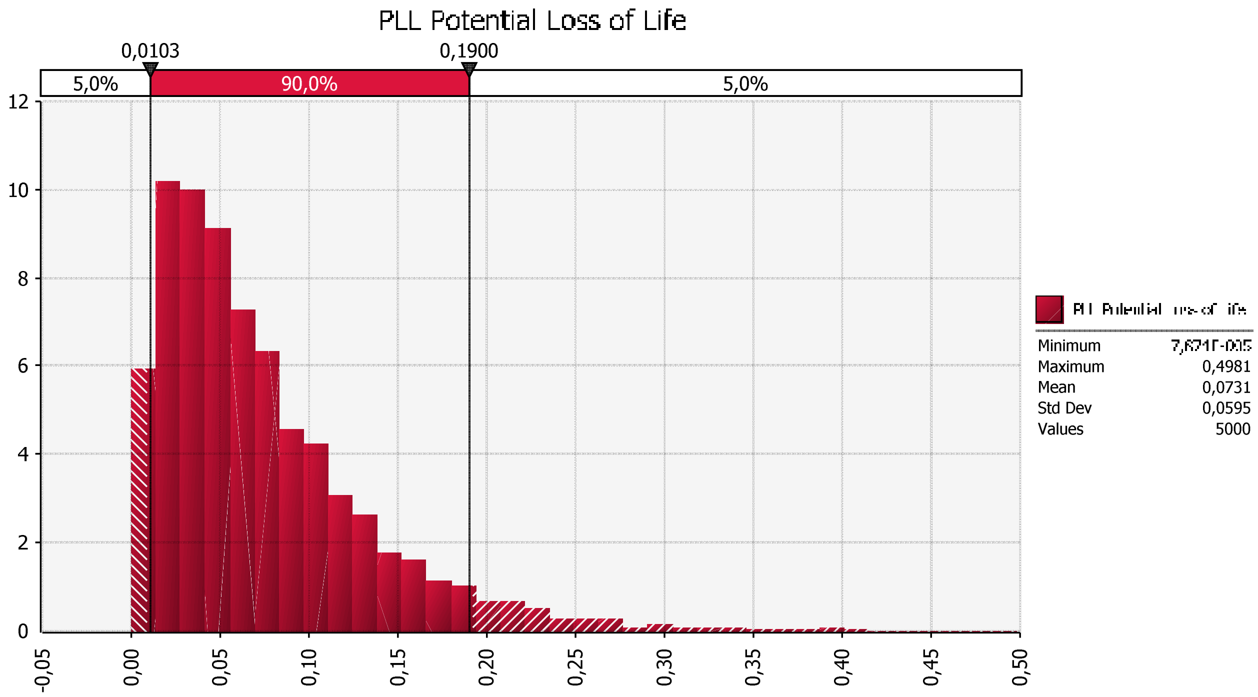


Figure 7-17 PLL distribution for large cruise ship with maximum capacity of 6,730 persons and 90% occupancy.

The development of the risk model for the medium size cruise ship in terms of PLL per ship year plotted versus different attained indices and considering uncertainty is shown in Figure 7-18. These results relate to 90% occupancy rate.

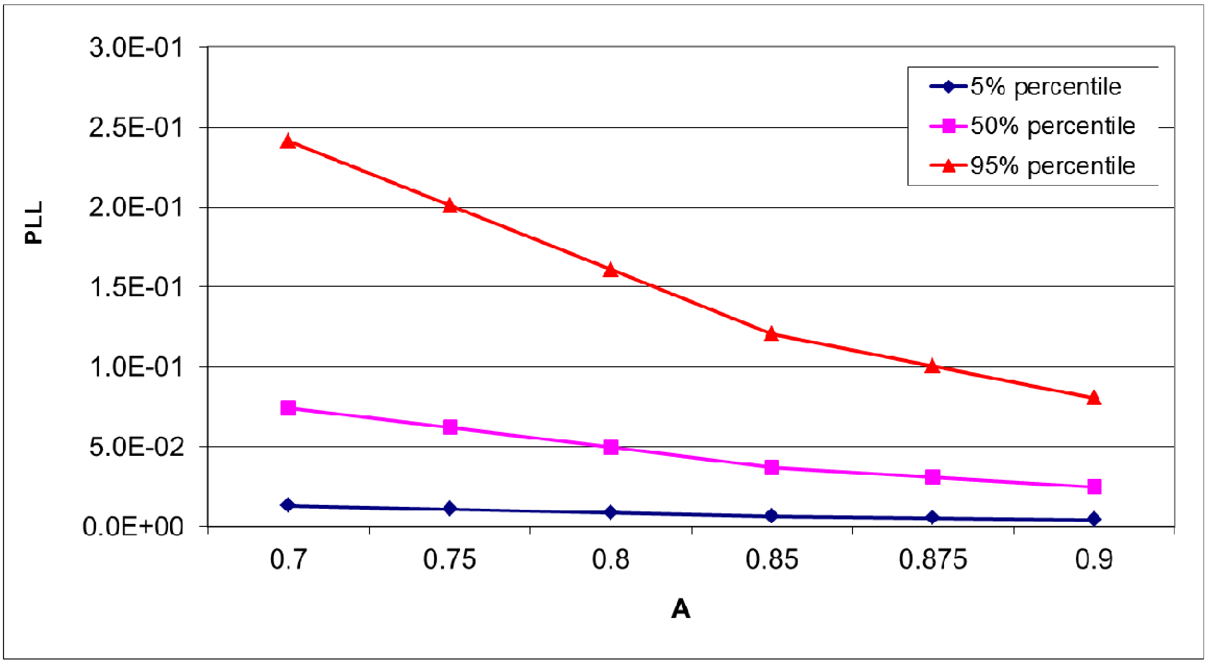


Figure 7-18 PLL for medium size cruise ship plotted over attained index A.

The CAF values specified for this investigation are 4 and 8 million US Dollar as was the suggestion from the work documented in the first interim report and accepted for use by EMSA. These values are used to calculate the monetary thresholds as input for the cost-benefit assessment in form of cost thresholds plotted versus ∆A-Index (Figure 7-19,Figure 7-20,Figure 7-21). These figures show mean value as well as 5% and 95% percentile for the costs which would provide a "band" for assessing cost effectiveness.

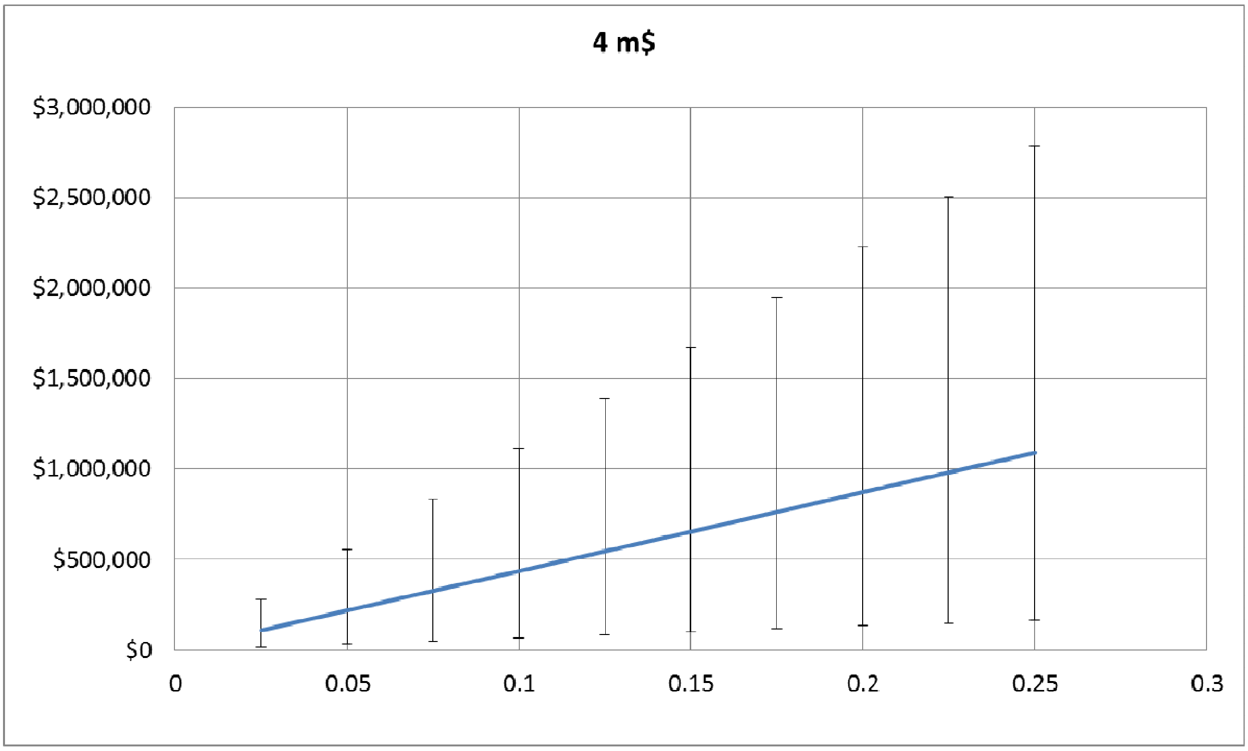


Figure 7-19 Cost threshold for 4 m$ CAF for small size cruise ship plotted over ∆A and including 5% and 95% percentile confidence.

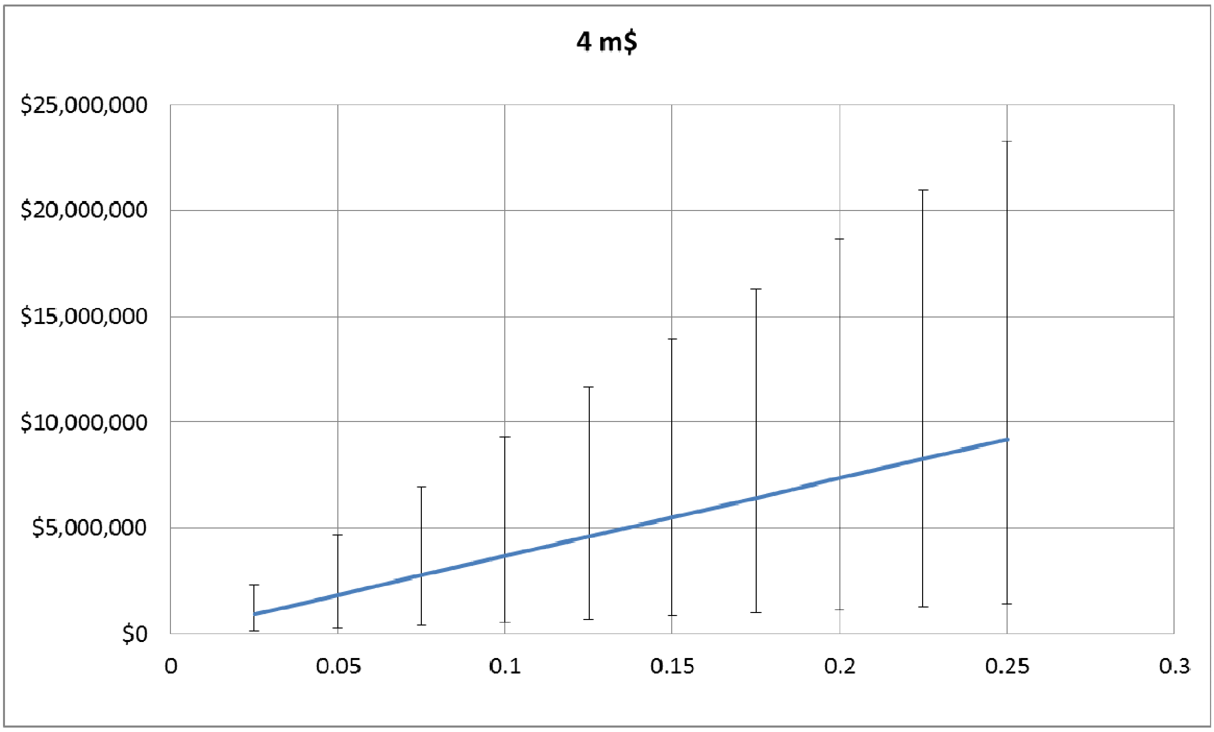


Figure 7-20 Cost threshold for 4 m$ CAF for medium size cruise ship plotted over ΔA and including 5% and 95% percentile confidence.

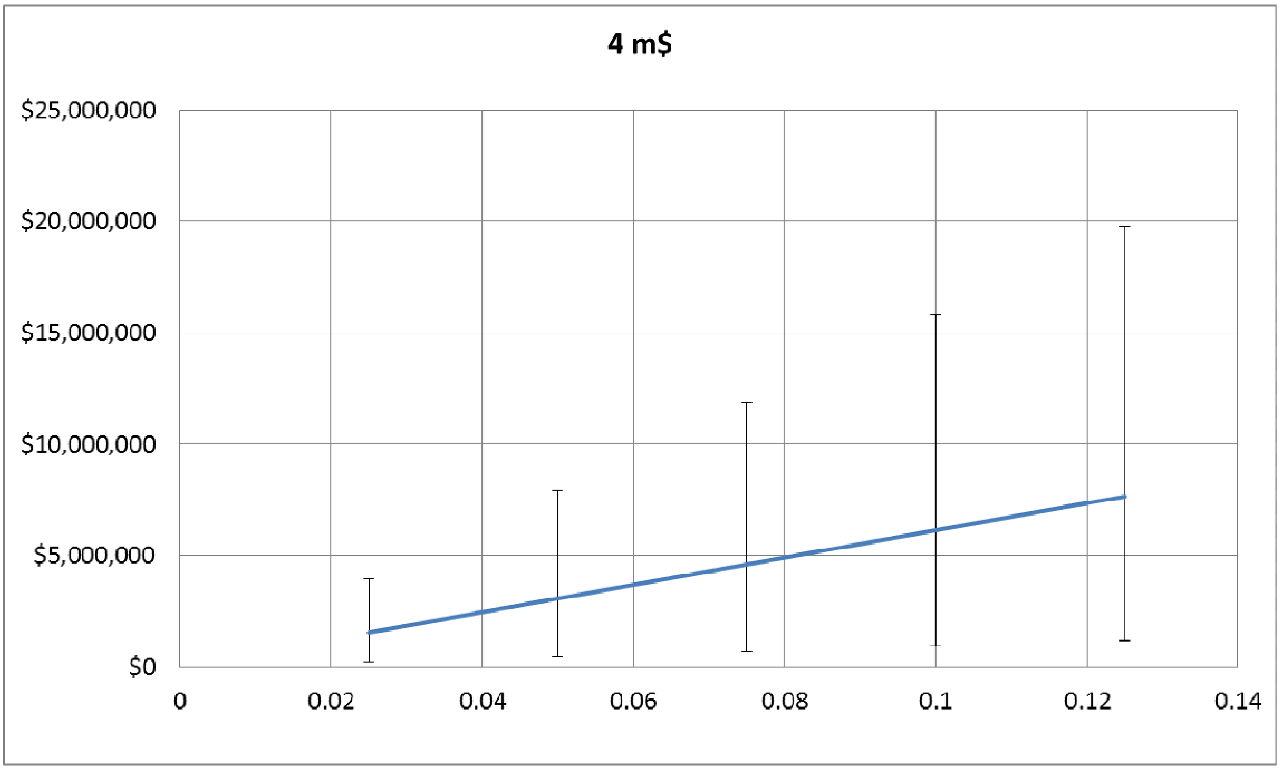


Figure 7-21 Cost threshold for 4 m$ CAF for large size cruise ship plotted over ΔA and including 5% and 95% percentile confidence.

7.2 Sensitivity Analysis

In this section the sensitivity of the risk model is discussed using the high-level event sequence for orientation in the risk mode (lFigure 7-22). The sensitivity is analyzed by means of the medium size cruise ship and finally the differences in the risk model for RoPax are discussed.

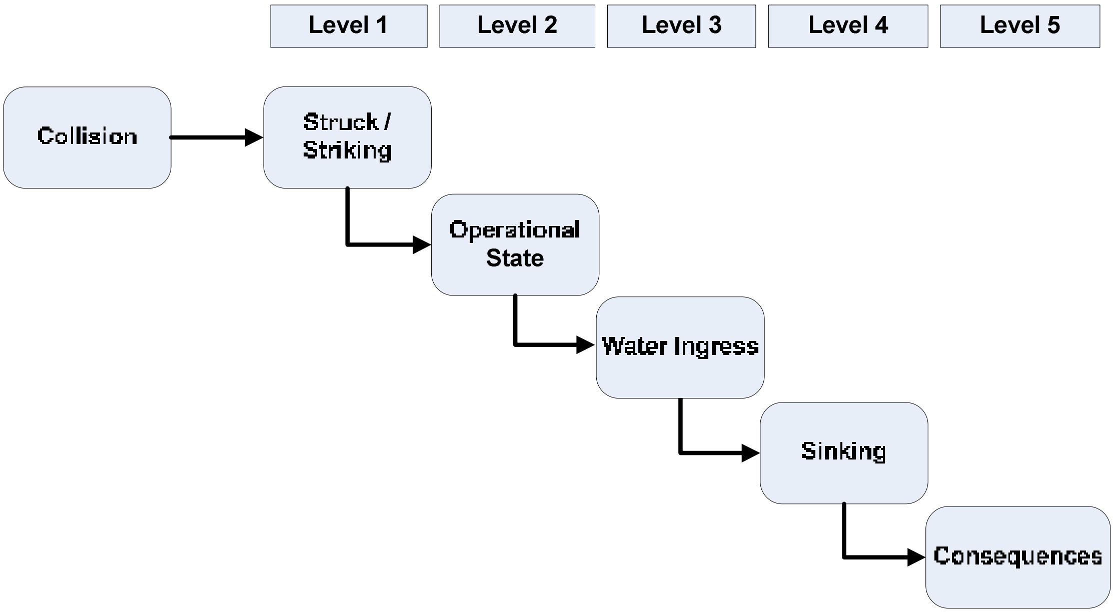


Figure 7-22 High-level event sequence for collision of Cruise and RoPax

The analyses carried out show that the risk to person on board in terms of PLL depends linearly on the initial accident frequency, i.e. an increase of the initial accident frequency by 10% lead to 10% increase of PLL (10% is about two more collisions in 13 years period). The same is observed for the parameter struck/striking where approximately seven additional struck collisions would cause an increase in the risk by 10%. A lower sensitivity is observed for the operational state. An increase of 10% in the dependent probability for accidents outside of the terminal area leads to an increase of the risk by ~8.5%. However, due to the small number of casualty reports only two more accidents "en route" would lead to an increase by ~11% of the dependent probability and 9.7% PLL. Two more accidents in "terminal area" would lead to a decrease of PLL by 4.8%.

Dependent probability for water ingress in "terminal area" is based on 14 casualty reports of which only one case lead to water ingress. One additional accident leading to water ingress would change the dependent probability significantly (~86%) but has a smaller effect on the risk (+ 9%).

Dependent probability for water ingress "en route" and "limited water" is based on six casualty reports of which two reported water ingress. One additional accident leading to water ingress would change the dependent probability significantly (~29%) and also in the risk (+ 25%).

Also a significant influence is observed for the relation between fast and slow sinking (fast sinking leads to 80% fatality rate) considered in the event sequence for collision "en route" and "limited waters". For cruise ship that for 18% of ship loses the ship will sink fast. A doubling of this value would lead to an increase in risk by ~63%.

The occupancy also lineary influences the risk, i.e. a decrease of occupancy by 10% leads to a decrease in risk by 10%.

The number of casualty reports for RoPax vessel I significantly higher than for cruise ships and therefore the effect on the risk of one additional accident is rather small (~1.9%; cruise ship 5.9%).

For RoPax ships three different occupancy rates are considered (100% occupancy for 12.5% of the year; 75% occupancy for 12.5% of the year and 50% occupancy for 62.5% of the year). A reduction in occupancy reduces the risk, for instance using 30% instead of 50% occupancy would reduce PLL by ~14%.

7.3 Comparison between GOALDS and Updated Model

In this paragraph, the dependent probabilities of the collision risk models that were used in the GOALDS project as well as the findings of current investigation are presented and discussed.

7.3.1 Level 1 – Struck/Striking

In the GOALDS project, the probability of struck/striking vessel was considered as ship subtype dependent and the values used in the Event Tree analysis are included in table Table 7-2.

Table 7-2 Struck/Striking- values used in GOALDS

Cruise		RoPax	
$P_{STRUCK \mid Cruise/Pax \mid Collision}$	0.38	$P_{STRUCK \mid RoPax/RoPax\text{-}Rail \mid Collision}$	0.69
$P_{STRIKING \mid Cruise/Pax \mid Collision}$	0.62	$P_{STRIKING \mid RoPax/RoPax\text{-}Rail \mid Collision}$	0.31

Updated results derived from the current investigation are presented in the Table 7-3 . For each ship subtype, the percentage of struck, striking and unknown is given.

Excluding the unknown cases, the struck/striking percentage for the cruise ships is 42% / 58% respectivelly, whereas for the RoPax ships the corresponding percentages are 53% and 47%.

Table 7-3 Struck/Striking - Updated values

Cruise				RoPax		
Struck	8	35%		Struck	25	35%
Striking	11	48%		Striking	22	31%
Unknown	4	17%		Unknown	25	35%
total	23			total	72	
Struck	8	42%		Struck	25	53%
Striking	11	58%		Striking	22	47%
Unknown				Unknown		
Total number	19			Total number	47	

Merging data from both ship subtypes, the probability of struck-striking is 50%-50%. Table 7-4 presents the struck and striking numerical values and the lower and upper confidence intervals for the struck vessels considering 90% confidence.

Table 7-4 Struck/Striking-Merged values for Cruise and RoPax

Struck	33
Striking	33
SUM	66
For Struck	
lower confidence level[3]	0.39284358
upper confidence level	0.60715642
mean	0.5

In conclusion the probability of 50% /50% struck/striking ship calculated by merging both ship subtypes can be used for the updated risk model, since the range of the confidence intervals includes all relevant values.

7.3.2 Level 2 – Operational State

In the GOALDS project, the used distribution of operational state is given in the Table 7-5. The particular values are considered independent of ship subtype.

Table 7-5 Operational state – Values used in GOALDS

$P_{EN\text{-}ROUTE|STRUCK|Collision}$	0.04
$P_{LIMITED\ WATERS|STRUCK|Collision}$	0.23
$P_{TERMINAL\ AREAS|STRUCK|Collision}$	0.73

Similarly, the updated values from the current investigation are given in Table 7-6.

Table 7-6 Operational state – Updated values

Struck ships - Operational State		
Terminal areas	22	67%
Limited waters	8	24%
En Route	3	9%
Total number	33	

[3] 90% confidence interval

Merging both groups (Limited waters + En Route) yields results as shown in Table 7-7.

Table 7-7 Operational state – Values when merging "Limited waters" and "En Route"

Struck ships	
Limited / En Route	11
Terminal	22
SUM	33
For Terminal	
lower confidence level	0.50914
upper confidence level	0.80052
mean	0.667[4] ()

7.3.3 Level 3 – Water Ingress

In the GOALDS project, two different considerations were assumed with respect to the water ingress, as illustrated in Table 7-8, given the fact that the particular probability is independent from ship subtype.

Table 7-8 Water ingress as applied in GOALDS

Limited waters & En-Route in Open Sea (Taking into account the unknown cases as potential existence of water ingress)	
$P_{WATER\ INGRESS|STRUCK|COLLISION}$	0.43 [0.35 (unknown) +0.08 (existence of W.I.)]
$P_{NO\ WATER\ INGRESS|STRUCK|COLLISION}$	0.57
Terminal Areas (Excluded unknown cases)	
$P_{WATER\ INGRESS|STRUCK|COLLISION}$	0.12
$P_{NO\ WATER\ INGRESS|STRUCK|COLLISION}$	0.88

In Limited waters and En-Route in Open Sea: 43% existence of water ingress – 57% no water ingress. During the operation in limited waters or in the open sea the ship has a considerable speed, thus the impact is expected to be more severe than in terminal waters (unknown information in records was interpreted as potentially existence of water ingress).

In Terminal Areas: 12% existence of water ingress – 88% no water ingress. The values have been calculated excluding the unknown cases from the sample.

[4] For risk model 75% as mean value used; Log-normal distribution truncated

The updated results according to the present study are presented in the following tables:

Table 7-9 Water ingress – updated values including unknown

Struck ships - Water Ingress		
Yes	3	9%
No	17	52%
Unknown	13	39%
Total	33	

Focusing on data with registered information on water ingress (sample of 20 cases), the next two tables. Table 7-10 and Table 7-11 present the distribution of events occurred in "Terminal Areas" and in "Limited waters and En-Route in Open Sea", along with the mean values and confidence intervals.

Table 7-10 Water Ingress in Terminal Areas

Yes	1
No	13
	14
Water ingress: Yes	
lower conf level	0.0036571
upper conf level	0.29673424
mean	0.07142857

Table 7-11Water Ingress in Limited waters + En route

Yes	2
No	4
	6
Water ingress: Yes	
lower conf level	0.06284989
upper conf level	0.72866163
mean	0.33333333

Thus, the following values for the relevant branches in the Event Tree are proposed:

<u>In Terminal Areas:</u> 7.1% occurrence of water ingress

<u>In Limited waters and En-Route:</u> 33.3% occurrence of water ingress

It should be noted that that all relevant values are included in the calculated confidence intervals.

7.3.4 Comparing the model with historical data

A comparison of the assumptions for the consequences of different scenarios of the risk model is presented, with particular emphasis on the number of fatalities. Two different sources are investigated in order to evaluate or/and propose possible revised values for discussion.

NTUA-SDL Database

From the NTUA-SDL Database, regarding the Cruise ships the followings were extracted:

No ship's total loss due to collision was registered in the database. Only in one case, the ship sunk but was subsequently raised and drydocked.

Regarding the number of fatalities, in only one event 4 fatalities were registered. In the particular event, the Cruise ship was the struck vessel suffering a side opening below the bulkhead deck with water ingress reported. The ship remained afloat. The number of persons onboard at the time of accident was unknown, thus based on the registered Persons On Board (POB=2063), the resulting *fatality rate is 0.194%.*

Regarding the RoPax ships, no total loss was registered in the database and no fatalities were reported for collision accidents.

Analysis from SEAWEB database

From the SEAWEB database, casualty records from various types of accidents were analyzed with respect to the number of fatalities. The studied time period is 1990-2012, pertaining to Passenger ships, Cruise and RoPax ships built after 1980 and without any limitation to the ship size.

Fatality rate definition

- When the persons on board at the time of accident (POBreal) is given, *Fatality rate= Number of fatalities/ POBreal*.
- If POBreal is unknown then "POB" (Persons On Board) registered in SEAWEB is used for the calculation, *Fatality rate= Number of fatalities/ POB*.

- If “POB” (Persons On Board) is not registered in SEAWEB, the registered number of passengers is used, *Fatality rate= Number of fatalities/ Number of passengers*.

It should be noted that there is no information on the distribution of fast/slow ship’s sinking. Thus, accounting only for total losses (24 cases in total), the fatality rate by accident category is given in the next table. For example, Event Case 1 is a contact case thus the relevant fatality rate 0.010 appears in the column “Contact-Fatality Rates”.

Table 7-12 Fatality rates for accidents leading to total loss

Event case	Collision-Fatality Rates	Contact-Fatality Rates	Wrecked/ Stranded-Fatality Rates	Foundered-Fatality Rates	Fire/ Explosion-Fatality Rates
1		0.010			
2			0.002		
3					0.008
4				0.655	
5				0.172	
6			0.045		
7			0.021		
8				0.003	
9					0.003
10				0.006	
11				0.006	
12				1.000*	
13				0.866	
14			0.983		
15					0.542
16					0.216
17				0.294	
18					0.207
19				0.772	
20					0.059
21				0.013	
22				0.006	
23				0.049	
24					0.001

* NOTE: In this particular case, the vessel was overloaded.

The average fatality rate, the median and the 25% and 75% percentiles are given inTable 7-13 for different combinations of assumed accident categories, namely:

CN+CT+GR+FD+FE: collision, contact, grounding, foundered, fire/explosion

CN+CT+GR+FD: collision, contact, grounding, foundered

CN+CT+GR: collision, contact, grounding

Table 7-13 Average fatality rates

	Average Fatality rate	Median	percentile-25	percentile-75
CN+CT+GR+FD+FE	0.247	0.047	0.006	0.356
CN+CT+GR+FD	0.288	0.045	0.006	0.655
CN+CT+GR	0.212	0.021	0.010	0.045

The average fatality rate, the median and the 25% and 75% percentiles are given next separately for each accident category.

Table 7-14 Average fatality rates for each accident category

	Average Fatality rate	Median	percentile-25	percentile-75
Collision				
Contact	0.010	0.010		
Grounding	0.263	0.033	0.016	0.279
Foundered	0.320	0.111	0.006	0.685
Fire/Explosion	0.148	0.059	0.005	0.211

Fire/Explosion events seem to be irrelevant for the particular subject under investigation. Also, it should be noted is that it is not considered likely to have a ship’s fast sinking because of a Fire/Explosion event.

Taking into account the fatalities from foundered cases might be under discussion as well.

Accounting only serious cases but **excluding total losses**, fatality rates by accident category are given in the following table:

Table 7-15 Summary of serious accident without sinking of vessel

Event case	Collision-Fatality Rates	Contact-Fatality Rates	Wrecked/ Stranded Fatality Rates	Foundered-Fatality Rates	Fire/ Explosion-Fatality Rates
1		0.002			
2					0.000
3					0.001
4	0.317				
5	0.031				
6					0.017
7	0.003				
8	0.027				
9			0.009		
10					0.189
11					0.135
12					0.008
13					0.010
14					0.010
15	0.002				
16	0.004				
17		0.000			
18	0.001				
19					0.000

	Average Fatality rate	Median	percentile-25	percentile-75
CN+CT+GR+FD	0.040	0.004	0.002	0.022
	3.96%	0.37%	0.20%	2.22%

8 NEW PASSENGER SHIP DESIGNS

New designs of 6 passenger ships have been developed to form the basis for the optimization and benchmark for the subdivision index, as well as for grounding and the effect of open water tight doors.

All designs comply with the current statutory rules and regulations, e.g. SOLAS2009 including SRtP where applicable. The design of the Ropax vessels use the revised formulation for the s-factor to consider water on deck as agreed atSLF55 and approved by SDC1.

The designs have been selected in close cooperation between the designers and ship operators in such a way that the world fleet will be well represented.

Table 8-1 Overview of sample ships

No	Yard	Type	Length bp	Breadth	Draught	Gross Tonnage	Number of Persons
1	MW	Large cruise	294,64 m	40,80 m	8,75 m	153400	6730
2	FC	Small cruise	113,70 m	20,00 m	5,30 m	11800	478
3	STX-FIN	RoPax Baltic	232,00 m	29,00 m	7,20 m	60000	3280
4	STX-FRA	RoPax Mediterranen	172,40 m	31,00 m	6,60 m	43000	1700
5	KEH	RoPax ferry	95,50 m	20,20 m	4,90 m	7900	625
6	KEH	Double end	96,80 m	17,60 m	4,30 m	5040	610

Figure 8-1 shows the current distribution of ro-ro passenger and cruise ships. The ships that were used in the GOALDS project are indicated in the figure as well as the selected designs in this project. It can be seen that the selection of sample ships covers the whole range of the world fleet with regard to ship size and number of persons on board. Based on the feedback from the EU member states a small double ender RoPax ferry has been added to the original set off ships to cover in a better way the fleet of passenger ship operating in the EU.

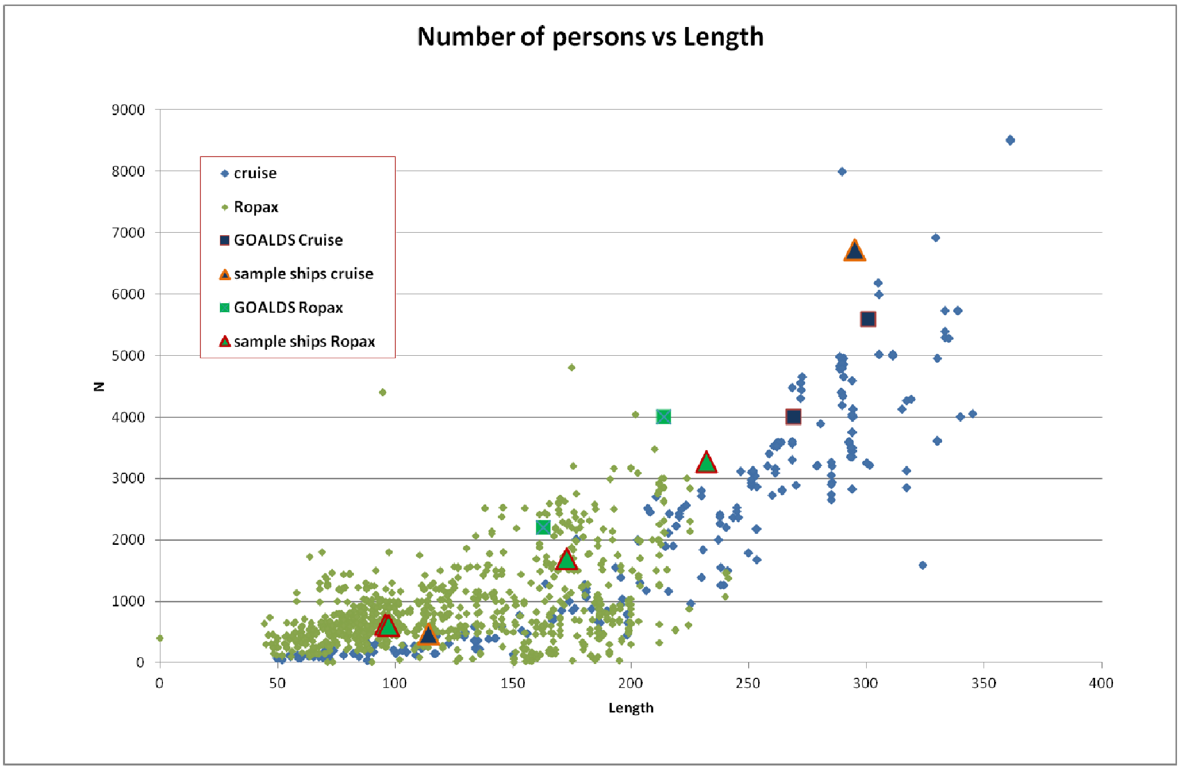


Figure 8-1 Distribution of world fleet RoPax and Cruise

Also with regard to the covered range of required subdivision index the sample of ships to be investigated closes the gaps left by the GOALDS study.

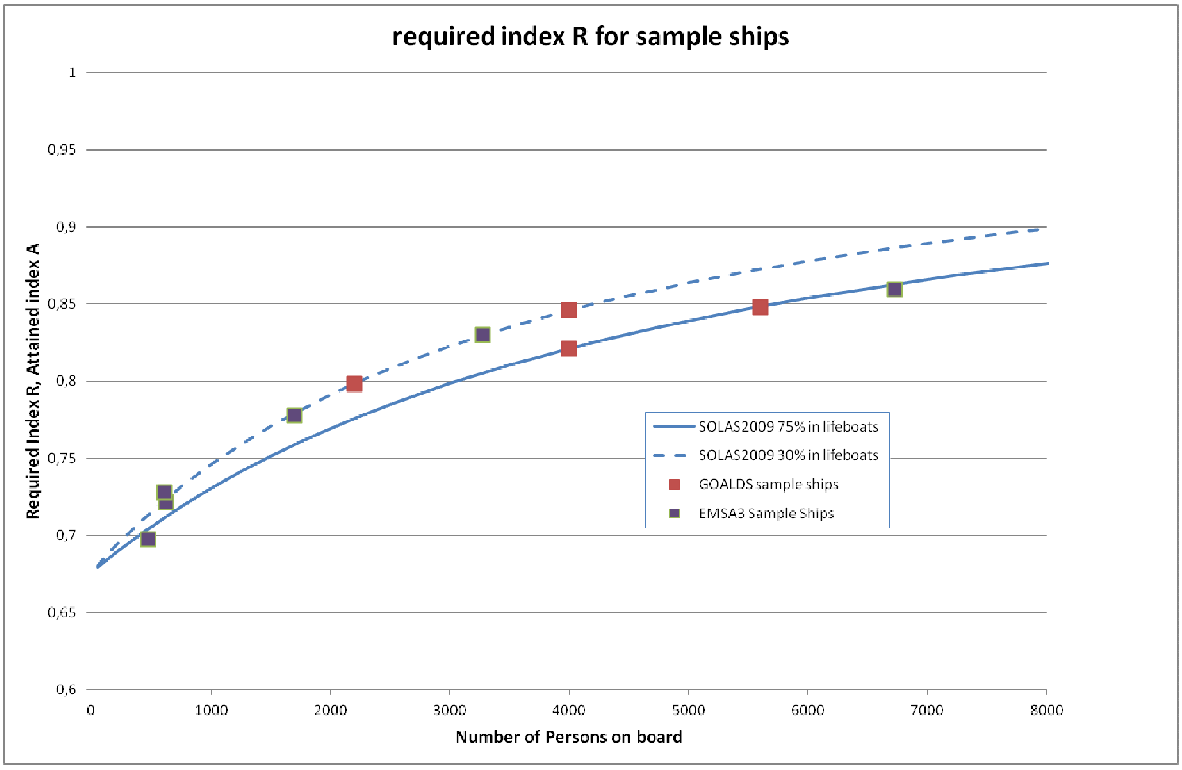


Figure 8-2 Required index for passenger ships

The ro-ro passenger ships represent typical designs for specific routes and their functional requirements, including one route in the Baltic Sea and one in the Mediterranean. Also for the cruise ships specific functional requirement have been agreed with the operators to reflect realistic designs.

The functional requirements of the designs are completed by operational profiles to form a business model for each ship. This business model will be kept constant during the optimization process to allow a fair and realistic comparison of the design options.

The detailed design is worked out by design teams consisting of a shipyard/designer and an operator for each ship. In the following pages each basic design is described more in detail.

8.1 Ship #1 Large Cruise Ship

8.1.1 Business Model

As the basis for the design of this ship a business model has been agreed with the operator to define the basic parameters which need to be fulfilled. These parameters and the business model will be kept unchanged throughout the design process and also during further design studies during a later stage of this project.

The vessel is designed as a worldwide operating cruise vessel for itineraries between 7 and 14 days.

Following main parameters are to be kept to maintain the business model of this vessel:

1. 2050 guest staterooms whereof approximately 78% have sea view and approximately 70% are balcony cabins. The required percentage of cabins for disabled persons according CLIA guidelines
2. 5100 passengers
3. 1580 crew berths where of approximately 50 in single cabins (officers) and the remaining in double cabins
4. Public rooms on lower decks
    a. Main theatre with approximately 1000 seats
    b. One two-deck level main dining room with adjacent main galley
    c. 12000 m² of other public spaces, like small restaurants, casino, shops, bars etc
5. Public rooms on upper decks
    a. Large lido restaurant with integrated galley
    b. Observation lounge in the front
    c. 4700 m² of other public spaces like spa area, night club, kids area etc
    d. Open pool area with 2 pools in centre and one pool aft
    e. Covered pool area with sliding roof
6. Two public staircases connecting with in total 14 lifts connecting all passenger decks including tender area
7. Two tender areas with access to tender platforms
8. Crew mess and recreation areas
9. Medical centre according CLIA guidelines
10. Provision rooms for 3 weeks
11. Storage rooms and workshops according to ship size
12. Laundry of suitable size
13. 11 crew lifts connecting all passenger decks and service corridor

14. Separate crew stair cases and corridors to connect all crew spaces and cabins without crossing passenger areas
15. Longitudinal service corridor without any watertight door to connect stores, provision areas, workshops, laundry area and crew lifts to allow suitable transport of goods
16. Restrictions of main dimensions
    a. Length over all < 330.0 m
    b. Maximum draught < 9.0m
    c. Maximum air draught on design draught <61.0m (Bridge of Americas)
17. Tank capacities
    a. Heavy Fuel Oil 3900 m^3
    b. Gas oil 700 m^3
    c. Potable water 4000 m^3
    d. Heeling water 1400 m^3
    e. Waste water 3200 m^3
18. Deadweight 11500t at design draught
19. Stability requirements to be complied with including 1500 t growth margin
20. Service speed with 100% pod power and 15% sea-margin 22 knots
21. Sufficient power of the transverse thrusters to sustain 16,7 m/s wind in worst condition
22. Operational profile: as an average 360 days per year in service, whereof
    a. 17% in port
    b. 17% low speed (12 knots)
    c. 30% medium speed (18 knots)
    d. 36% high speed (21 knots)

8.1.2 General Description of the Ship

This sample ship is a state-of-the-art design of a Post Panama sized modern cruise ship with size of 153000 GT. It is designed for worldwide cruises with capacity of more than 6700 persons onboard. The design of the vessel complies with all relevant international rules and regulations which are in force at the beginning of 2014.

Life saving appliances are provided for 6730 persons onboard for long international voyage. The vessel is a mono hull design with seven main vertical zones and watertight subdivision below the bulkhead deck including partial bulkheads on the bulkhead deck.

Most of the passenger cabins are in the superstructure, but there are more cabins located in the hull. Passenger public spaces are located on three decks in the hull. Further public spaces and sun decks are located on the top of the vessel.

The vessel has a diesel-electric type propulsion plant located in two watertight compartments. Two electric pod-propulsion motors and the corresponding equipment are located in separate watertight compartments.

The ship has following main characteristics:

Length over all	~318 m
Length between perpendiculars	294.60 m
Subdivision length	315.67 m
Breadth	40.80 m
Subdivision draught	8.75 m
Height of bulkhead deck	11.80 m
Number of passengers	5135
Number of crew	1595
Gross tonnage	153400 GT
Deadweight	11500 t
No of cabins	2050
GT/Stateroom	74.8
GT/Lower Bed	37.4
Service speed	22 knots
Trial speed	23 knots
Installed propulsion power	38000 kW
Installed power of main engines	76800 kW

8.1.3 Regulations

The design complies with all relevant IMO rules and regulations applicable for ships with keel layed after 1 January 2014, which includes following codes:

1. SOLAS1974 as amended, including probabilistic damage stability and "Safe Return to Port" (SOLAS2009)
2. Intact Stability Code (IS Code 2008)
3. Load line Convention
4. MARPOL, including fuel oil tank protection
5. MLC2006

8.1.4 General Arrangement

The following figure, show the General Arrangement plan

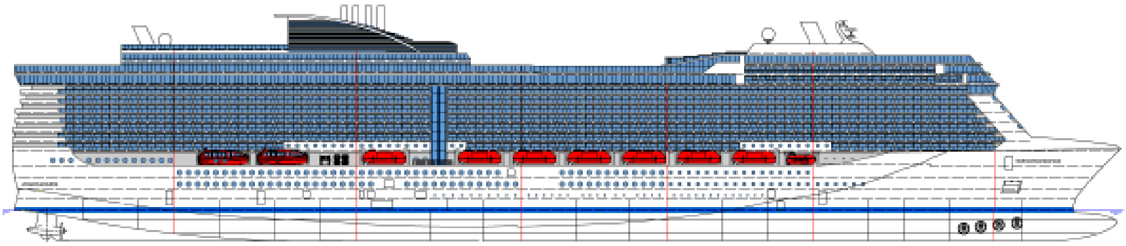


Figure 8-3 Profile – Large Cruise vessel

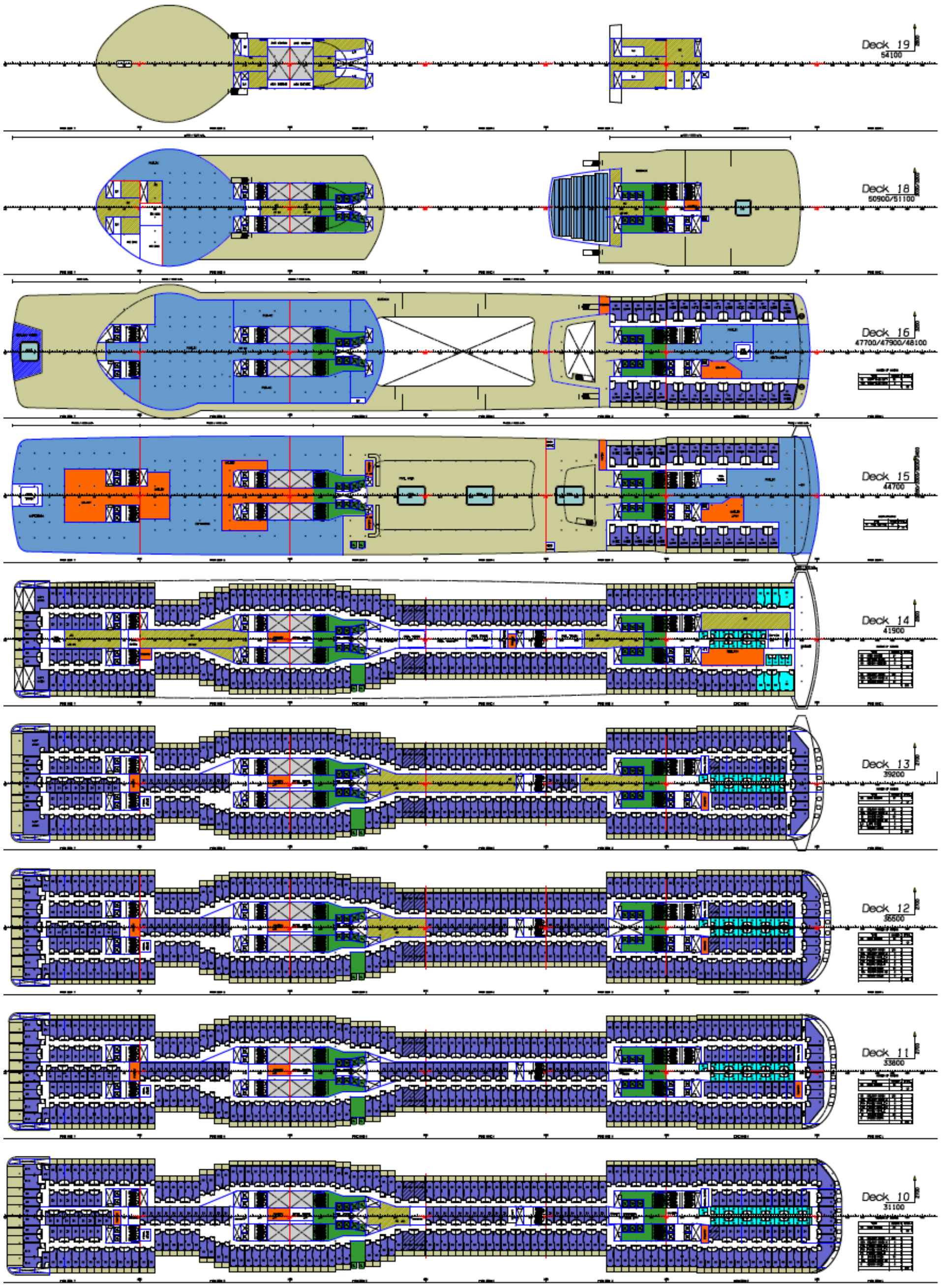


Figure 8-4 Deck 10 – 19 – Large Cruise Vessel

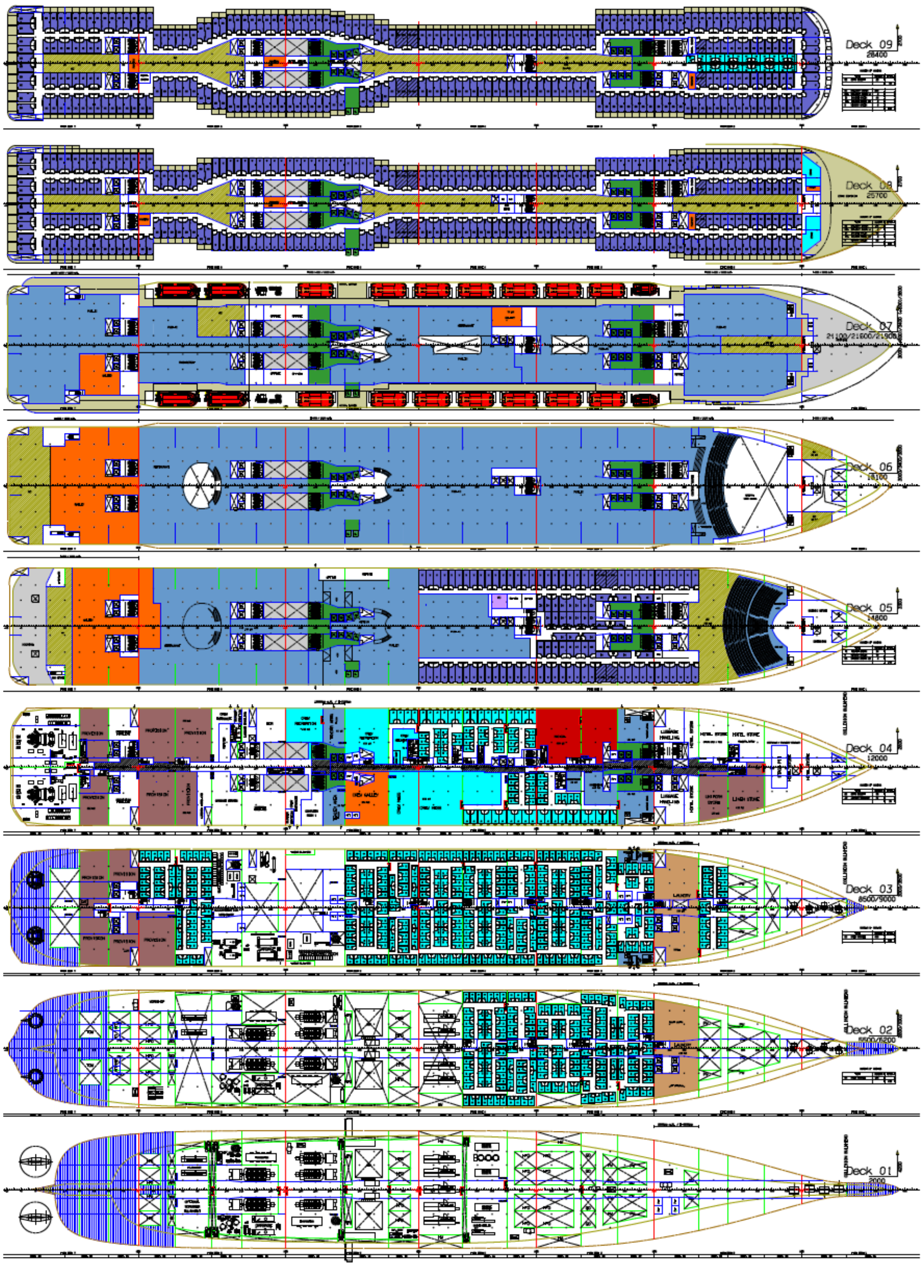


Figure 8-5 Decks 01 – 09 – Large Cruise Vessel

8.1.5 Hullform

The ship has a conventional modern hull form of a twin screw vessel with bulbous bow, slender skeg and transom stern.

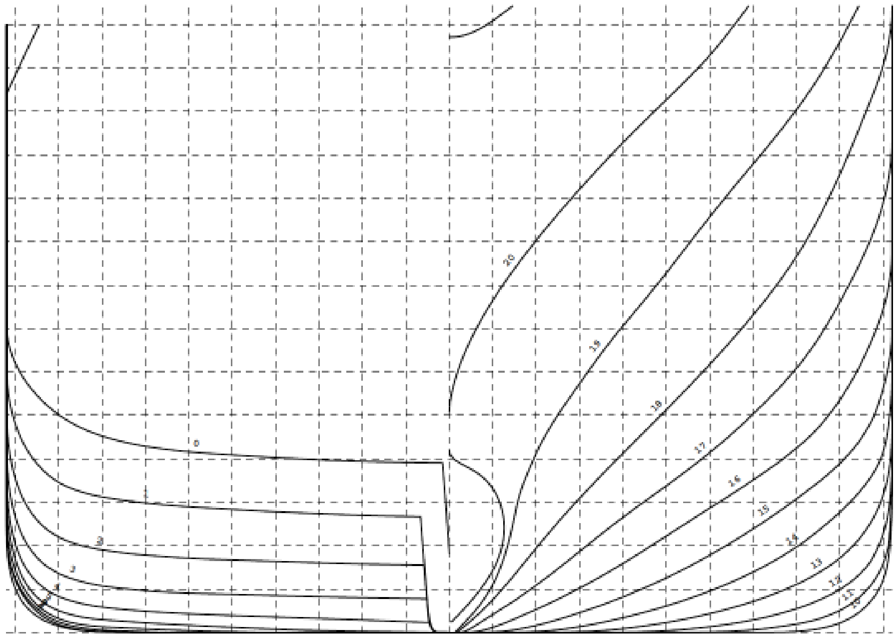


Figure 8-6 Body plan – Large Cruise Vessel

8.1.6 Engine configuration

The engine configuration is based on a diesel-electric concept with 5 power stations each consisting of a medium speed diesel engine with generator and two podded propulsors.
The engine plant is designed to deliver the full load (propulsion and hotel load) with four main engines running on maximum 95% MCR, while the fifth engine is installed as a back-up engine for redundancy purposes only. The hotel load required in port should be covered by one engine only.
The anticipated hotel load is 12500 kW under tropical conditions.

All five main engines are equipped with scrubbers to be able to burn heavy fuel with higher sulphur contents also within SECAs.

8.1.7 Tankplan and capacities

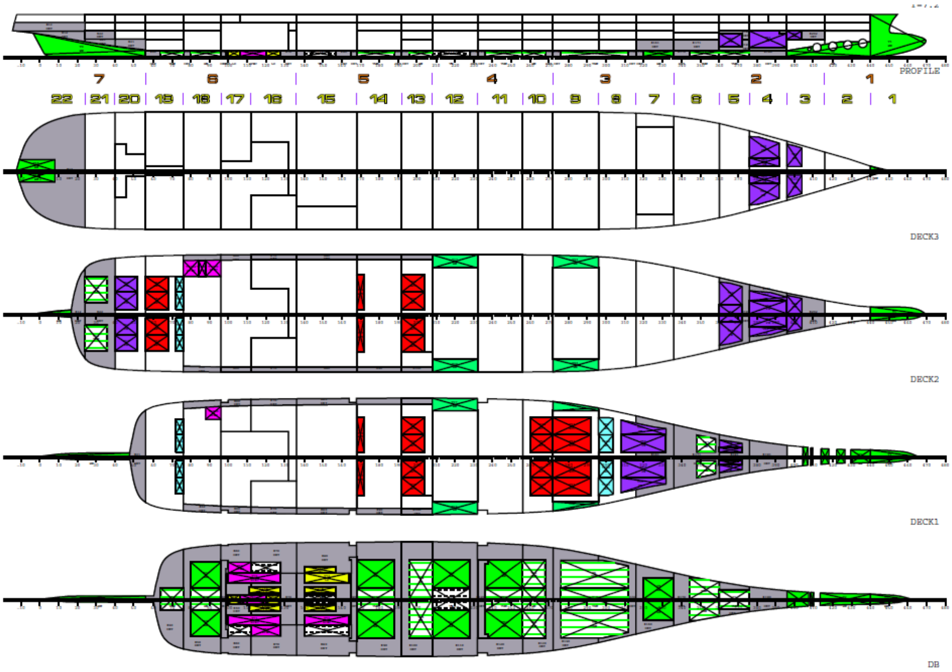


Figure 8-7 Tank plan – Large Cruise Vessel

The capacities achieved for the various purposes are shown in **Table 8-2**:

Table 8-2 Tank capacities– Large Cruise Vessel

Description	RHO	Volume	Requirement	DELTA	Weight
POTABLE WATER	1.000 t/m³	4101.35 m³	4000.00 m³	101.35 m³	4101.35 t
HEELING WATER	1.000 t/m³	1455.87 m³	1400.00 m³	55.87 m³	1455.87 t
BALLAST WATER	1.025 t/m³	3520.70 m³	3400.00 m³	120.70 m³	3608.72 t
TECHNICAL WATER	1.000 t/m³	504.17 m³	500.00 m³	4.17 m³	504.17 t
HEAVY FUEL OIL	0.980 t/m³	3917.72 m³	3900.00 m³	17.72 m³	3839.37 t
LUBRICATING OIL	0.900 t/m³	290.23 m³	275.00 m³	15.23 m³	261.21 t
GAS OIL	0.880 t/m³	732.87 m³	700.00 m³	32.87 m³	644.93 t
SPECIAL TANKS	1.000 t/m³	731.05 m³	500.00 m³	231.05 m³	731.05 t
GREY WATER	1.000 t/m³	854.50 m³	0.00 m³	854.50 m³	854.50 t
TREATED WASTE WATER	1.000 t/m³	2457.60 m³	0.00 m³	2457.60 m³	2457.60 t

8.1.8 Subdivision

Following subdivision is used for damage calculations:

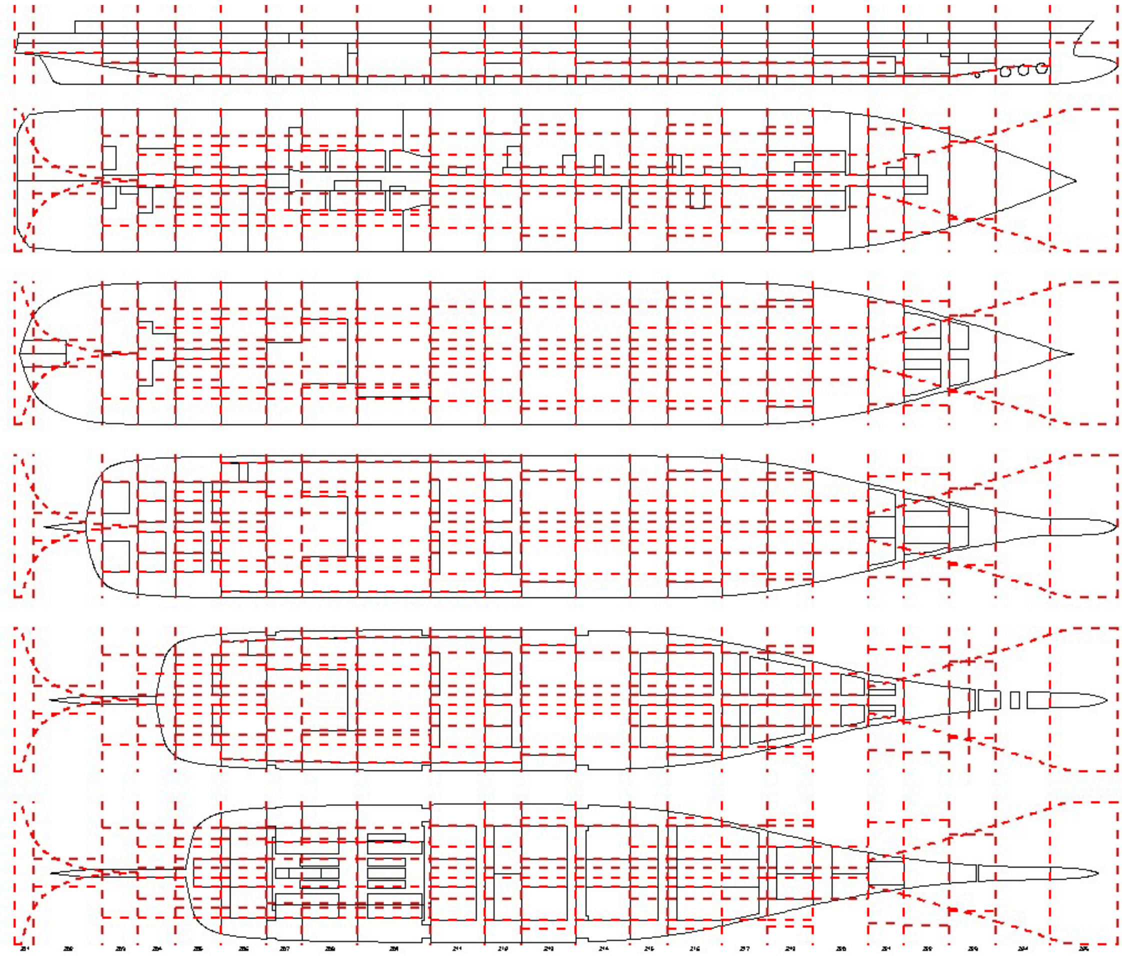


Figure 8-8: Subdivision used for calculations - – Large Cruise Vessel

8.1.9 Hydrodynamics

8.1.9.1 Speed power performance

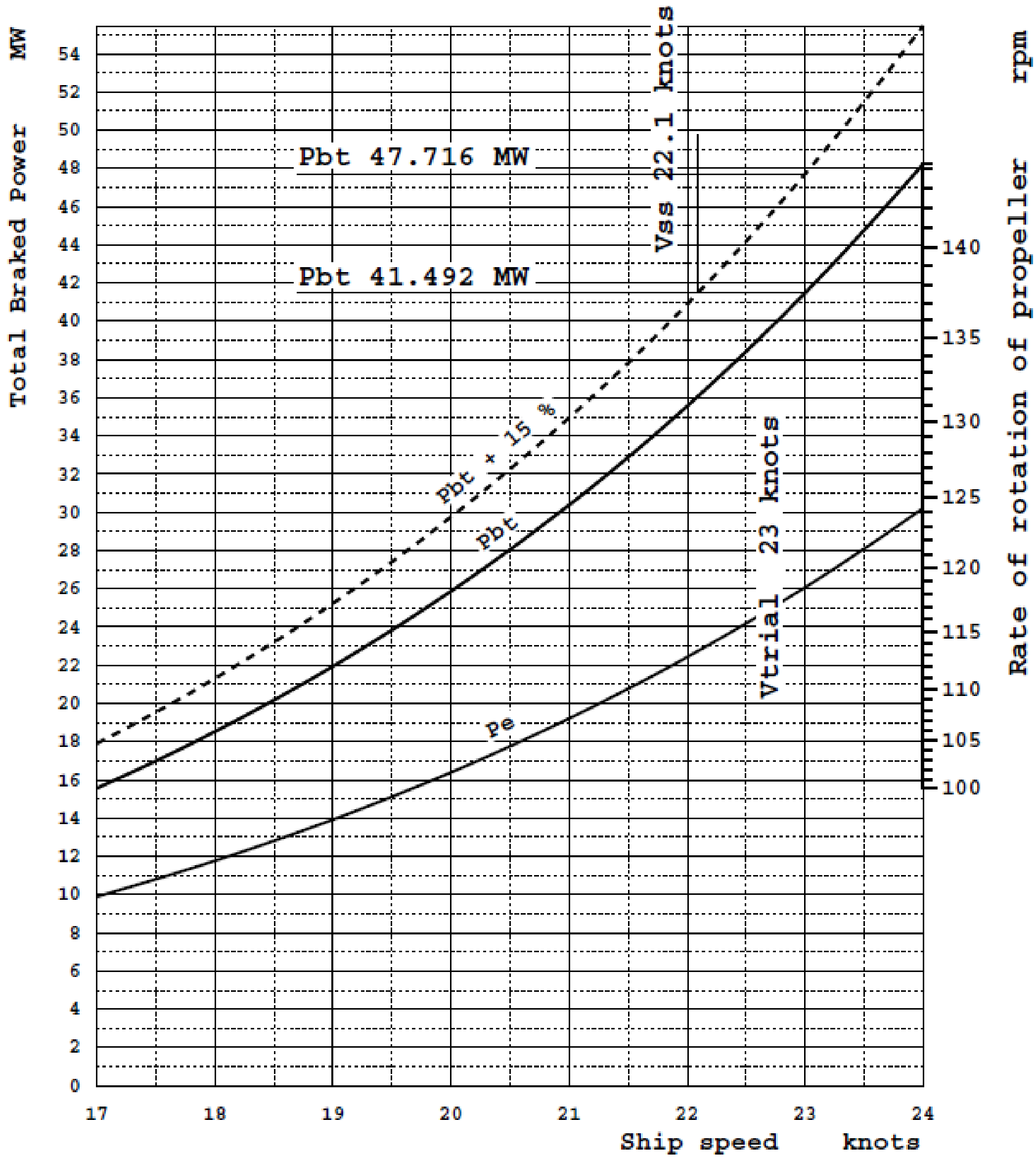


Figure 8-9: Speed power performance- – Large Cruise Vessel

8.1.9.2 Manoeuvrability

The ship is equipped with 3 bow thrusters of 3500 kW each to maintain manoeuvrability at the required wind speed in the worst direction.

Under the given wind speed the ship will be able to keep its position without the help of tugs.

8.1.10 Intact stability

8.1.10.1 Loading conditions

Table 8-3 shows an overview of the loading conditions designed for further examination of the sample ship, while further details are given in Table 8-4:

Table 8-3 Description of the designed loading conditions– Large Cruise Vessel

NAME	Description
LD20	100% Consumables max. Draught
LD23	50% Consumables
LD25	10% Consumables
LD33	20% HFO, 100% PW, 20%GW
LD35	100% HFO, 20% PW, 100%GW

Table 8-4 Loading condition details– Large Cruise Vessel

NAME	Dead Weight	Ballast water	Trim	HEEL	GM	Bending moments	Shear Forces
LD20	14878.20 t	0.00 t	-0.05 m	0.20 °	3.30 m	75.58 %	91.74 %
LD23	9360.65 t	601.42 t	-0.11 m	0.27 °	2.87 m	65.72 %	96.04 %
LD25	7918.54 t	1370.74 t	-0.08 m	0.30 °	2.82 m	52.22 %	96.76 %
LD33	10531.70 t	601.42 t	-0.21 m	0.25 °	2.84 m	68.55 %	96.15 %
LD35	13098.40 t	963.58 t	0.17 m	0.21 °	3.26 m	76.90 %	92.41 %

As requested by the business model 1500 t of future growth have been assumed and added to the loading conditions. This growth margin enables the ship to compensate any likely weight increase during the life time. Table 8-5 shows the appropriate loading conditions and the achieved floating positions.

Table 8-5 Loading conditions details with 1500t of future growth

NAME	Dead Weight	Ballast water	Trim	HEEL	GM	Bending moments	Shear Forces
LD200	14954.00 t	0.00 t	0.06 m	0.22 °	3.14 m	78.52 %	91.18 %
LD230	11356.30 t	1097.10 t	-0.19 m	0.26 °	2.93 m	92.78 %	95.01 %
LD250	9676.95 t	1593.37 t	-0.01 m	0.29 °	2.86 m	96.91 %	95.56 %
LD330	12031.70 t	601.42 t	-0.20 m	0.25 °	2.83 m	41.58 %	94.59 %
LD350	14785.50 t	1150.63 t	0.02 m	0.21 °	3.24 m	95.99 %	91.51 %

8.1.10.2 GM Limiting curve

Figure 8-10 shows the summary of the GM requirements together with the actual loading conditions.

There are various limits shown which all need to be complied with, in particular there is the limit of the intact stability criteria as defined by the IS code 2008, and 3 limits for compliance with the damage stability requirements.

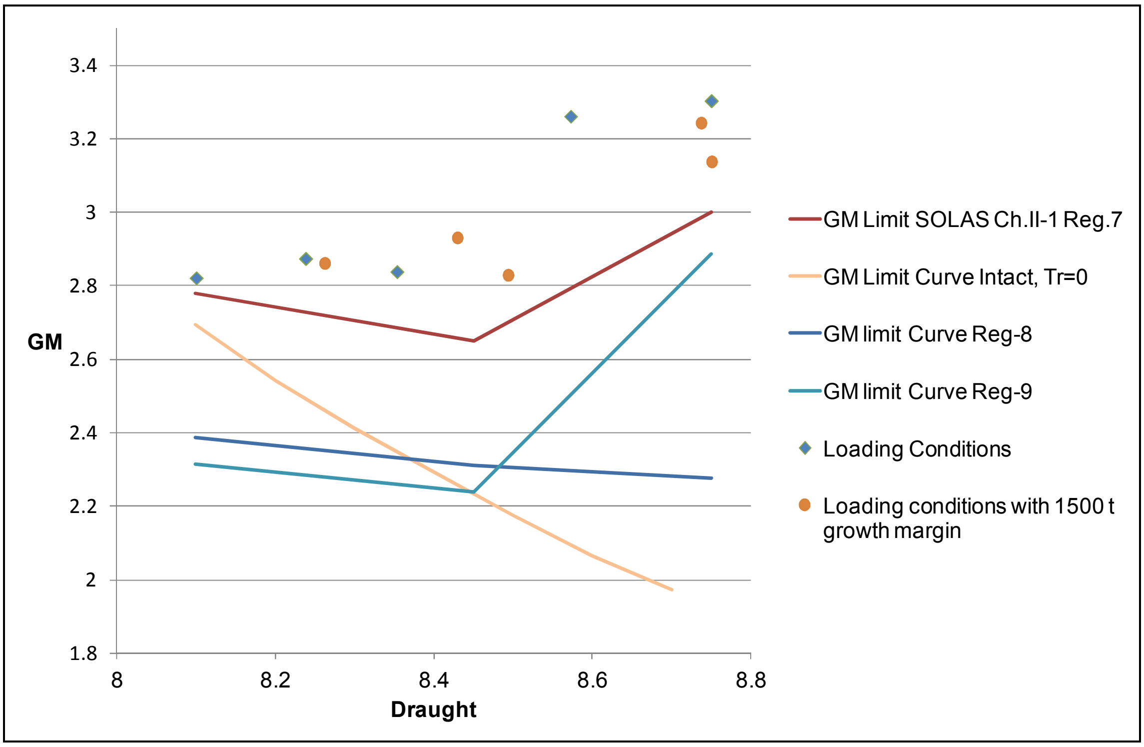


Figure 8-10 GM Limiting curves

8.1.11 Results of damage stability calculation

8.1.11.1 Attained index A vs R

The following tables show the result of the damage stability calculations according SOLAS II-1.

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	316.511 m
Breadth at the load line	40.800 m
Breadth at the bulkhead deck	40.800 m
Number of persons N1	5422
Number of persons N2	1308

Required subdivision index R = 0.85969

Attained subdivision index A = 0.86255

Table 8-6 Attained index for each initial condition

INIT	DAMTAB	Draught	GM	A/R	A	A*WCOEF	WCOEF
DL	DAMP	8,1	2,78143	1,00383	0,862984	0,0862984	0,1
DL	DAMS	8,1	2,78143	1,01383	0,871582	0,0871582	0,1
DP	DAMP	8,45	2,65466	0,991154	0,85209	0,170418	0,2
DP	DAMS	8,45	2,65466	0,9968	0,856943	0,171389	0,2
DS	DAMP	8,75	3,00165	1,0054	0,864341	0,172868	0,2
DS	DAMS	8,75	3,00165	1,01483	0,872447	0,174489	0,2

Table 8-7 Index according to number of zones.

DAMAGES	W*P*V*S	W*P*V
1-ZONE DAMAGES	0.29997	0.29997
2-ZONE DAMAGES	0.38202	0.38281
3-ZONE DAMAGES	0.16165	0.18965
4-ZONE DAMAGES	0.01798	0.07463
5-ZONE DAMAGES	0.00091	0.01965
A-INDEX TOTAL	0.86255	0.96671

8.1.11.2 SOLAS Reg.II-1/ 8 and 9.8 results

Although the compliance with the required subdivision index R is for this ship more stringent the damage requirements according regulation 8 need to be complied with.

The following table shows the GM limits to achieve s>0.9 for all damage cases according regulation 8.3

Table 8-8 GM limits for s>0.9 acc. Reg 8.3

Draught	MINGM
8.10 m	2.388 m
8.45 m	2.311 m
8.75 m	2.275 m

Regulation 9 requires a continuous double bottom throughout the ship. However in the compartments 15, 16 and 18 this requirement cannot be met. Therefore calculations for bottom damages according regulation 9.8 have been made showing that all cases of bottom damage will be survived with s=1.

Table 8-9 GM limits for S=1 acc. Reg 9.8

Draught	MINGM
8.10 m	2.314 m
8.45 m	2.238 m
8.75 m	2.887 m

The corresponding GM limiting curves are shown in Figure 8-10.

8.2 Ship #2 Small Cruise Ship

8.2.1 Business Model

As the basis for the design of this ship a business model has been agreed with the operator to define the basic parameters which need to be fulfilled. These parameters and the business model will be kept unchanged throughout the design process and also during further design studies during a later stage of this project.

The vessel is designed as a worldwide operating cruise vessel for itineraries of a range 9-21 days.

The cruise ship is oriented for cruises in arctic and antarctic regions. Passengers experience is focused on observation and exploration.

The ship is "destination oriented":

- Main public areas located on upper decks for enhanced observation
- experience
- Unique restaurant for full day service
- Large scenic observation lounges
- No theatre, no casino, no pool

Following main parameters are to be kept to maintain the business model of this vessel:

1. Number of persons on board: 478 (316 passengers and 162 crew)
2. Pax Accomodation as follow:
   a. 158 Total pax cabins
   b. 316 Total pax lower berths
   c. Outside cabin ratio 100%
   d. 3 Suites
   e. 4 Window cabins
   f. 151 Balcony cabins
   g. Balcony cabins ratio (97%)
3. Crew accommodation as follow:
   a. 84 Total crew cabins
   b. 162 Total crew berths
   c. 2 Captain Class cabins (single)
   d. 2 Senior Officer cabins (single)
   e. 12 Officer cabins (single/double)
   f. 68 Crew cabins (double/triple/quadruple)
4. Space utilization details for public and service spaces :
   a. One Pax Restaurant with 320 seats and abt.650m^2 with integrated galley
   b. Abt.1400 m^2 of other internal public spaces
   c. Abt. 1250 m^2 of outside public spaces
   d. One exploration bar
   e. One Explorer Lounge
   f. One SPA Area
   g. One Gym
   h. One embarkation area to RIBS
   i. One public area with:
   j. Expedition area
   k. Conference room
   l. Shop & internet Bar
   m. Hospital
   n. Abt. 30m^2 for pantry
   o. One laundry of abt.140m^2
   p. One refrigerated garbage store
   q. Abt. 320m^2 for provisions
   r. Abt. 320m^2 for technical spaces
5. 3 pax lifts connecting all passenger decks
6. 3 service lifts (all connecting passenger decks e 1 of them connecting laundry also)
7. Longitudinal service corridor without any watertight door to connect provision embarkation area, provision stores, and laundry area
8. Tank capacities
   a. Marine Gas Oil 550 m^3
   b. Lube Oil 30 m^3
   c. Potable water 310 m^3
   d. Heeling water 180 m^3
   e. Ballast/Waste wat. 630 m^3
   f. Technical water 80 m^3

9. Deadweight 1240t at design draught
10. One bow thruster and one aft thruster (1200 KW each) with controllable pitch propeller type
11. Fresh water production system capable to produce 240t/day
12. Waste water treatment system capable to treat 114m3/day of black water and 119m3/day of gray water
13. Four Diesel generators of 2575KW each
14. Propulsion system with 2x3500KW electric motors and shaft lines
15. Trial speed of 17knots at T=5.10m, calm water, and propulsion motors each developing 2850KW at the motor output flange
16. Operational profile: as an average 360 days per year in service, whereof 36% in port and 64% in navigation.

8.2.2 General Description of the Ship

This sample ship is a design of a small cruise ship designed for exploration cruises worldwide with capacity of 478 persons onboard. The design of the vessel complies with all relevant international rules and regulations which are in force at the beginning of 2014.

Life saving appliances are provided for 478 persons onboard for long international voyage. The vessel is a mono hull design with three main vertical zones and watertight subdivision below the bulkhead deck including partial bulkheads on the bulkhead deck.

Passenger cabins are located in three decks, crew cabins are located in five decks.

The vessel has a diesel-electric type propulsion plant located in two watertight compartments. Two electric motors, connected to shaft line, are separated by a longitudinal watertight bulkhead.

The ship has following main characteristics:

Length over all	~128 m
Length between perpendiculars	113.7 m
Subdivision length	125.8 m
Breadth	20.0 m
Subdivision draught	5.3 m
Height of bulkhead deck	7.23 m
Number of passengers	316
Number of crew	162
Gross tonnage	11800 GT
Deadweight	1240 t
No of pax cabins	159
GT/Stateroom	74.8
GT/Lower Bed	38.7
Service speed	16 knots

Trial speed	17 knots
Installed propulsion power	7000 kW
Installed power of main engines	10300 kW

8.2.3 Regulations

The design complies with all relevant IMO rules and regulations applicable for ships with keel laying after 1 January 2014, which includes following codes.

1. SOLAS1974 as amended, including probabilistic damage stability and "Safe Return to Port" (SOLAS2009)
2. Intact Stability Code (IS Code 2008)
3. ICE rules (Ice Class 1C)
4. Load line Convention
5. MARPOL, including fuel oil tank protection

8.2.4 General Arrangement

The following figures show the General Arrangement plan:

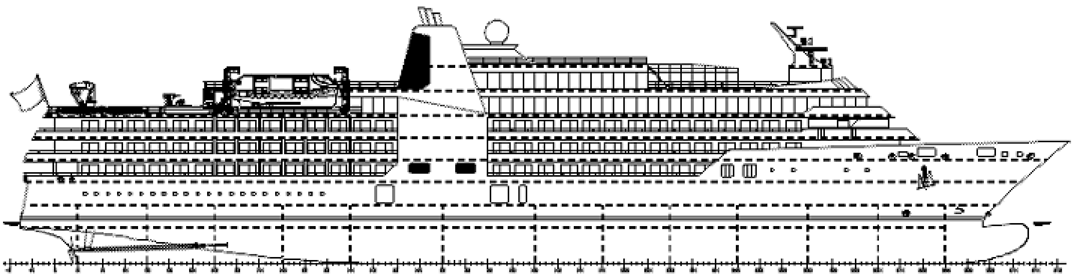


Figure 8-11 Profile view – Small Cruise Vessel

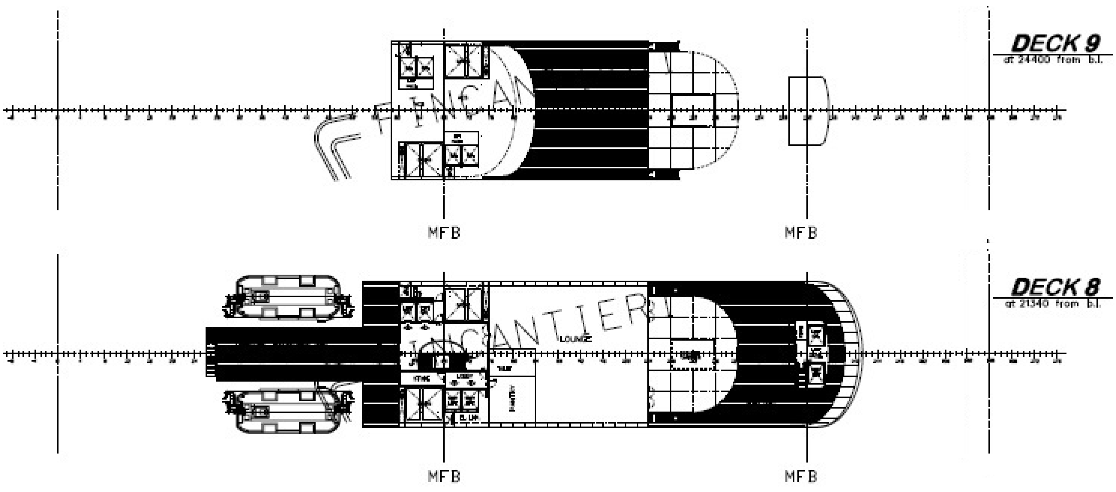


Figure 8-12 Deck 8 – 9 – Small Cruise Vessel

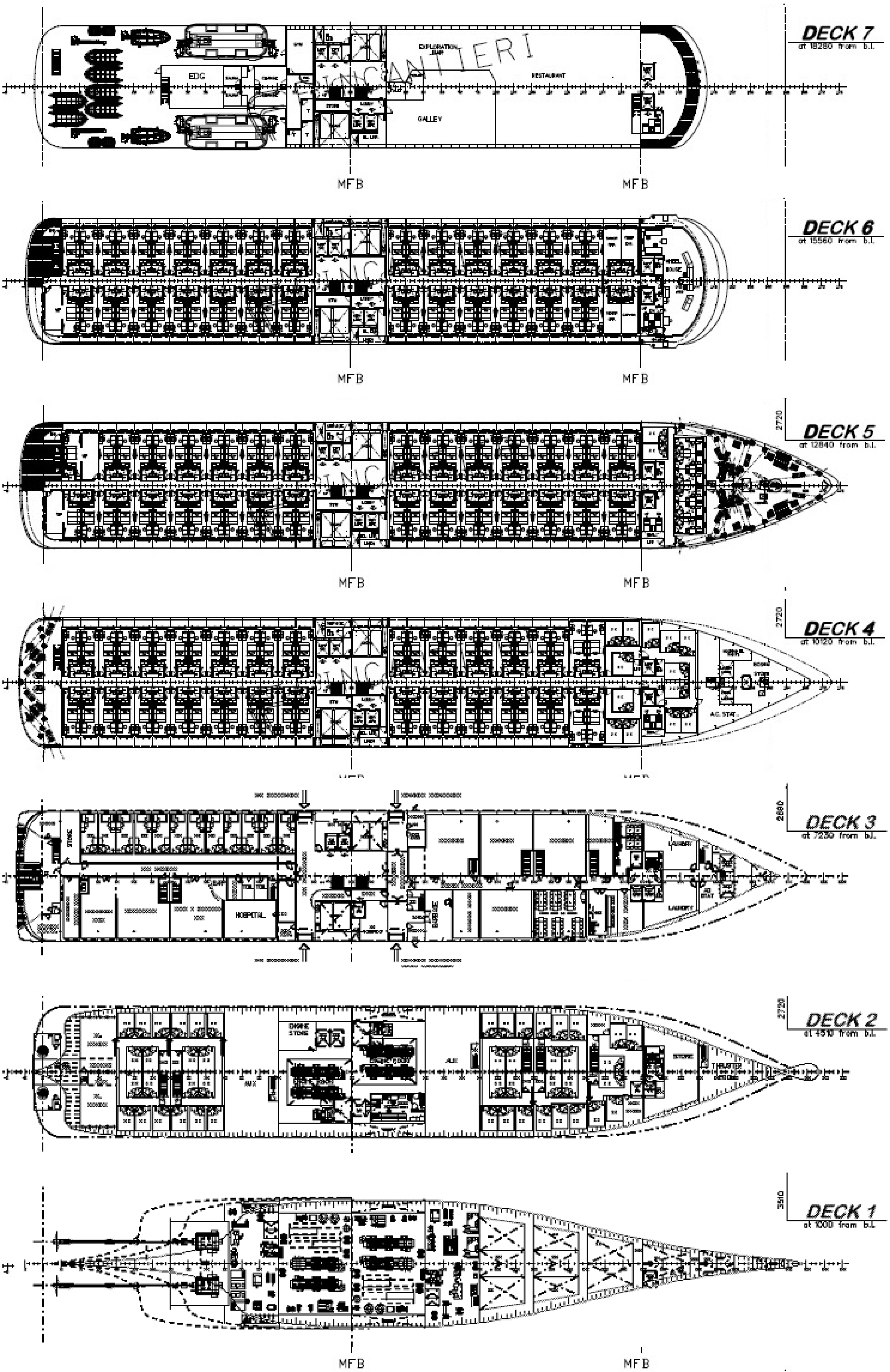


Figure 8-13 Decks 1 – 7 – Small Cruise Vessel

8.2.5 Hullform

The ship has a conventional modern hull form of a twin screw vessel with bulbous bow and slender skeg and transom stern.

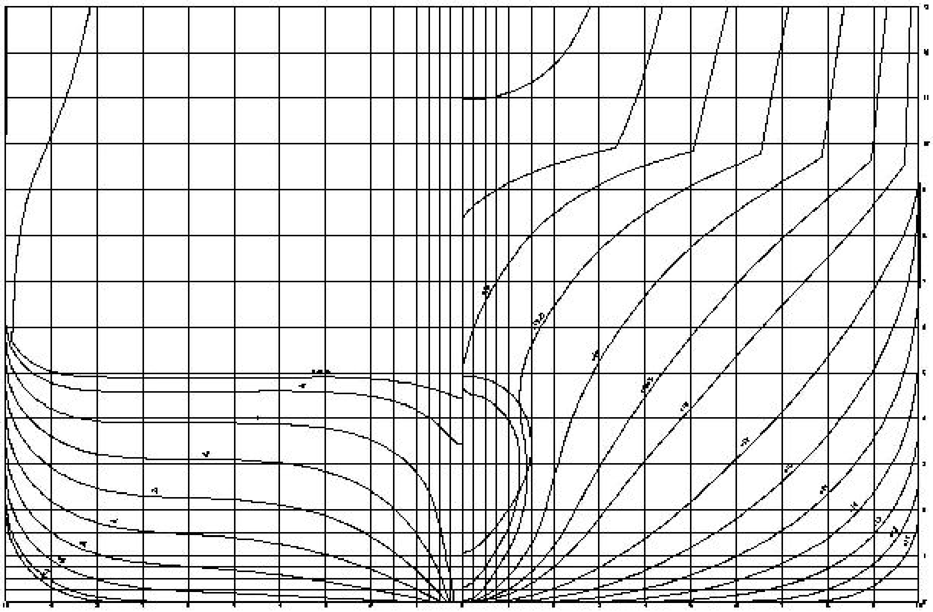


Figure 8-14 Bodyplan – Small Cruise Vessel

8.2.6 Engine configuration

The engine configuration is based on a diesel-electric concept with 4 GEN-SETS.
The engine plant is designed to deliver the full load (propulsion at service speed and hotel load) with three main engines running on maximum 90% MCR and without sea margin. The hotel load required in port should be covered by one engine only.

With four engines running at 85% of MCR the ship is able to reach the maximum speed (17 knots) with a sea margin of 15%.

The anticipated hotel load is 2000 kW in port and 2800Kw in navigation under tropical conditions.

Scrubbers are not necessary because of using MGO only.

8.2.7 Tankplan

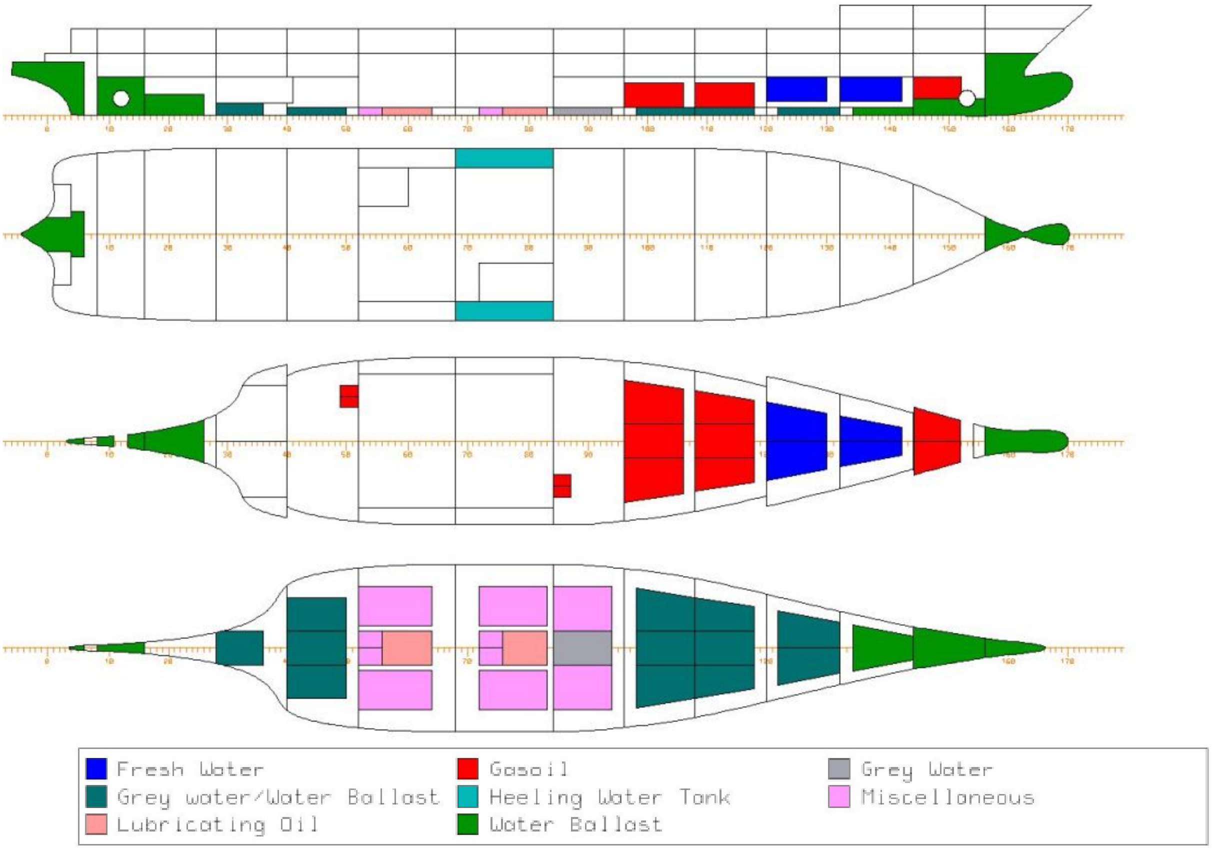


Figure 8-15 Tankplan – Small Cruise Vessel

The following capacities are achieved for the various purposes:

Table 8-10 Tank capacities – Small Cruise Vessel

Description	RHO t/m³	Volume m³	Requirement m³	Delta m³	Weight t
Marin Gas Oil	0.880	584	550	34	514
Potable Water	1.000	315	310	5	315
Lube Oil	0.900	43	30	13	39
Heeling Water	1.000	182	180	2	182
Ballast/Grey water	1.025/1.000	707	630	77	725/707
Technical water	1.000	107	80	27.3	107
Miscellaneous tanks	1.000	129	100	28.7	129

8.2.8 Subdivision

Following subdivision is used for damage calculations:

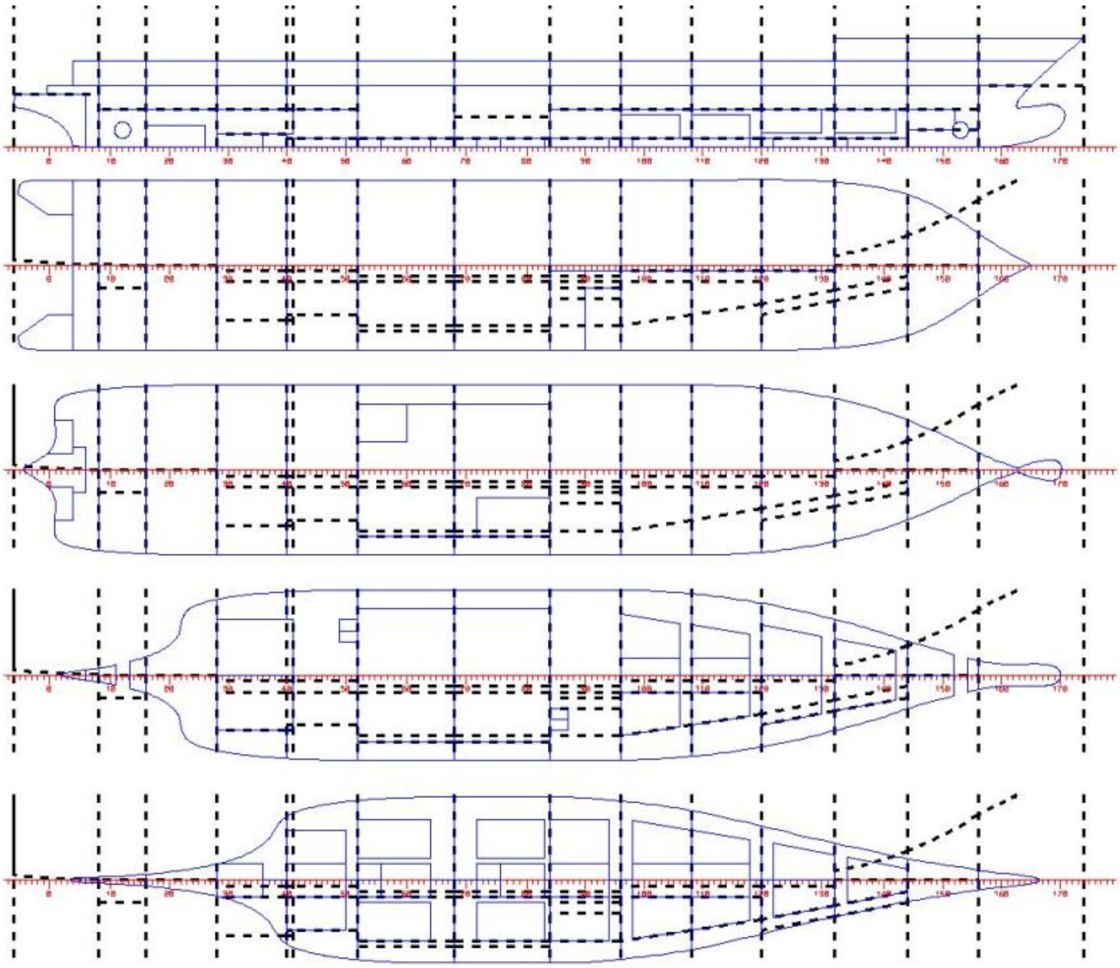


Figure 8-16 Subdivision used for calculations – Small Cruise Vessel

8.2.9 Hydrodynamics

8.2.9.1 Speed power performance

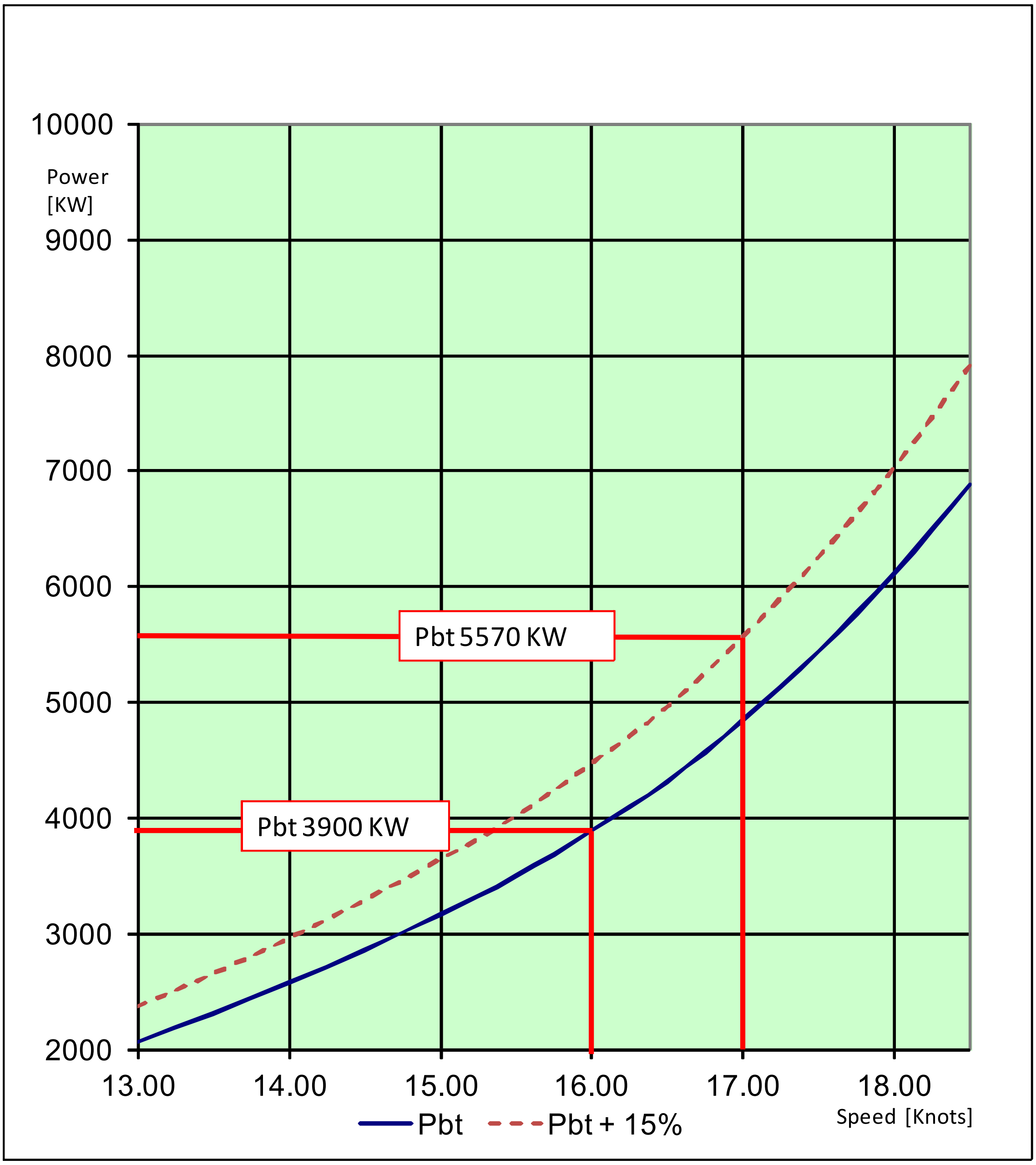


Figure 8-17 Speed power performance – Small Cruise Vessel

8.2.9.2 Manoeuvrability

The ship is equipped with 1 bow thruster and 1 stern thruster of 1200 kW each to maintain manoeuvrability at the required wind speed in the worst direction.

Under the given wind speed the ship will be able to keep its position without the help of tugs.

8.2.10 Intact stability

8.2.10.1 Loading conditions

Table 8-11 and Table 8-12 show the loading conditions designed for further examination of the sample ship:

Table 8-11 Description of the designed loading conditions – Small Cruise Vessel

NAME	Description
LD01	Contractual deadweight
LD02	10% Consumables
LD03	100% Consumables max. Draught
LD04	ICE Condition

Table 8-12 Loading condition details – Small Cruise Vessel

NAME	Dead Weight	Ballast water	T	Trim	HEEL	GM
LD01	1240 t	81.1 t	5.09 m	0.04 m	0.0 °	1.38 m
LD02	903 t	201.9 t	4.92 m	0.11 m	0.0 °	1.32 m
LD03	1670.3 t	391.8 t	5.30 m	-0.21 m	0.0 °	1.57 m
LD04	1503.8 t	113.9 t	5.19 m	0.26 m	0.0°	1.38 m

8.2.10.2 GM Limiting curve

The following diagram, Figure 8-18 shows the summary of the GM requirements together with the actual loading conditions.

There are various limits shown which all need to be complied with, in particular there is the limit of the intact stability criteria as defined by the IS code 2008, and 2 limits for compliance with the damage stability requirements.

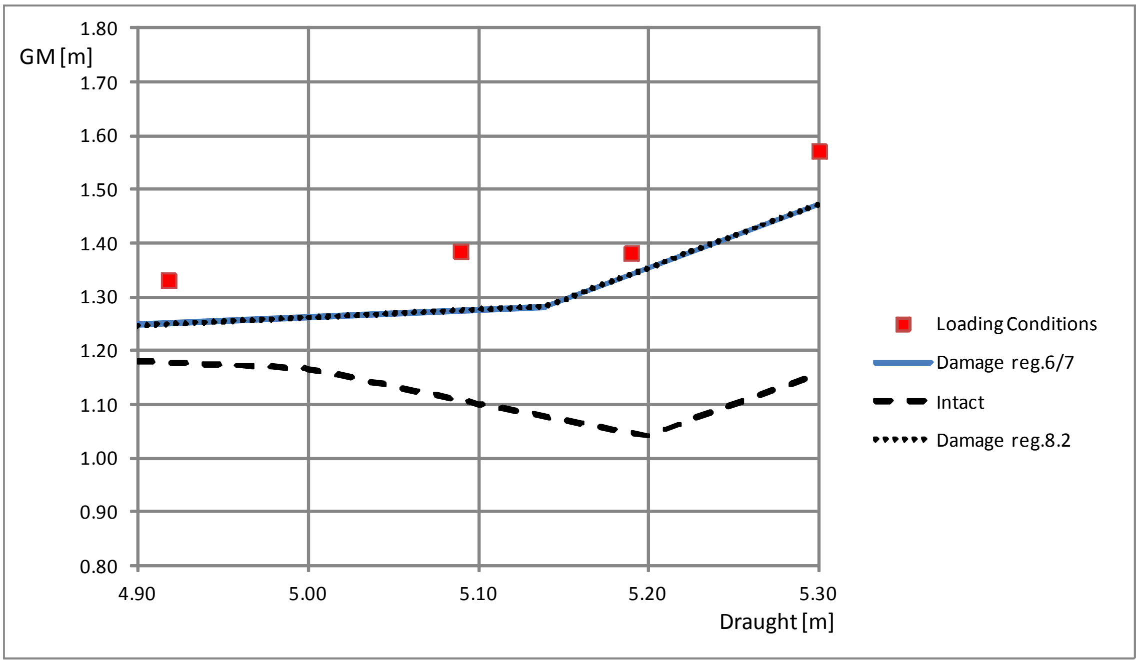


Figure 8-18 GM Limiting curve – Small Cruise Vessel

8.2.11 Results of damage stability calculation

Attained index vs R

The following tables show the result of the damage stability calculations according SOLAS II-1.

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	125.798 m
Breadth at the load line	20.000 m
Breadth at the bulkhead deck	20.000 m
Number of persons N1	478
Number of persons N2	0

Required subdivision index R = 0.69781

Attained subdivision index A = 0.72023

Table 8-13 Attained index for each initial condition – Small Cruise Vessel

INIT	Draught	GM	A/R	A	A*WCOEF	WCOEF
DL	4.900	1.250	1.04	0.72777	0.14555	0.2
DP	5.140	1.280	1.03	0.72127	0.28851	0.4
DS	5.300	1.470	1.03	0.71625	0.28650	0.4

Table 8-14 Index according to number of zones.

DAMAGES	W*P*V*S	W*P*V
1-ZONE DAMAGES	0.36601	0.36601
2-ZONE DAMAGES	0.31606	0.38807
3-ZONE DAMAGES	0.03817	0.14676
4-ZONE DAMAGES	0.00000	0.05364
A-INDEX TOTAL	0.72023	0.95448

8.2.11.1 Reg 8 and 9 results

The following table shows the GM limits to achieve s>0.9 for all damage cases according regulation 8.2-3

Table 8-15 GM limits for s>0.9 acc. Reg 8.3

Draught	MINGM
4.90 m	1.246 m
5.14 m	1.280 m
5.30 m	1.470 m

Based on this data the reg.8.2-3 is more stringent as with same value of GM for the initial conditions the reg.7 has some margin.

The vessel complies with reg.9 as a continuous double bottom with a height of 1m (B/20) or more has been placed along the ship.

8.3 Ship #3 Baltic cruise ferry

8.3.1 Business Model

The Vessel is intended to operate on a short international voyage in Baltic Sea as a passenger ship with 3280 seagoing persons on board.

Following main parameters are to be kept to maintain the business model of this vessel:

1. 720 passenger staterooms.
2. 3060 passengers
3. 220 crew berths where all cabins are outdoor type. 68 double person crew cabin and 82 single crew/officer cabins.
4. 1200 trailer lane meters on deck 3
5. 1350 car lane meters on deck 5
6. Public rooms on decks 5,6,7,8,9

7. Two public staircases and four passenger lifts connecting all passenger decks
8. Crew mess and lounge on deck 10
9. Storage rooms and workshops according ship size
10. Two service lifts
11. Tank capacities
    a. Liquefied natural gas 800 m^3
    b. Gas oil 1200m^3
    c. Potable water 1600 m^3
    d. Heeling water 800 m^3
    e. Grey water 1200 m^3
12. Deadweight 5450 tonnes in water having a density of 1,005 ton/m^3
13. The speed of the vessel with an output power maximum 85 % of MCR of the main engines and 15 % sea margin shall be 27.0 knots.
14. Two bow and two stern thrusters

8.3.2 General Description of the Ship

The vessel shall be a modern RoPax ferry for operation on the Baltic Sea with size of 60000 GT. The vessel is rated for a maximum of 3280 persons onboard and able to carry trucks, cars, and road trailers on short international voyages. This consists of 220 crewmembers and 3060 passengers.

The vessel is mono hull design with bulbous bow and a transom stern. The ship has six main fire zones and watertight subdivision below the watertight bulkhead deck.

The ship has diesel-mechanical propulsion with medium speed dual fuel engines driving two CP propellers. Two medium-speed diesel engines are connected via a reduction gearbox for both shaft lines. These equipment's located in separate watertight compartments for each shaft line.

The ship has following main characteristics:

Length over all	~251 m
Length between perpendiculars	232 m
Subdivision length	250,96 m
Breadth	29,00 m
Subdivision draught	7,20 m
Height of bulkhead deck	10,10 m
Number of passengers	3060
Number of crew	220
Gross tonnage	60000 GT
Deadweight	5450 t
No of pass cabins	720
No of crew cabins	150
Trailer lane meters on deck 3	1200
Car lane meters on deck 5	1350
Installed power of main engines	54 960 kW

8.3.3 Regulations

The design complies with all relevant IMO rules and regulations applicable for ships with keel laying after 1 January 2014, which includes the following:

1. SOLAS 1974 as amended and as applied for short international voyages, including probabilistic damage stability and Safe return to Port. In the context of Safe return to Port-safety concept the operation area is the Baltic Sea with max. 12 hours operation.
2. Damage stability requirements of EC Directive 2003/25/EC("Water on Deck) with 4 metres wave height
3. Intact Stability Code (IS CODE 2008)
4. International Convention on Load Lines, 1966 (LL 1966) as amended
5. International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL 1973) as amended including Annex IV(without certification), V and VI
6. ILO, Marine Labour Convention 2006

8.3.4 General Arrangement

Figure 8-19 shows the General Arrangement plan.

In the bigger RoPax ships there are possibilities to utilize spaces forward of machinery spaces and below the bulkhead deck to different purposes. Typically there is located big room (lower hold) inside the B/5 limits for either for cargo or stores. The choice between these two different uses of this available space is typically made subject to the operation profile of the ship.

The sample ship 3 is chosen to be overnight passenger RoPax operating in the Baltic Sea with a high passenger capacity. The high passenger capacity implies s that there is a bigger need of spaces for stores and provision in the ship compared to a ship that is dedicated more to transport cargo. Environmental requirements to operation in the operation area will be tightened during the coming years and these raised also demands for the machinery solution of the ship. The environmental issues can be tackled either by the choosing of more green fuel such as LNG or clean the exhaust gas by scrubbers.

To fulfil these different demands the available space below the bulkhead deck is chosen to utilize for LNG tanks and stores instead of long lower hold for the cargo in this case. The advantage of long hold for storage purposes is that the area can be operated without open the water tight doors. The machinery using LNG as bunker fuel is an advanced solution. By this solution the ship will fulfil all coming environmental requirements and at same time machinery maintenance demands become lower for different components due the cleaner fuel.

The Baltic overnight ferries typically have very short time in port and it is not practical to operate long lower hold as the loading of this space is quite slow. For these reasons it is already quite a common practise in the Baltic area that there are no lower holds for the cargo in this kind of ship.

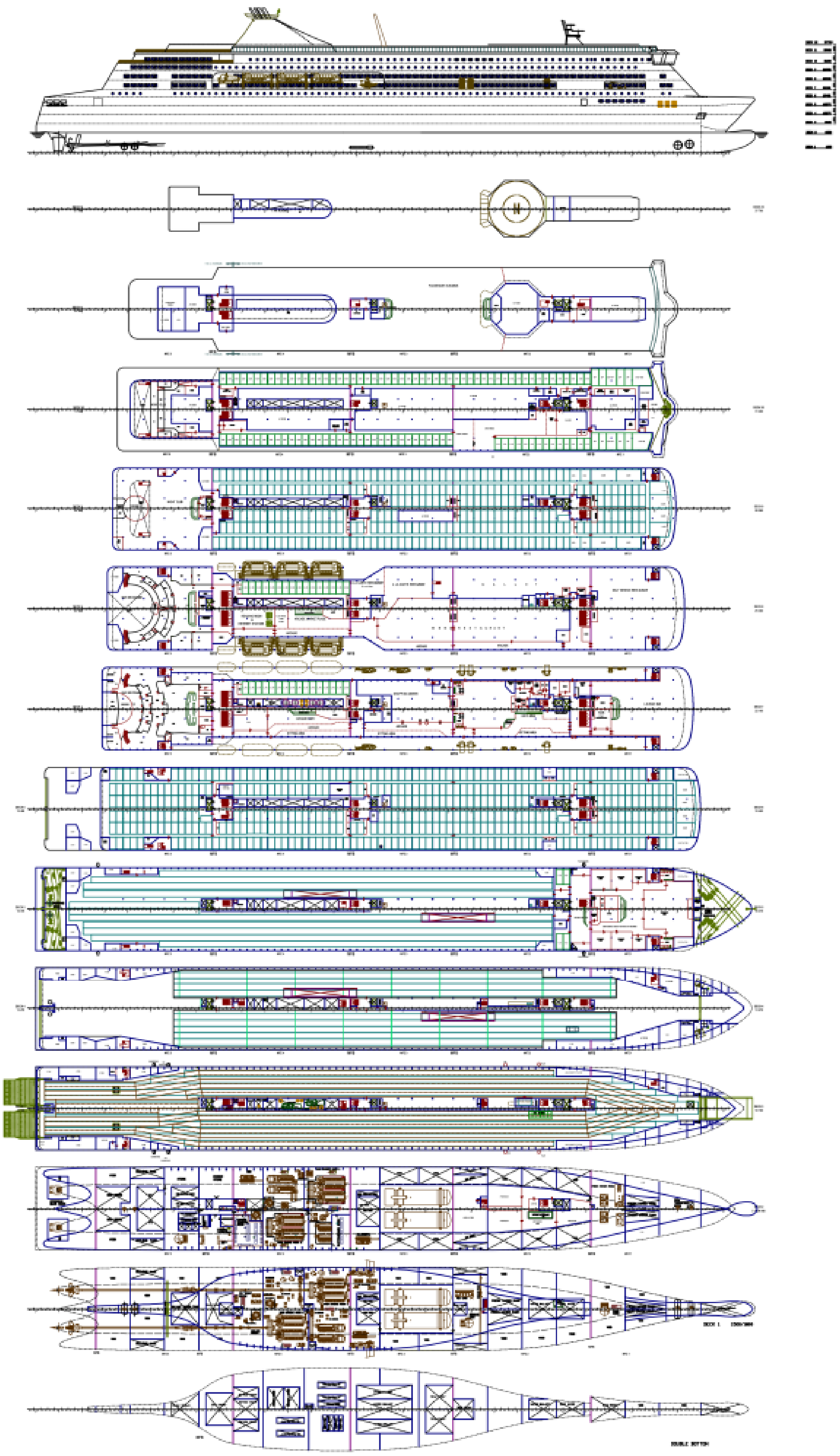


Figure 8-19 General Arrangement – Baltic RoPax

8.3.5 Hullform

The ship has modern hull form with bulbous bow and transom stern as shown in Figure 8-20.

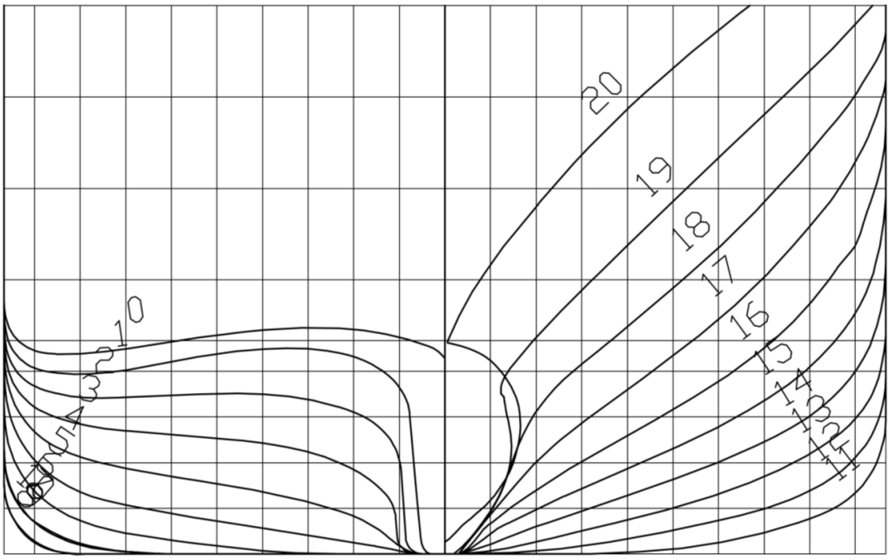


Figure 8-20 Body plan – Baltic RoPax

8.3.6 Engine Configuration

The ship has diesel mechanical propulsion. Each CP-propeller is driven by two medium-speed dual fuel engines via a reduction gearbox. The engines and reduction gear box for each shaft line are located different watertight compartments. Four auxiliary dual fuel engines each driving a generator for to supply power for the ships network. These auxiliary engines are also divided into two different watertight compartments.

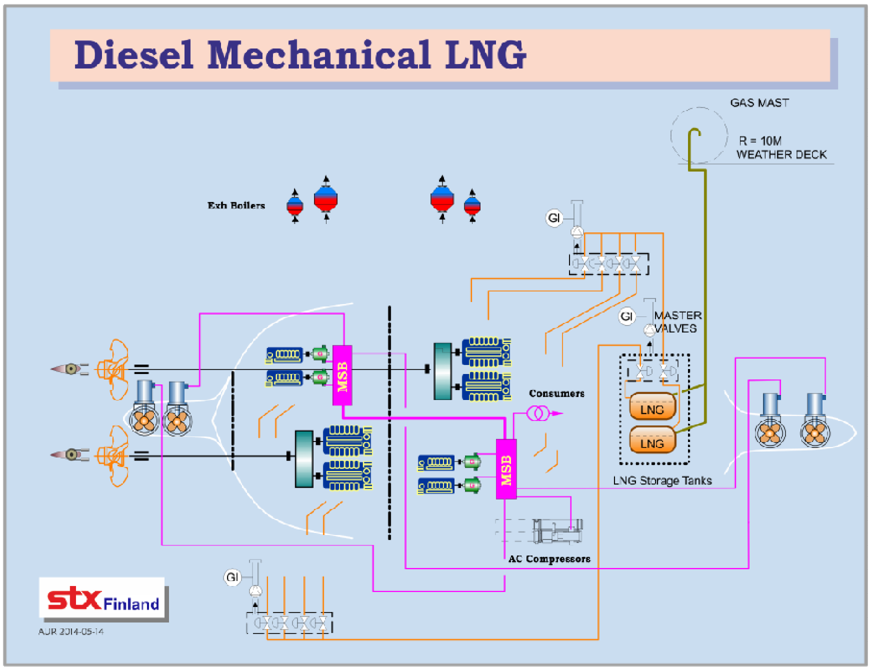


Figure 8-21 Machinery lay out

8.3.7 Tank Plan

The following figure shows the tank arrangement of the sample ship.

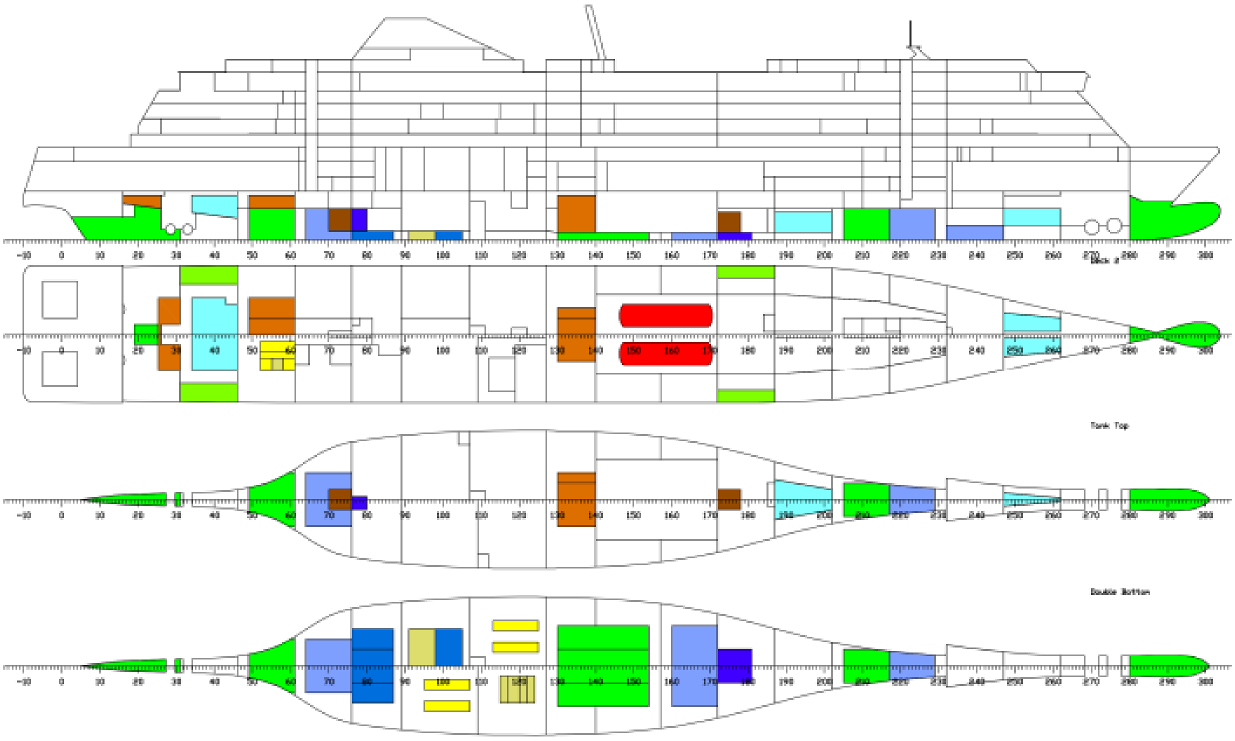


Figure 8-22 Tank plan – Baltic RoPax

The following capacities are achieved for the various purposes with this layout:

Table 8-16 Tank capacities – Baltic RoPax

Purpose	Description	Rho	VNET
PW	Potable Water	1,000 t/m³	1650 m³
HWB	Heeling Water	1,000 t/m³	890 m³
WB	Ballast Water	1,005 t/m³	2080 m³
SW	Technical Water	1,000 t/m³	290 m³
LO	Lubrication Oil	0,900 t/m³	175 m³
GO	Gas Oil	0,860 t/m³	1290 m³
LNG	Liquefied Natural Gas	0,470 t/m³	830 m³
MIS	Miscellaneous	Varies	150 m³
GW	Grey Water	1,000 t/m³	1270 m³
BLW	Black Water	1,000 t/m³	175 m³

8.3.8 Subdivision

The vessel has been divided into 19 watertight compartments below the bulkhead deck, i.e the car deck. The car deck (deck 3) has been assumed as horizontal subdivision preventing progressive flooding upwards to reach above deck 3. Thus watertight car deck has been utilized in the attained index in damage cases, when damage will extend only up to bulkhead deck. Above the bulkhead deck the aft and fore corners (P+S) has been divided into a few separate partial watertight compartments to increase the residual stability after damage.

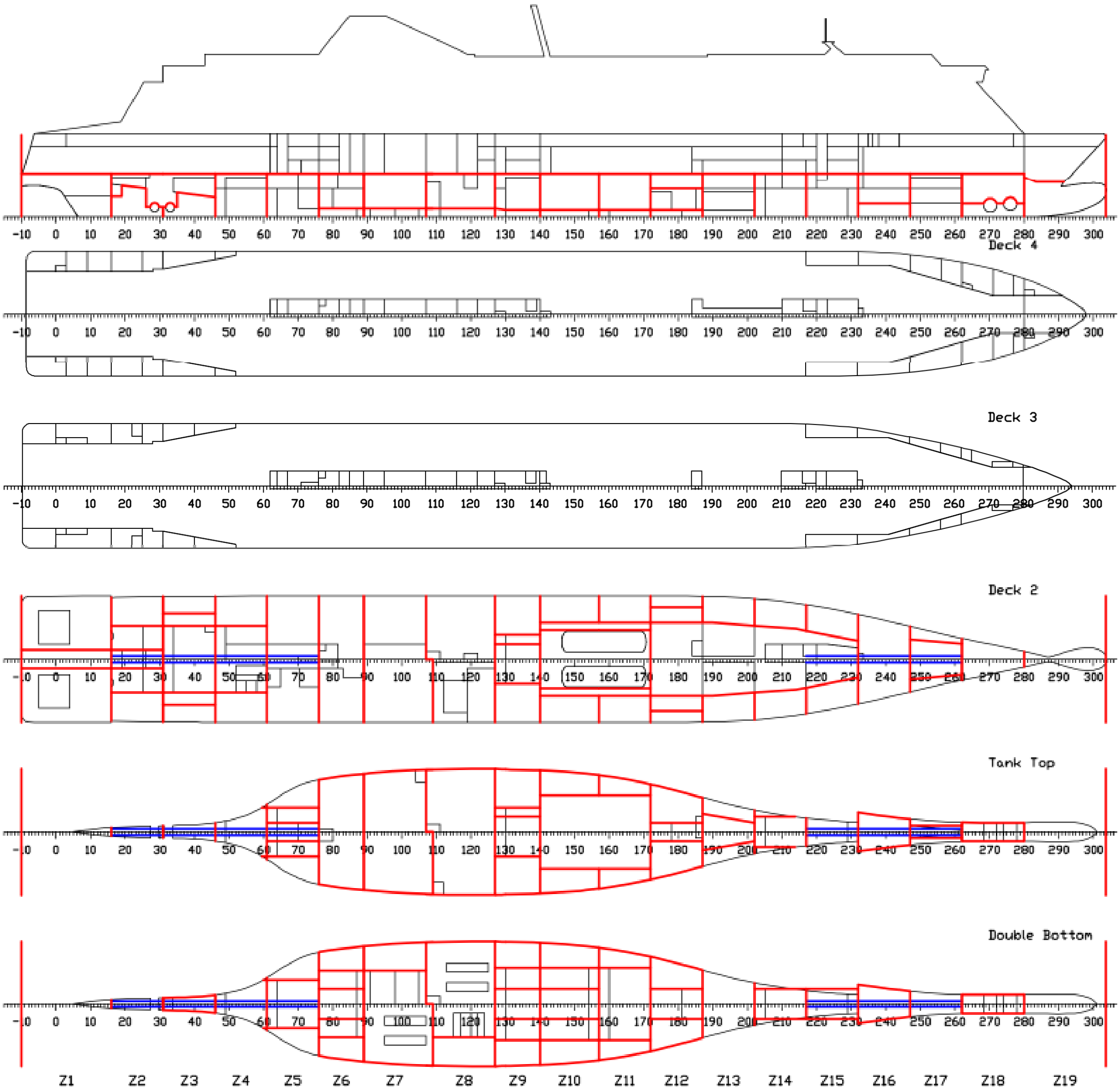


Figure 8-23 Subdivision – Baltic RoPax

8.3.9 Hydrodynamics

8.3.9.1 Speed Power Performance

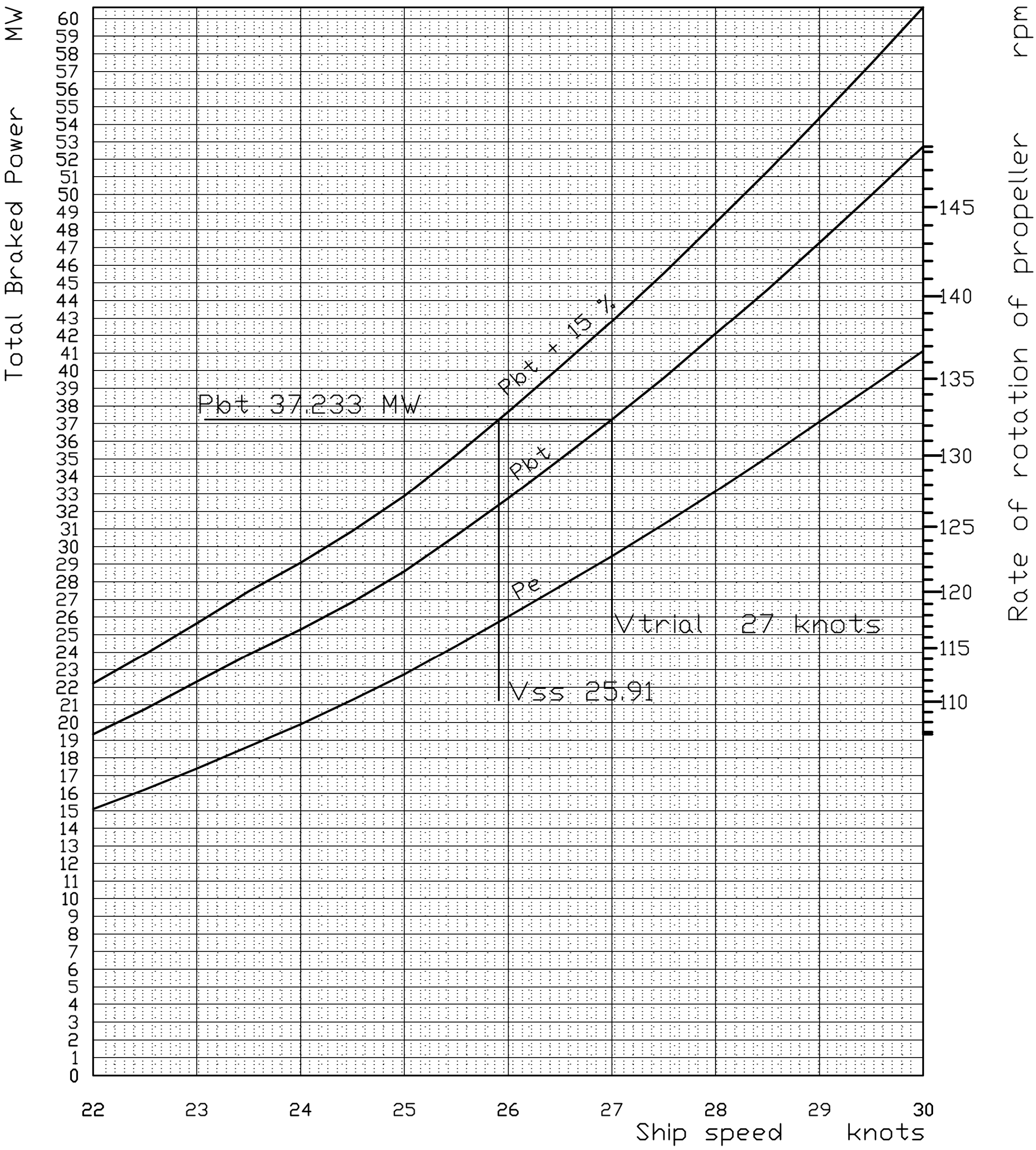


Figure 8-24 Speed-Power performance – Baltic RoPax

8.3.10 Intact Stability

8.3.10.1 Loading Conditions

The design deadweight of the vessel is 5450 tonnes when it is loaded at a design moulded draught of 7,00 meters in water having a density of 1.005 ton/m3.

Design Deadweight of the vessel shall be assumed to be as follows:

Trailers	2150 t
Cars	350 t
Passengers and crew	300 t
LNG	350 t
MGO	250 t
Lubrication oil	100 t
Fresh water	750 t
Technical water	150 t
Heeling water	400 t
Ballast water	50 t
Grey water	50 t
Provision and stores	350 t
Miscellaneous	200 t
Total deadweight	5450 t

The following loading conditions are studied:

L1 – Trailers+cars specified DWT=5450 t
L2 - Trailers+cars specified, Arrival
L3 - Departure, passengers no cargo 100% bunkers
L4 - Arrival, passengers, no cargo, 10% bunkers
L5 - As L1 + Ice load
L6 - As L2 + Ice load
L7 - As L3 + Ice load
L8 - As L4 + Ice load
L9 – 50% Cargo/bunkers/stores

Table 8-17 Loading condition details – Baltic RoPax

NAME	DWT	WB	Draught	Trim	GM
L1	5450	50,00	7,00	-0,02	2,76
L2	4018	175,00	6,75	-0,03	2,58
L3	2900	50,00	6,55	0,04	2,77
L4	1775,51	432,51	6,35	-0,01	2,73
L5	5720,7	50,00	7,04	0,01	2,66
L6	4664,42	555,72	6,86	-0,01	2,56
L7	3448,21	327,51	6,65	0,00	2,67
L8	2499,42	885,72	6,48	0,01	2,69
L9	3298	50,00	6,62	-0,02	2,65

8.3.10.2 GM Limiting Curve

The following diagram, Figure 8-25, shows the summary of the GM requirements with actual loading conditions. There are shown limit curves of the intact and damage stability.

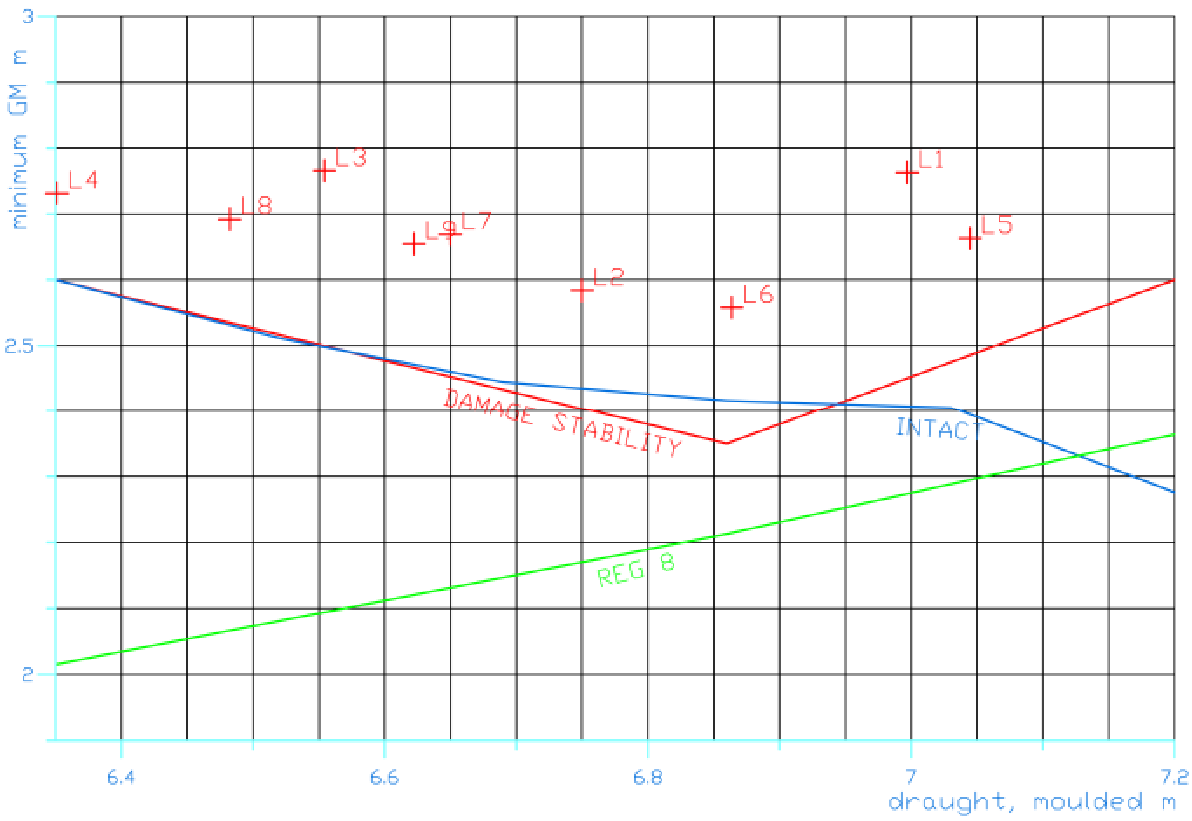


Figure 8-25 GM Limiting curves – Baltic RoPax

8.3.11 Damage Stability

8.3.11.1 Attained Index vs Required Index

Damage stability calculations according SOLAS2009 (MSC.216(82)) have been carried out.

Required index according to regulation 6:

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

where:

Ls = Subdivision length
N = N1 + 2* N2
N1 = persons in lifeboats
N2 = persons in excess of N1

For the sample ship 3 the required index has been calculated with following parameters:

Subdivision Length	250.96 m
Number of persons N1	984
Number of persons N2	2296

Required subdivision index for the ship 3: R= 0.830

The attained index has been calculated according the Solas 2009 and explanatory notes MSC.1/Circ. 1226 and the results are summarised in Table 8-18.

Table 8-18 Summary of attained index A calculations

INIT	Draught	GM	A/R	A	A*WCOEF	WCOEF
DL	6.35	2.60	1.106	0.91806	0.09181	0,1
DL	6.35	2.60	1,1082	0,91982	0,09198	0,1
DP	6.86	2,35	1.0163	0,84350	0,1687	0,2
DP	6.86	2,35	1.0241	0.85002	01700,	0,2
DS	7.20	2.60	1,0118	0,83983	0,16797	0,2
DS	7.20	2.60	1,0167	0,84382	0,16876	0,2

Attained subdivision index port side A =0.85694

Attained subdivision index starboard side A =0.86150

Attained subdivision index for the ship 3: A=0.85922

8.3.11.2 SOLAS Reg II-1/8 and 9.8 Results

In addition to fulfil the required subdivision index the passenger ships have special requirements that have to be met. Regulation 8 includes special requirements concerning ships stability and regulation 9 includes requirements concerning double bottom.

According to regulation 8 the passenger ship is to be capable of withstanding damages along the side shell. It is required that t "si" shall not be less than 0.9 for the defined damages for the three loading conditions used in the index calculation. Assumed extent of minor damage shall be as follows:

Longitudinal extent 0.03Ls or 3.0 m = 7,53 m
Transverse extent 0.1B or 0.75 m = 2,90 m
Vertical extent up to ds + 12.5 m = 19,70 m

Table 8-19 shows the GM limits to achieve si>0.9 for all damage cases.

Table 8-19 Minimum GM values according regulation 8.3

Draught	MINGM	GM in index calculation
6,35m	2,015m	2,60m
6,86m	2,213m	2,35m
7,20m	2,364m	2,60m

The sample ship 3 fulfils Regulation 9 concerning the height and extent of the double bottom and therefore it is not required to analyse double bottom damages as presented for unusual bottom arrangements according to Regulation 9.8.

8.4 Ship #4 Mediteranean RoPax

8.4.1 Business Model

8.4.2 Purpose and General Standard of the Vessel

The Vessel is designed to operate on short international voyages with 1700 (1600 passengers and 100 crew) seagoing persons. The vessel is built for transporting cars, road trailers and other light roro cargo.

The Vessel and its systems are designed for world-wide traffic, and tailored for a year round service in Mediterranean Area.

8.4.3 General Description

The Vessel is designed as a roro passenger ship with a bulbous bow, transom stern, two semi-balanced rudders and two propellers.

The Vessel's main cargo deckis designed for easy and fast cargo handling. Loading and unloading takes place via stern and bow.

Three decks 3, 5 and 7 are arranged for carriage of roro vehicles and considered as special category spaces arranged in two horizontal fire zones.

The Vessel's hull beneath Deck 3 is divided by transversal and longitudinal watertight bulkheads into compartments with house tanks, main propulsion machinery, electric plant, air condition cooling plant, provision stores, sanitary arrangements, bow thruster room and steering gear room.

Emergency helicopter landing area is arranged on Deck 13.

Accommodation is situated in the superstructure. Public spaces are situated on Decks 8 and 9. Passenger cabins are located at Decks 10 and 11, and crew quarters on Decks 11 and 12. The wheelhouse is located on Deck 11.

Assembly stations are located inside on decks 8 & 9.

Heeling tank pairs are fitted for compensation of list due to asymmetric load and wind. Manoeuvring is to be aided by two bow thrusters and a stern thruster.

8.4.4 Main Dimensions and free heights

Length overall	185.00 m
Length between perpendiculars abt.	172.40 m
Breadth moulded max.	31.00 m
Depth moulded to the Main Deck abt	9.60 m
Depth moulded to the Upper Deck	15.45 m
Design draught moulded	6.60 m
Scantling draught moulded	6.70 m
Gross Registered Tonnage	43 000 UMS

Free Heights:

Main trailer Deck 3	5.00 m
Upper trailer Deck 5	4.80 m
Upper car deck 7	3.00 m
Passenger public spaces, generally	2.50 m
Passenger accommodation excl. toilet units	2.10 m
Crew areas, and galleys generally	2.10 m
Crew accommodation excl. toilet units	2.10 m

8.4.5 Deadweight and Capacities

Example distribution of the deadweight at the design draught with homogenous trailer cargo:

Trailers deck 3 & 5	4500 t	at +2 m/deck
Cars, Upper Car Deck	350 t	at +0.7 m/deck
Passengers with luggage	170 t	
Crew with effects	11 t	
Heavy fuel oil	600 t	
Diesel oil	80 t	
Lubricating oil	55 t	
Heeling water for 4000 t.m	350 t	
Potable Fresh Water	300 t	
Technical fresh water	50 t	
Sprinkler water	50 t	

Miscellaneous stores	150 t
Provision and shop stores	80 t
Sludge	5 t
Sewage	5 t
TOTAL	6755 t

Fuel capacity corresponds to operating for 7 days.

Capacity of tanks:

Heavy fuel oil storage	600 m^3
Heavy fuel oil daily & settling	4 x 60 m^3
Diesel oil	200 m^3
Potable water	400 m^3
Technical fresh water	60 m^3
Grey Water	150 m^3
Black water	30 m^3
Lubricating oil storage	100 m^3
Dirty oil	30 m^3
Bilge water	90 m^3
Sludge	40 m^3
Cooling water drain	18 m^3
Heeling Water	700 m^3
Sprinkler water tank	50 m^3
Ballast water abt.	2500 m^3

Cargo capacity:

Cars on Upper Deck, 1100 lane meters/231 cars (slot size 4.75 x 2.40 m)

Trailer lanes on Main Deck 3	1200 m
Trailer lanes on Lower Deck 1	1200 m
Total	2400 m

Width of trailer lanes on generally 3.1 m, may be reduced by up to 30 cm in way of walkways, local bulkheads and pillars shown in the General Arrangement.

Passengers and crew Cabins:

Total number of pax cabins:	333
beds+Pullmans :	994
Total number of crew cabins:	100

8.4.6 Regulations

The Vessel is designed to fulfil the following international regulations:

- IMO, International convention of Safety of Life at Sea SOLAS-1974 as amended and including probabilistic damage stability and Safe return to port

- Intact stability Code (IS Code 2008)

- IMO, LL - 1966, International Convention on Load Lines,

- IMO, MARPOL-1973/78 International Convention for the Prevention of Pollution from Ships. Annexes I, III, IV, V et VI

(EC Directive 2003/25/EC - Specific stability requirements for ro-ro passenger ships with a wave height of 4.0 m = Stockholm agreement)

- ⇨ Alternative to previous regulation: future regulation 7-2.3 of SOLAS II.1 with TGZmax 0.20m and TRange 20deg for each damage case that involves a ro-ro space.

8.4.7 Speed

The Vessel's trial speed and service speed is 22.0 knots at the moulded draught corresponding to the design deadweight with 90 % MCR and 15 % sea margin on power. The above mentioned parameters are related to each other as follows:

Ps = 90% * MCR * 0.985 /(1.15) = 0.771 MCR , where

Ps = maximum allowable shaft power at trial speed,
MCR = maximum continuous rating of the main engines,
0.985 = mechanical efficiency of gears and shafts.

8.4.8 Stability and Trim

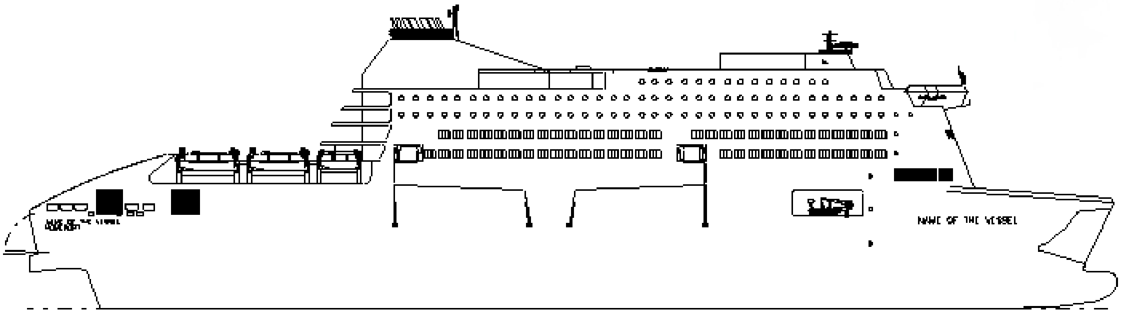
The vessel is designed to sail on about even keel (trim of less than 0.2 m by bow and 0.4 m by stern) when loaded with homogeneous and the design stowage plan cargo according to deadweight distribution given here above for the design draught.

Trim adjustment +/- 1 m at draught corresponding to 50% design deadweight by filling fwd / aft ballast to be checked.

8.4.9 GENERAL ARRANGEMENT

The general arrangement is shown on following figures.

External View



Longitudinal Section

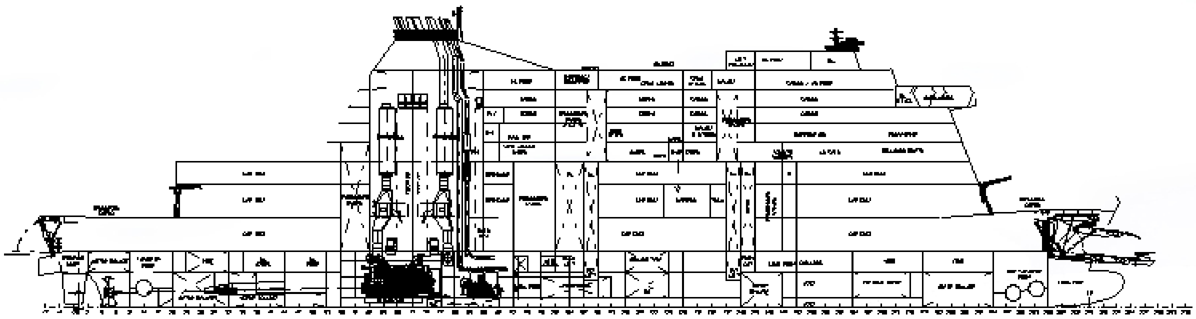


Figure 8-26 External view and longitudinal section – Mediterranean RoPax

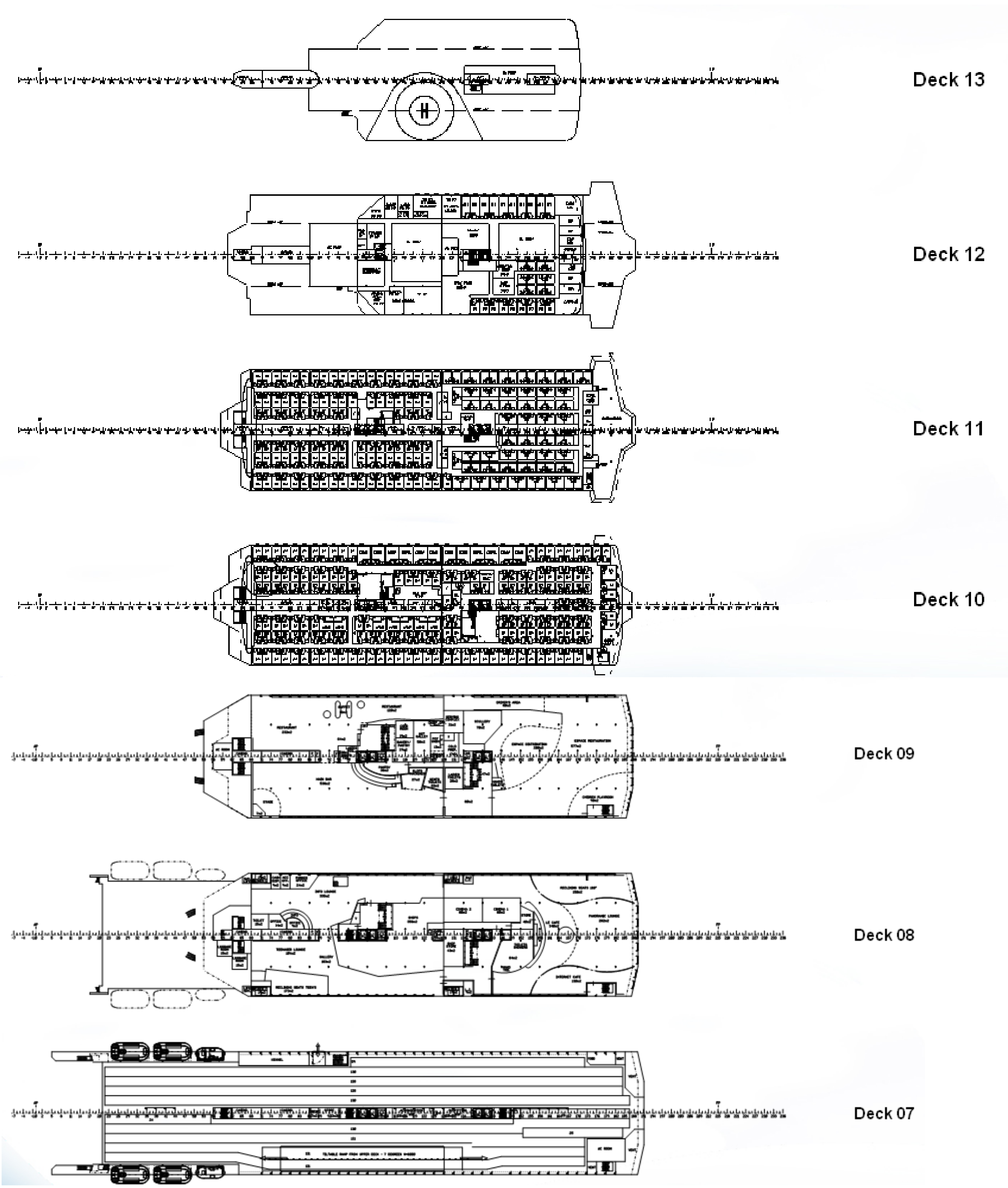


Figure 8-27 Decks 07 to 13– Mediterranean RoPax

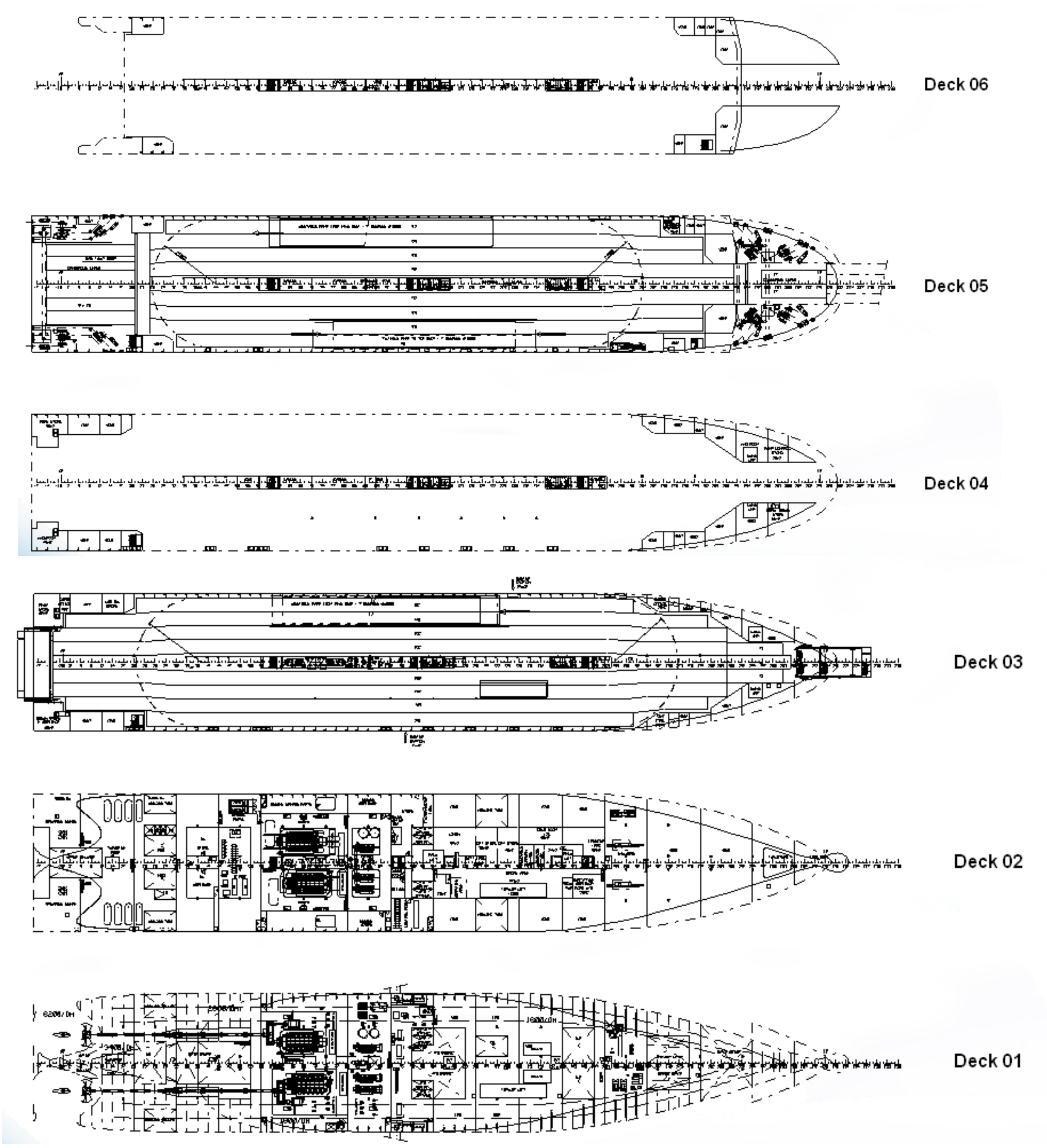


Figure 8-28 Decks 01 to 06– Mediterranean RoPax

8.4.10 MACHINERY

The ship is designed according to the Diesel mechanical propulsion concept.

The propulsion plant consists of two shaft lines with controllable pitch propeller. Each shaft line is driven by two medium speed Diesel engines via a reducing gear box.

The electrical power is produced by two medium speed diesel generators and two shaft generators.

The heat is produced by two oil fired boilers and four exhaust gas economizers (one on each propulsion Diesel engine exhaust gas system).

The equipment and the fuel oil systems are designed to operate with Heavy Fuel Oil 380 cST at 50°C, (RMH35 according to ISO 8217) and Marine Gas Oil (DMA according to ISO 8217).

Propulsion Plant

The propulsion plant consists of:

4 main diesel engines rated to obtain the speed defined section 8.4.?. For guidance
4 x MAN 6L 48/60 at 500 RPM rated at 6900 kW each or equivalent is considered.
2 reducing gear boxes
2 thrust bearings (thrust bearing can be integrated into the reducing gear box)
2 shaft lines
2 controllable pitch propellers

Diesel Generators

Two diesel generators, medium speed, four stroke, non-reversible are provided. For guidance MAN 7L 27/38 or equivalent, rated at about 2200 kW each at 750 RPM are considered.

Two shaft generators.

8.4.11 Capacity plans

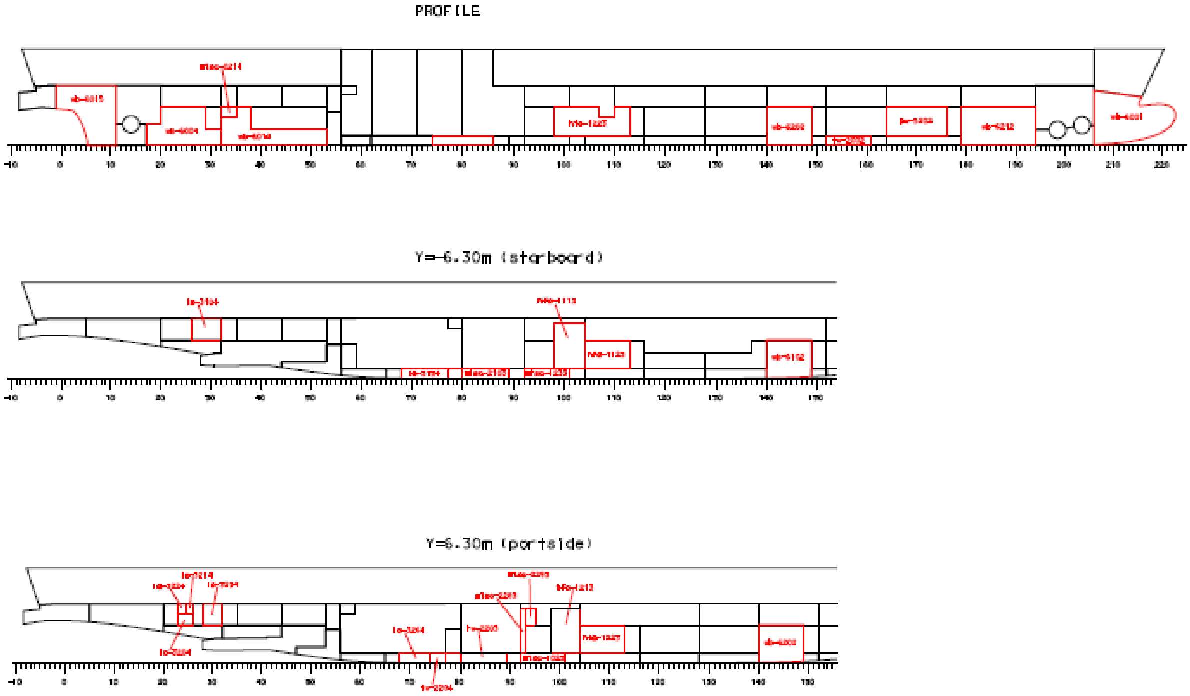


Figure 8-29 Tank Plan - profile

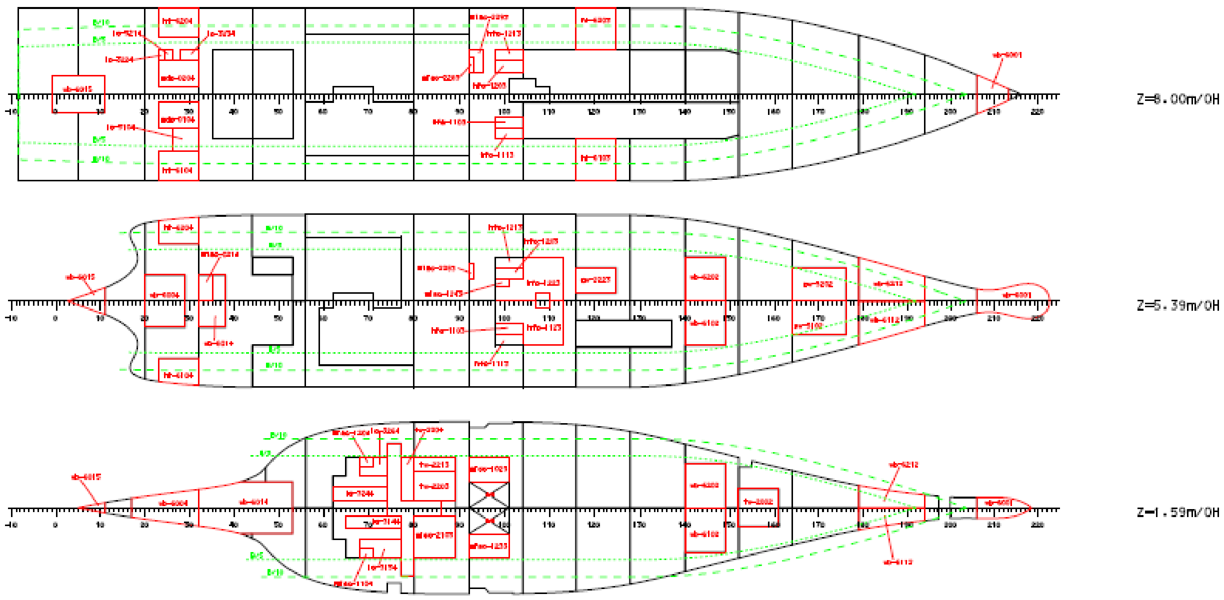


Figure 8-30 Tank plan– Mediterranean RoPax

8.4.12 LOADING CONDITIONS

Table 8-20 Loading conditions– Mediterranean RoPax

Description	Draft (m)	Trim (m)	GM(corrected) (m)	KG(corrected) (m)
Design DW=6755 t	6.600	-0.007	3.52	14.99
Max Load FB	6.700	0.000	3.61	14.82
Cars and trailers 10 % consumables	6.519	0.001	3.48	15.06
Cars and trailers, 50 % consumables	6.558	0.001	3.48	15.06
No cars and trailers 10 % consumables	5.800	0.000	4.29	14.22

8.4.13 Intact stability

Intact stability is including in the minimum required GM curves shown in Figure 8-32.

It is seen that the damage stability limit curve is more restrictive than the intact stability one.

8.4.14 Damage stability

8.4.14.1 Stockholm agreement vs future reg. 7-2.3 of SOLAS II.1

The calculation has been done according to EC Directive 2003/25/EC - Specific stability requirements for ro-ro passenger ships with a wave height of 4.0 m.

The corresponding limiting curve is shown on the Required GM curve at paragraph 2.12
In the context of this EMSA3 study, the calculation has also been performed according to the future regulation 7-2.3 of SOLAS II.1 with TGZmax 0.20m and TRange 20deg for each damage case that involves a ro-ro space.

This calculation leads to a bit more than 1% loss of attained index

8.4.14.2 Probabilistic requirements according to SOLAS 2009

Total persons on board used for R calculation : 1700
Total persons in lifeboats used for R calculation : 568

Subdivision length	184.997 m
Breadth at the load line	31.000 m
Breadth at the bulkhead deck	31.000 m

Required subdivision index R = 0.778

Draft / GM :	6.7 / 3.4	6.34 / 3	5.8 / 4.1

Attained subdivision index A = 0.852

Margin on the index = 0.074 This margin is reduced to 0.062 with the new agreement from SLF55 concerning the regulation 7-2.3 of SOLAS II.1

This figure below (Figure 8-31) shows that there is some loss of attained index in the fore part for 3 zones damages.

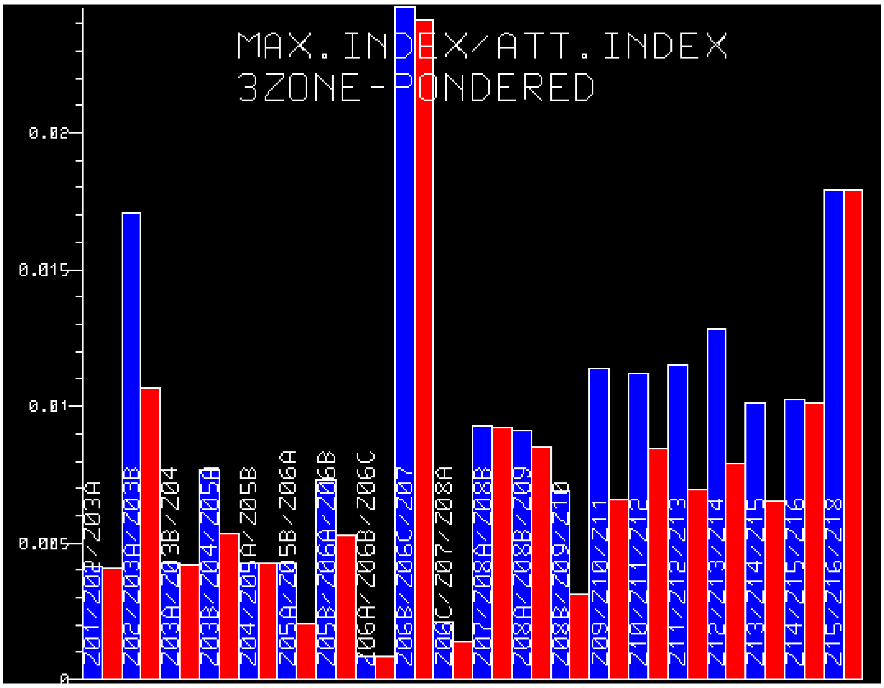


Figure 8-31 3-Zone damages max index vs attained index

8.4.15 GM limiting curves

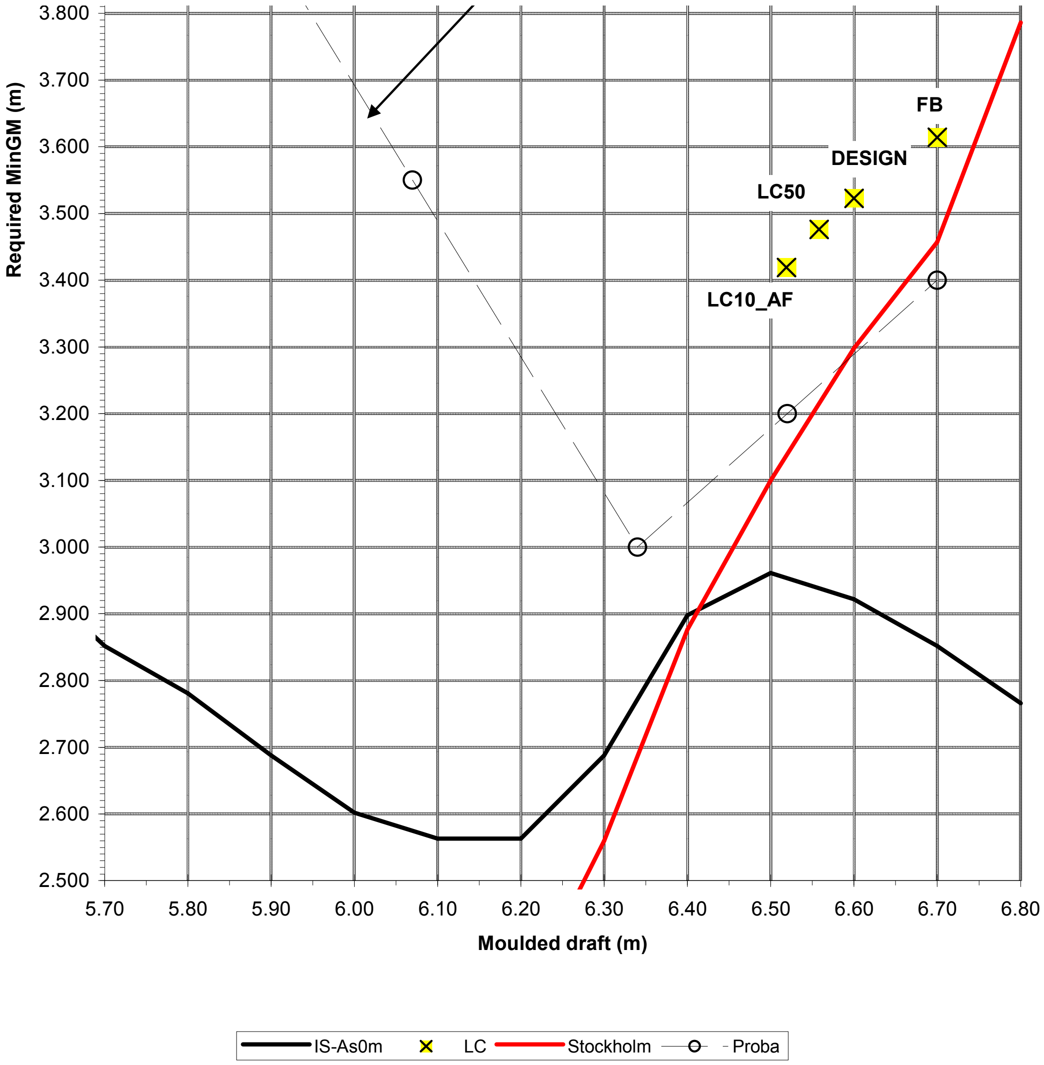


Figure 8-32 GM limit diagram

8.5 Ship #5 Small ropax

8.5.1 INTRODUCTION

This section describes the basic information about the sample ship number 5, a small RoPax. Small passenger ships have been less researched in previous projects concerned with stability and there is a growing concern that any increase in the R index may unduly penalise small ships.

In selecting a candidate type of small ship, we are presented with a choice between a passenger ship and a RoPax ship. From a technical point of view, it would seem that a RoPax vessel with a large undivided special category space carrying vehicles ought to have a lower survivability compared to a similar passenger ship, and therefore a RoPax vessel would be more suitable for analysing the potential for raising the R index. In addition, the new formulation for the s value from SLF 55 would further lower the A index, potentially making it more difficult to meet an increased R index.

This is of course a qualitative judgement based on experience, and it would not be possible to completely rule out the possibility of a similar passenger ship having inherent design features which would lead to a lower A index compared to a similar RoPax vessel. It may be that a small sensitivity or parametric study would need to be conducted to deal with this issue.

At the first EMSA coordination meeting, it was decided that the small RoPax vessel ought to have a length of around 100 m and have sufficient passengers to trigger the 2 compartment standard for minor damages.

8.5.2 Business Model

The business model for this vessel had to be derived by analysing similar vessel types and their associated routes since there was no clear route or business model among the RoPax operators in the research consortium.

A search was carried out on the Shippax Database for RoPax vessels between 70 and 100 m, built in the last 5 years. Significant numbers of these vessels were double ended RoPax vessels and were discarded. The relevant ones are tabulated below. It should be noted that all the vessels found serve domestic routes do not by default fall under SOLAS, however some operators do choose to build their vessel to comply with SOLAS. Some of the routes would in all likelihood receive some kind of subsidy, and so the commercial case for these vessels is somewhat difficult to evaluate. The Fogo ferry is a KNUD E. HANSEN A/S design that is currently being constructed.

Table 8-21 Overview- some small RoPax ferries in operation

Name	LOA (m)	LBP (m)	B (m)	T (m)	D (m)	L/B	SPEED (knots)	MCR (kW)	GT	DWT (tonnes)	LM (m)	CARS	PAX
Finlaggan	89.90	81.80	16.90	3.50	5.50	4.84	16.50	8000	5626	780	135	85	550
Atlantida	96.94	86.50	18.00	4.60	7.00	4.81	16.40	10604	6820	800		140	750
Landegode	96.00	89.98	17.40	4.20	5.50	5.17	17.00	5200	5695	650	324	120	390
Pasio per Formentera	101.00	86.60	17.00	4.30	6.00	5.09	20.00	9002	6146	850	304	150	800
Fogo	80.90	71.00	17.20	4.00	6.50	4.13	14.00	5100	4437	905	190		200

The route details of the various vessels are shown in the table below:

Table 8-22 Route details of some small RoPax Ferries

Name	Voyage	Turnaround
Finlaggan	1h55m-2h20m	25m-55m
Atlantida	45m-4h	30m-17h15m
Landegode	3h15m	2h-6h15m
Pasio per Formentera	3h30m	16h
Fogo	45m	15m-1h15m

It should be noted that the Atlantida was never put into its intended service, and so the voyage and turnaround times are estimated from the timetable of the replacement vessel. Similarly, the details for the Fogo vessel are estimated from the schedule of the current vessel.

For the vessels above with relatively short turnaround times, they all cease operations at night and so have a longer layover after the final voyage

As can be seen above, there is a significant variation in voyage length and turnaround time among the sample vessels investigated. One trend is that the vessels with the longer layover times tend to have a larger passenger capacity, perhaps balancing passenger numbers against the number of daily voyages.

Based on the above, and taking into account the wishes of the operator, the business case is stated as follows:

- Vessel to be for short international voyages of up to around 4 hours in length
- Deadweight and lane metres are prioritised for commercial revenue purposes
- 600 day passengers accommodated in public spaces only, no cabins

8.5.3 General Description

The sample ship is a small RoPax ferry designed for short international voyages of around 4 hours in duration, with a short turnaround time, and multiple trips per day, as befits a revenue earning route based on carrying trailers.

The main vehicle deck is of sufficient clear height for trailers and has around 400 trailer lane metres of 3.0 m width. The vehicle deck is fitted with 4 sections of hoistable car decks on the port side for increased flexibility. Bow and stern doors are fitted for drive through operation, though only single tier loading is supported.

Accommodation for 600 passengers is arranged on 2 decks in public spaces, no cabins are provided due to the short voyage duration. Lifeboats arranged for at least 30% of total number of persons onboard as per SOLAS requirements for short international voyages.

Propulsion is provided by a diesel mechanical system consisting of 2 main engines driving 2 controllable pitch propellers via a gearbox. 2 PTOs are provided as well as 2 auxiliary engines for the electrical load.

Main characteristics as follows:

Length over all	100.596 m
Length between perpendiculars	95.50 m
Subdivision Length	98.526 m
Breadth	20.20 m
Subdivision Draught	4.90 m
Height of Bulkhead Deck	7.10 m
Number of Passengers	600
Number of Crew	25
Gross Tonnage	7900 approx
Deadweight	1487 tonnes
Trailer Lane Metres	400 approx
Service Speed	18 knots
Installed power main engines	2 x 3600 kW
Installed power auxiliary engines	2 x 632 kW

8.5.4 Regulations

The design complies with all relevant IMO rules and regulations for ships at the time of writing, in particular:

- SOLAS 1974 as amended, including probabilistic damage stability (SOLAS 2009)
- Intact Stability Code (IS Code 2008)
- Load Line Convention

It is assumed that the vessel is not operating in a SECA area, so scrubbers or LNG fuel are not part of the design. Scrubbers would certainly affect the stability of the design, however switching to LNG or MGO would have less impact, but it is beyond the scope of this project to investigate these options.

Ballast water treatment is not explicitly considered here, but there should be sufficient space in the vessel to include this if required.

8.5.5 General arrangement

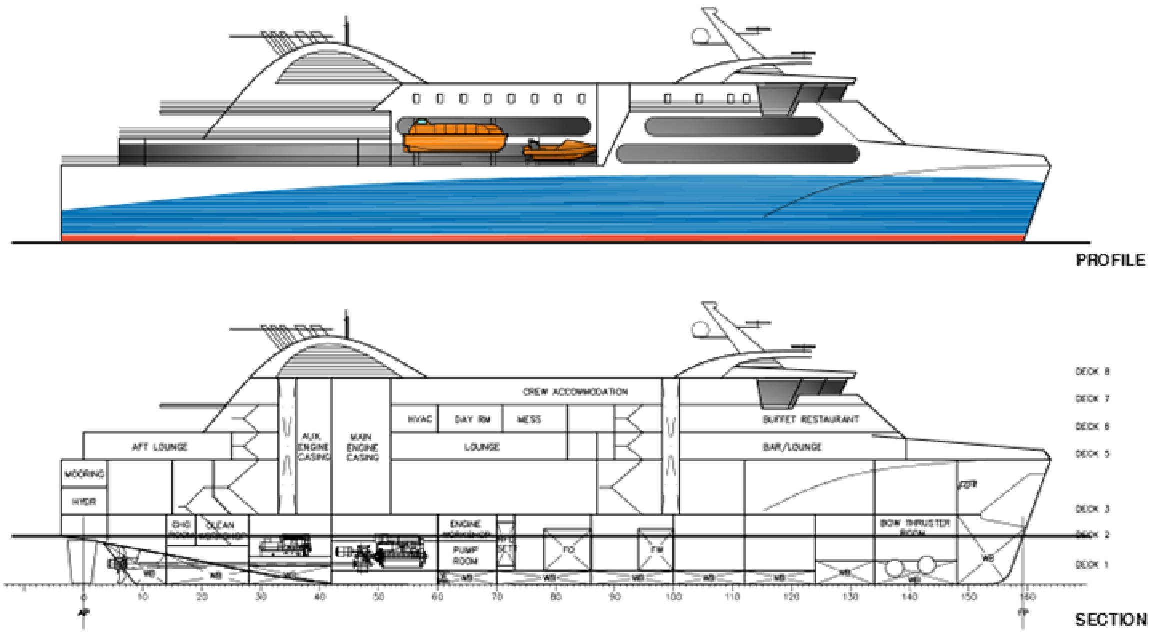


Figure 8-33 Profile – Small RoPax

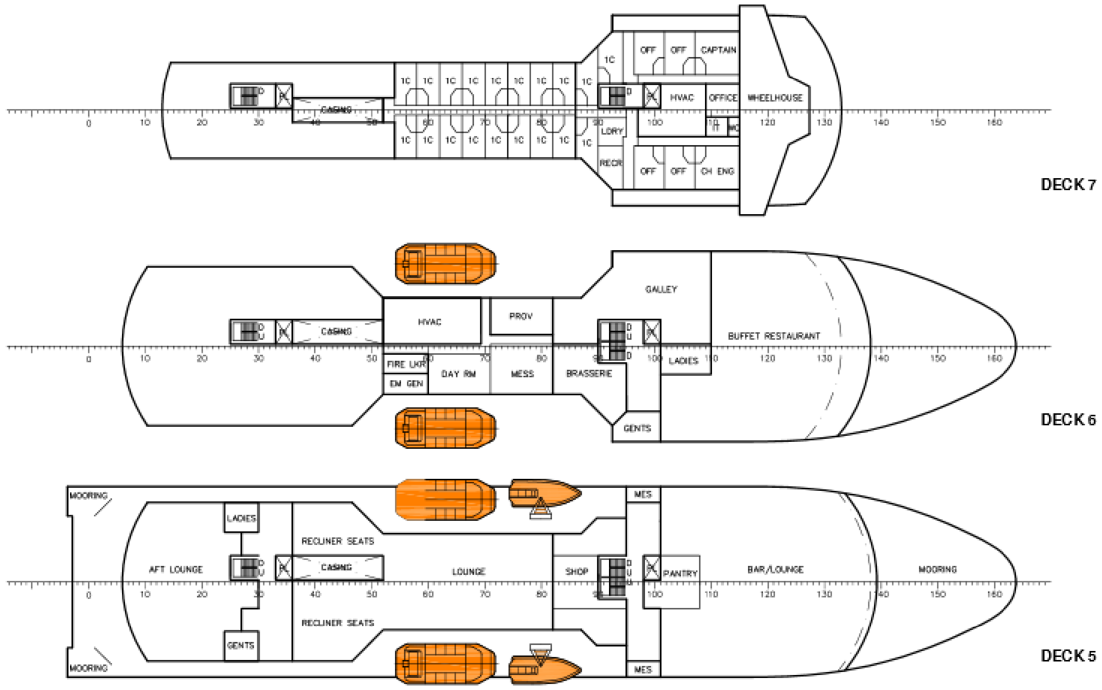


Figure 8-34 General arrangement deck 5 – deck 7 – Small RoPax

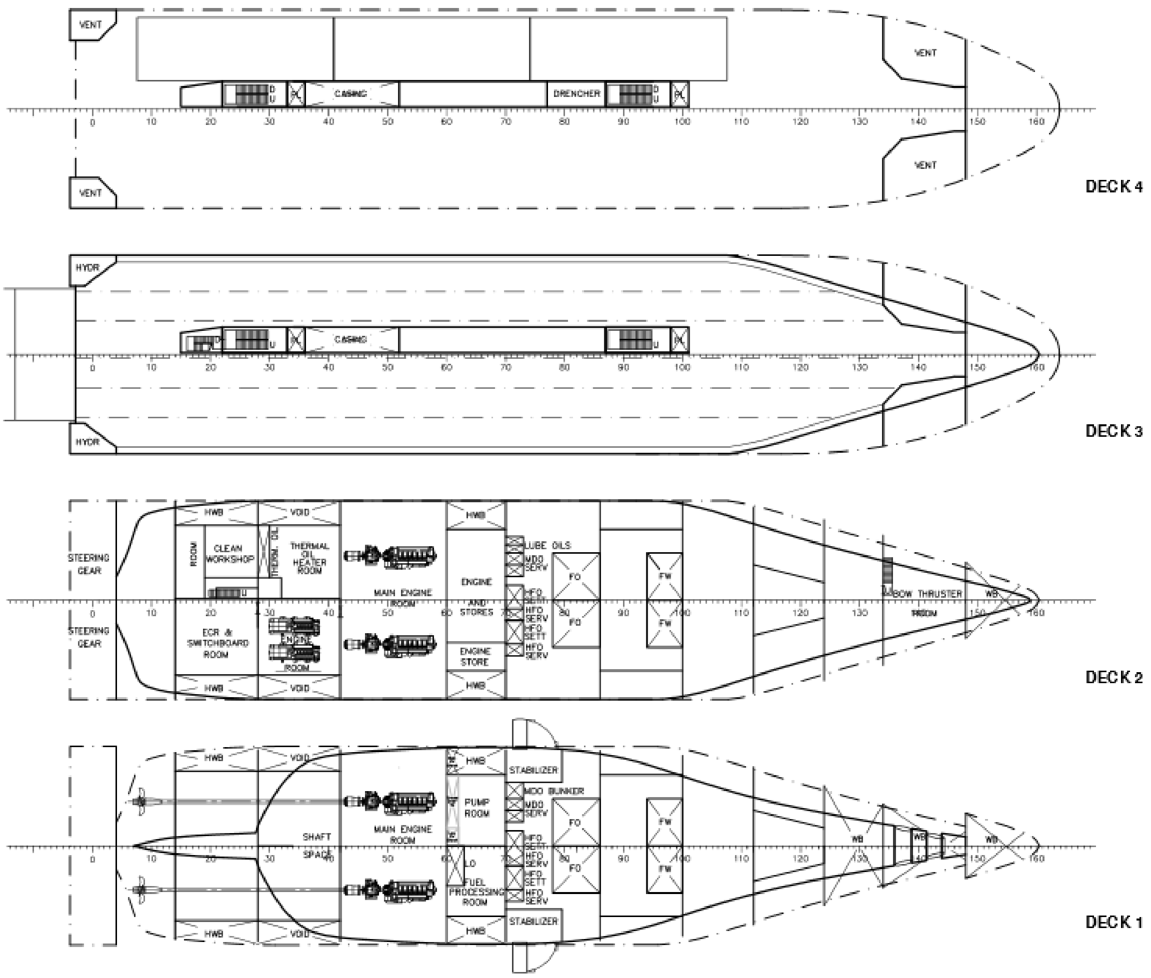


Figure 8-35 General arrangement deck 1 - 4 – Small RoPax

8.5.6 Hullform

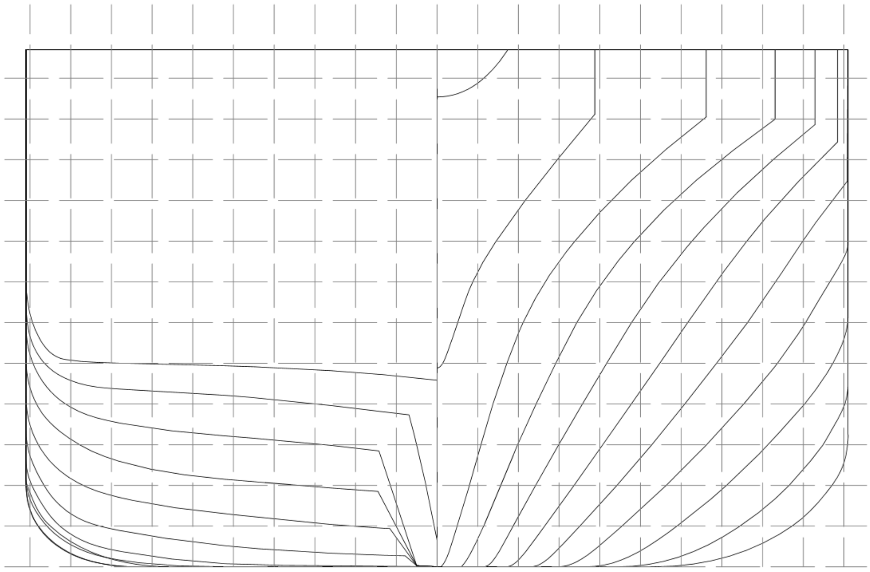


Figure 8-36Lines plan – Small RoPax

8.5.7 Engine configuration

The engine configuration utilises a diesel mechanical arrangement with 2 prime movers of 3600 kW each driving 2 controllable pitch propellers via a gearbox. Service speed of 18 knots is achieved at 90% MCR with 15% sea margin. Hotel load of approximately 600 kW served by 2 auxiliary engines of 632 kW each. PTO (600 kW each) on each engine to power the bow thrusters.

Engines assumed to run on HFO.

8.5.8 Tankplan

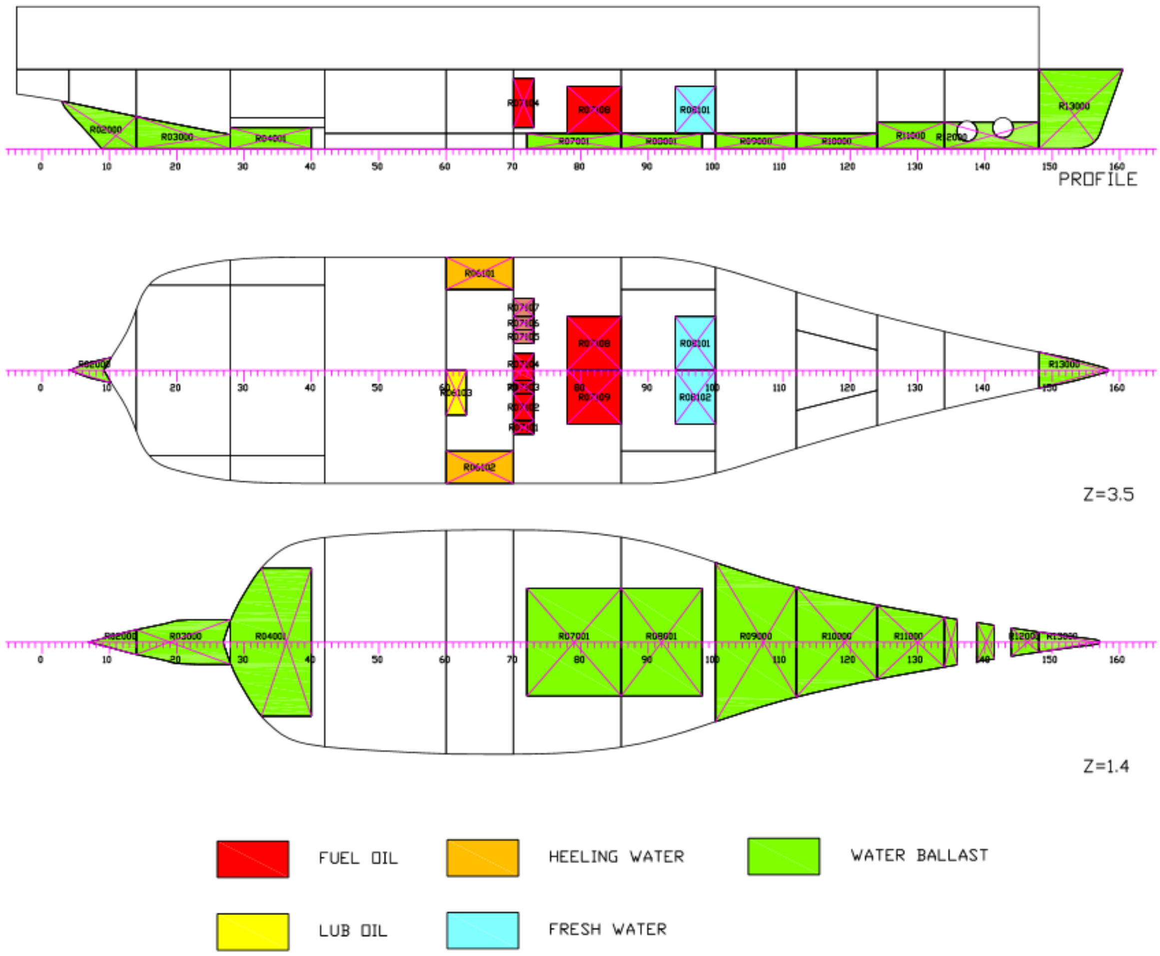


Figure 8-37 Tank Plan – Small RoPax

The following capacities are achieved for the various purposes:

Table 8-23 Tank capacities – Small RoPax

Description	RHO tonnes/m^3	Volume m^3	Weight tonnes
Heavy Fuel Oil	0.99	246	243
Diesel Oil	0.86	31	27
Lub Oil	0.90	21	19
Heeling Water	1.025	195	200
Fresh Water	1.00	140	140
Water Ballast	1.025	750	952

8.5.9 Subdivision

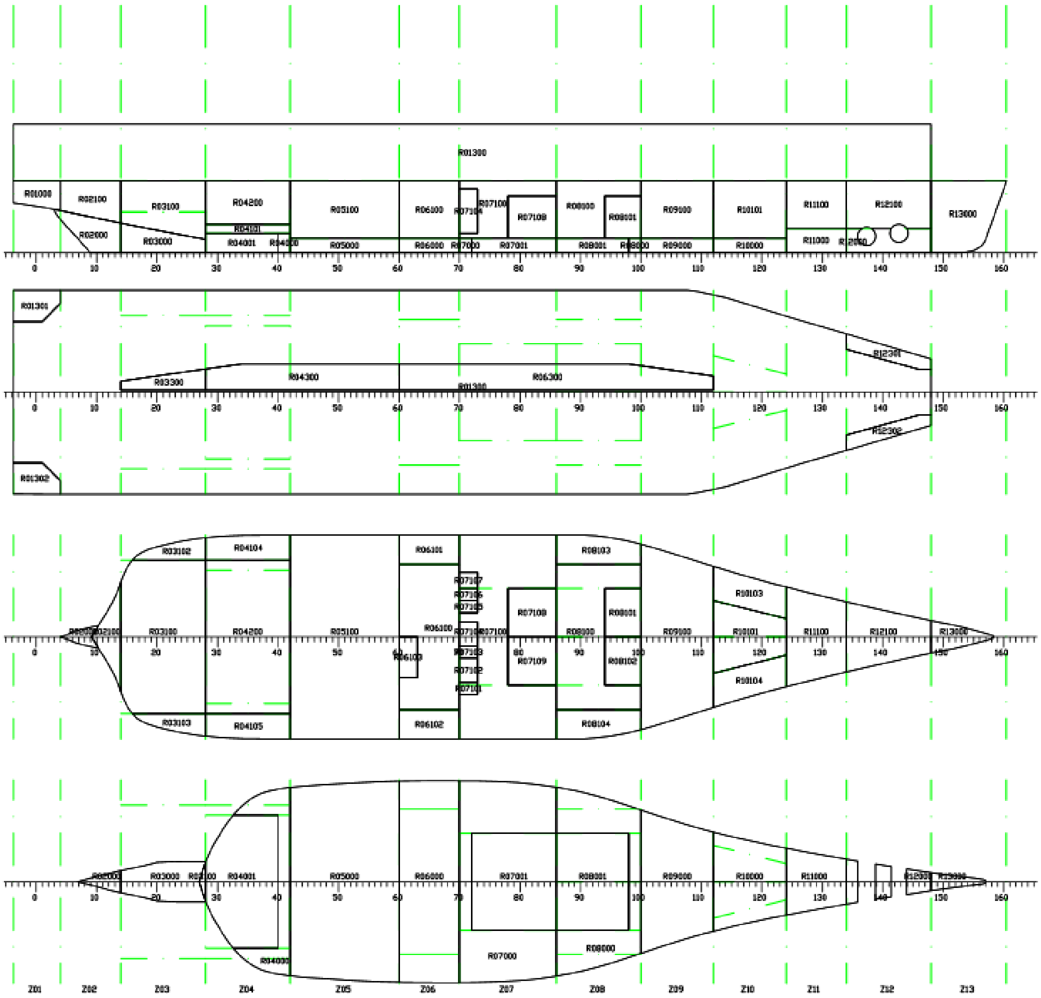


Figure 8-38 Subdivision – Small RoPax

8.5.10 Hydrodynamics

8.5.10.1 Speed power performance

Necessary delivered power (Pd) at 18 knot = 5910 kW

Necessary installed power (Pi*) at 16 knot = 6840 kW

Pi* is based on following efficiencies / coefficients:

Seamargin:	15 %	MCR:	90 %
Shaft eff.:	98 %	Gear Eff.:	98 %

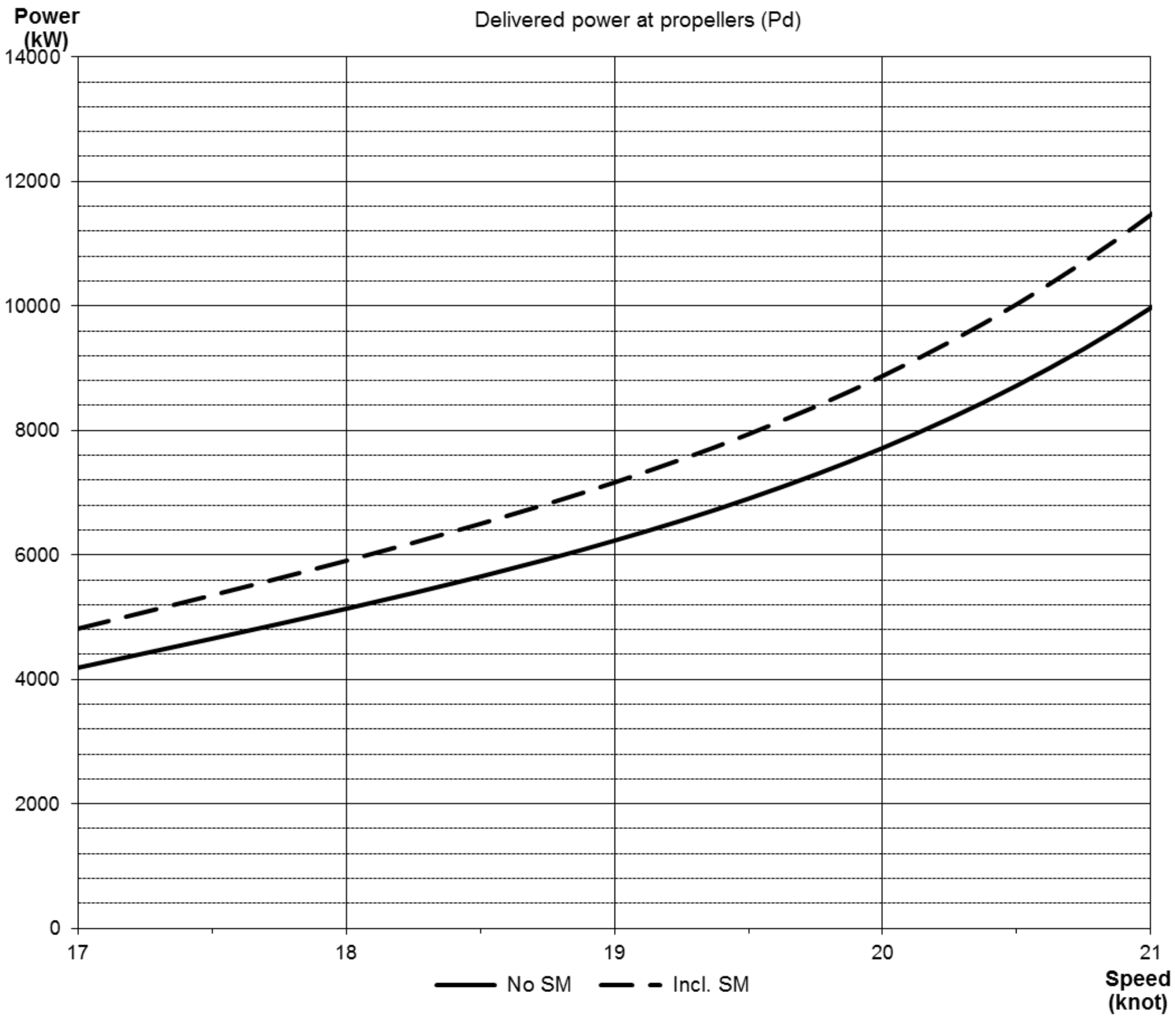


Figure 8-39 Speed/Effect diagram – Small RoPax

8.5.10.2 Manoeuvrability

The vessel is equipped with 2 bow thrusters of 600 kW each and 2 high lift rudders.

8.5.11 Intact Stability

8.5.11.1 Loading Conditions

The following table (Table 8-24) details the loading conditions considered for this design.

Table 8-24 Loading conditions – Small RoPax

ID		Draught mld (m)	Trim (m) (+ve by bow)	GMf (m)
Con02	Design Departure	4.877	0.007	2.102
Con03	Design Arrival	4.746	0.096	1.977
Con04	Full Passengers No Cargo Departure	4.372	0.119	2.404
Con05	Full Passengers No Cargo Arrival	4.206	-0.055	2.370
Con06	Ballast Arrival	4.202	0.086	2.496

Homogenous cargo is assumed at 2 tonnes per lane metre for a total of 800 tonnes of cargo.

8.5.11.2 GM Limiting Curve

GM limit curves have been generated to the requirements of the 2008 Intact Stability Code and SOLAS 2009. The following diagram (Figure 8-40) illustrates the GM limit curves with the loading conditions described above plotted to show compliance with both the intact and damage stability requirements.

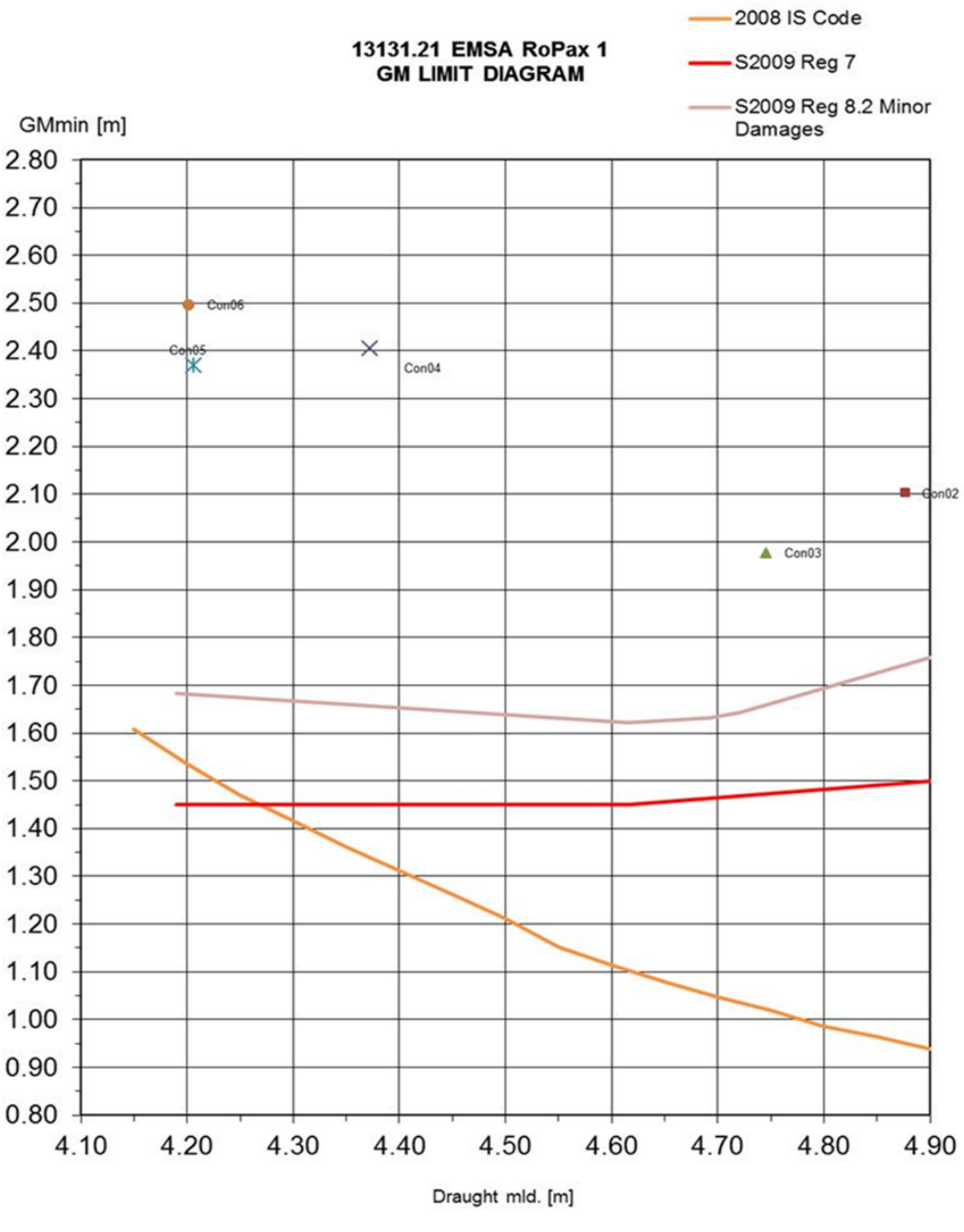


Figure 8-40 GM Limit Diagram – Small RoPax

8.5.12 Results of Damage Stability Calculation

Damage stability has been assessed to the requirements of SOLAS 2009 Chapter II-1. This has included the calculation of the attained index in accordance with Regulation 7 and the assessment of damage cases required by Regulation 8.

8.5.12.1 Attained index vs R

The following table shows the results of the calculations carried out to derive the Attained index. The damage assessment has included port and starboard damages with the values below showing the combined results.

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length:	98.528 m
Breadth at the load line:	20.219 m
Breadth at the bulkhead deck:	20.200 m
Number of persons N1:	200
Number of persons N2:	425

Required subdivision index R = 0.72143
Attained subdivision index A = 0.774042
Attained subdivision index AWOD[5] = 0.72252

Table 8-25 Attained index – Small RoPax

INIT	T m	GM m	A/R	A	A*WCOEF	WCOEF
DP	4.190	1.450	1.08	0.77818	0.15564	0.200
DP	4.616	1.450	1.04	0.75221	0.30088	0.400
DS	4.900	1.500	0.98	0.70974	0.28389	0.400

8.5.12.2 SOLAS Reg. II-1/8 and 9.8 Results

It was found that the assessment of damage in accordance with Regulation 8 derived more onerous limiting GM values than those necessary to achieve the Required index alone. The initial GM values listed in the calculation of the Attained index above were those derived from the requirements of Regulation 8.2. The full range of limiting GMs derived from Regulation 8.2 is shown in the table below:

Table 8-26 Limiting GM based on SOLAS Reg.II-1/8.2

Draught (m)	Minimum GM (m)
4.190	1.694
4.616	1.622
4.693	1.631
4.722	1.644

Using these GM values, the attained index A is 0.81552 and AWOD is 0.79473. The summarised results are shown below in Table 8-27.

5 AWOD denotes use of the formulations for s agreed at SLF55 for cases when ro-ro deck is open to sea

Table 8-27 Attained index using GM required according to SOLAS Reg.II-1/8.2

INIT	T m	GM m	A/R	A	A*WCOEF	WCOEF
DP	4.190	1.694	1.21	0.87443	0.17489	0.200
DP	4.616	1.622	1.13	0.81590	0.32636	0.400
DS	4.900	1.758	1.09	0.78569	0.31428	0.400

Given the double bottom arrangement of the design it was not considered necessary to assess any damage stability cases to meet the requirements of Regulation 9.

8.6 Ship #6 RoPax double end ferry

8.6.1 Introduction

This section describes the basic information about a double ended RoPax. Small passenger ships have been less researched in previous projects concerned with stability and there is a growing concern that any increase in the R index may unduly penalise small ships.

8.6.2 Business Model

The business model for this vessel is based on the route between Helsingør in Denmark and Helsingborg in Sweden. The voyage is considered a short international voyage therefore SOLAS applies. Currently 2 different classes of double ended roro passenger ferry operate on the route which consists of an 18 minute crossing and 12 minute turnaround time.

	Aurora af Helsingborg	Mercandia IV
LBP (m)	106.36	90.00
Breadth (m)	27.60	15.00
Draught (m)	5.50	3.60
GT	10918	4511
DWT (tonnes)	2300	1257
Passengers	1250	400
Lane Metres (lm)	535	290
Service Speed (knots)	14.00	12.00
Installed Power (kW)	9760	2750
Built	1992	1989

The Mercandia IV has 2 vehicle decks, although only the main deck has sufficient height for trailers. The design of Mercandia IV is unique in that there is no engine room, but it has 10 Cummins diesel engines at the side of the upper vehicle deck driving a diesel electric system. This unconventional arrangement will not be replicated in the new design.

The Aurora af Helsingborg was originally designed as a train ferry, and is also fitted with a platform deck for cars on one side of the vessel.

Given that the breadth of the Aurora af Helsinborg is derived from its original purpose as a train ferry (L/B ratio of 3.85), and that the general form of double enders in the EC (particularly in Norway and Croatia) have a L/B ratio around 5.5 to 6, it was decided that the Mercandia IV would be more representative as a basis vessel for this analysis.

8.6.3 General Description of the ship

The sample ship is a small double ended RoPax ferry designed for short international voyages of around 15 to 18 minutes in duration, with a short turnaround time, and multiple trips per day, as befits a revenue earning route based on carrying trailers.

The main vehicle deck is of sufficient clear height for trailers and has around 280 trailer lane metres of 3.0m width. A second vehicle deck, with a reduced clear height, suitable for cars and caravans, with around 320 lane metres is fitted above the main deck. Bow and stern doors are fitted for drive through operation, and double tier loading is supported. The main vehicle deck is fully enclosed, while the upper deck is open at both ends. There are no ramps between vehicle decks.

Accommodation for 600 passengers is arranged in public spaces primarily located on one deck and there are no passenger cabin provided due to the short voyage duration. Crew cabins and mess facilities are located on a separate deck.

Although the vessel operates on a short international voyage, due to the sheltered nature of the route and the short distance, the administration normally exempts vessels from the requirement to carry lifeboats, and consequently the vessel is fitted with MESs and liferafts only. From a damage stability point of view, this raises the R index compared with a vessel fitted with lifeboats meaning that such vessels are required to have a higher survivability standard than comparable vessels that carry lifeboats.

Propulsion is provided by a diesel electrical arrangement consisting of 4 main generator sets and 4 directional propellers driven by electrical motors. There is one additional smaller auxiliary generator set. The machinery arrangement is only an indicative solution; there are certainly other possible combinations that would work. We have also not considered LNG or batteries in this analysis

Main characteristics as follows:

Length over all	102.22 m
Length between perpendiculars	96.80 m
Subdivision Length	102.219 m
Breadth	17.60 m
Subdivision Draught	4.3 m
Height of Bulkhead Deck	5.70 m
Number of Passengers	600
Number of Crew	10
Gross Tonnage	5040 approx
Deadweight	1580 tonnes
Trailer Lane Metres	278 approx
Car Lane Metres	322 approx
Service Speed	16 knots
Installed power main engines	5840 kW
Installed power auxiliary engines	500 kW

Regulations:

The design complies with all relevant IMO rules and regulations for ships at the time of writing, in particular:

- SOLAS 1974 as amended, including probabilistic damage stability (SOLAS 2009)
- Intact Stability Code (IS Code 2008)
- Load Line Convention
- The intended area of operation is within the Baltic Sea Sulphur Oxide (SOx) Emission Control Area (SECA). MDO operation is assumed as is the case with the current tonnage in service on the route.

8.6.4 General arrangement

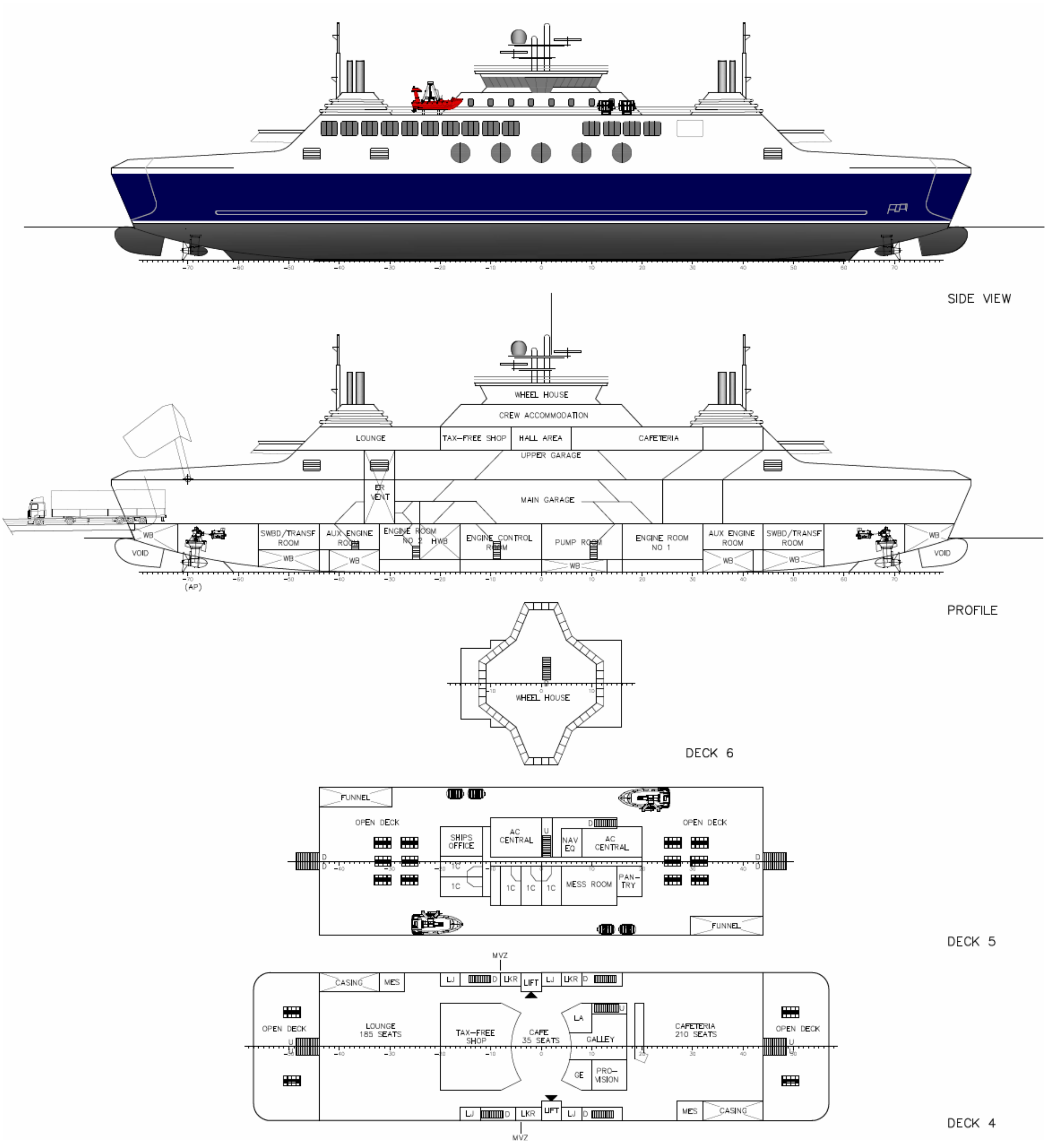


Figure 8-41 Profile and deck 4 & 5- Double end Ferry

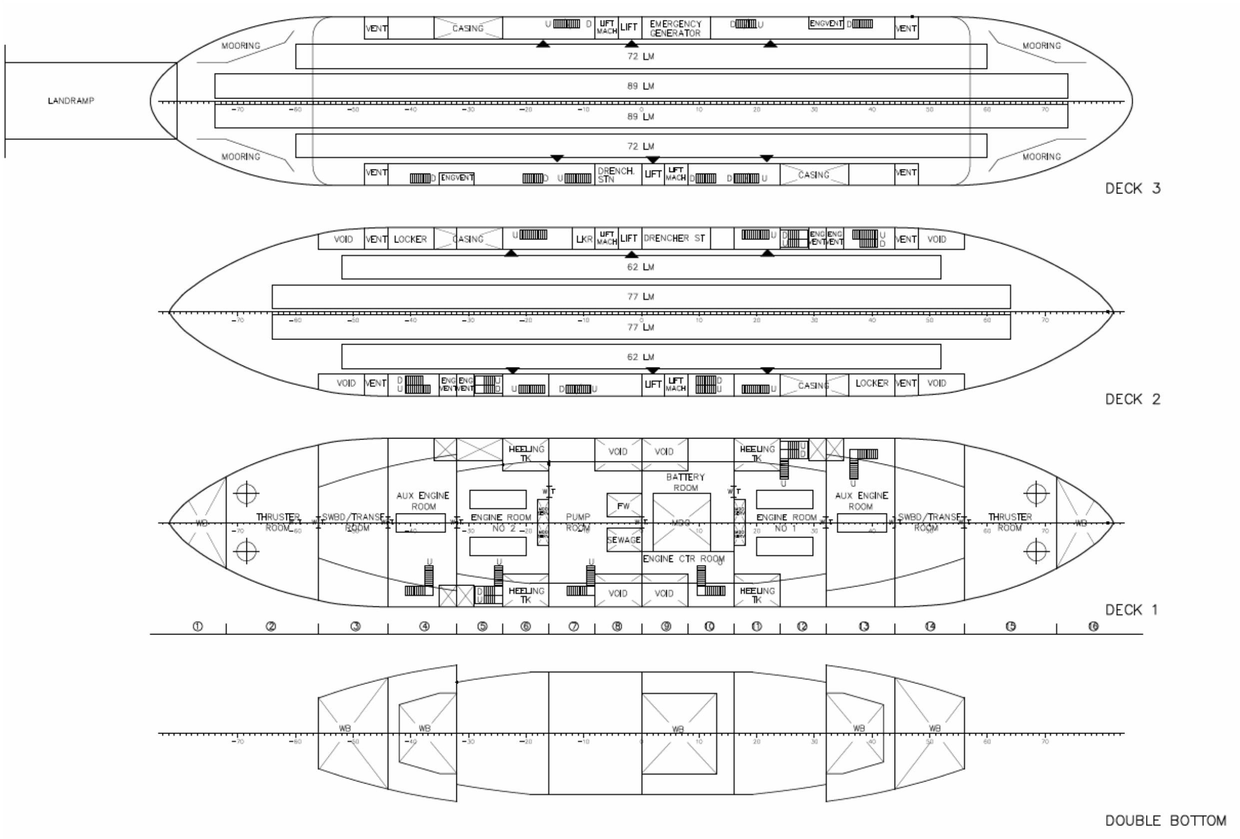


Figure 8-42 General arrangement double bottom - deck 3- Double end Ferry

8.6.5 Hullform

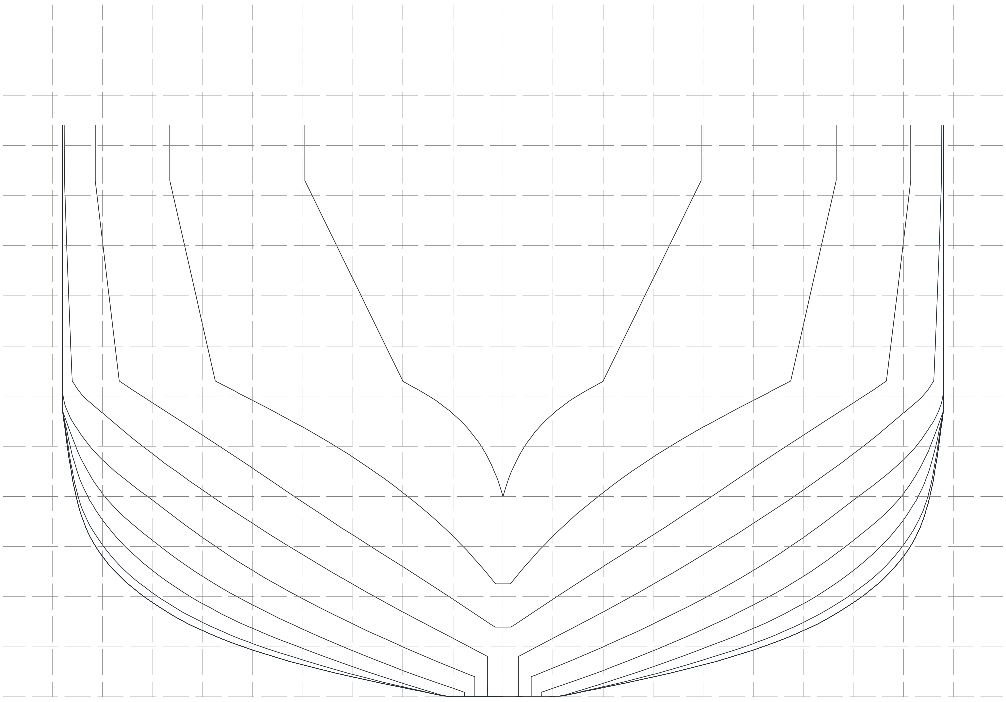


Figure 8-43 Lines Plan- Double end Ferry

8.6.6 Engine configuration

The engine configuration utilises a diesel electric arrangement with four medium speed diesel generator sets each producing 1460kW. A secondary 500kW diesel generator can be used to provide additional power and cater for harbour loads. Propulsion is by way of four electric motors of around 1170 kW each driving 4 directional propellers. Service speed of 16 knots is achieved at 90% MCR with 15 % sea margin.

The engines are assumed to run on MDO.

8.6.7 Tankplan

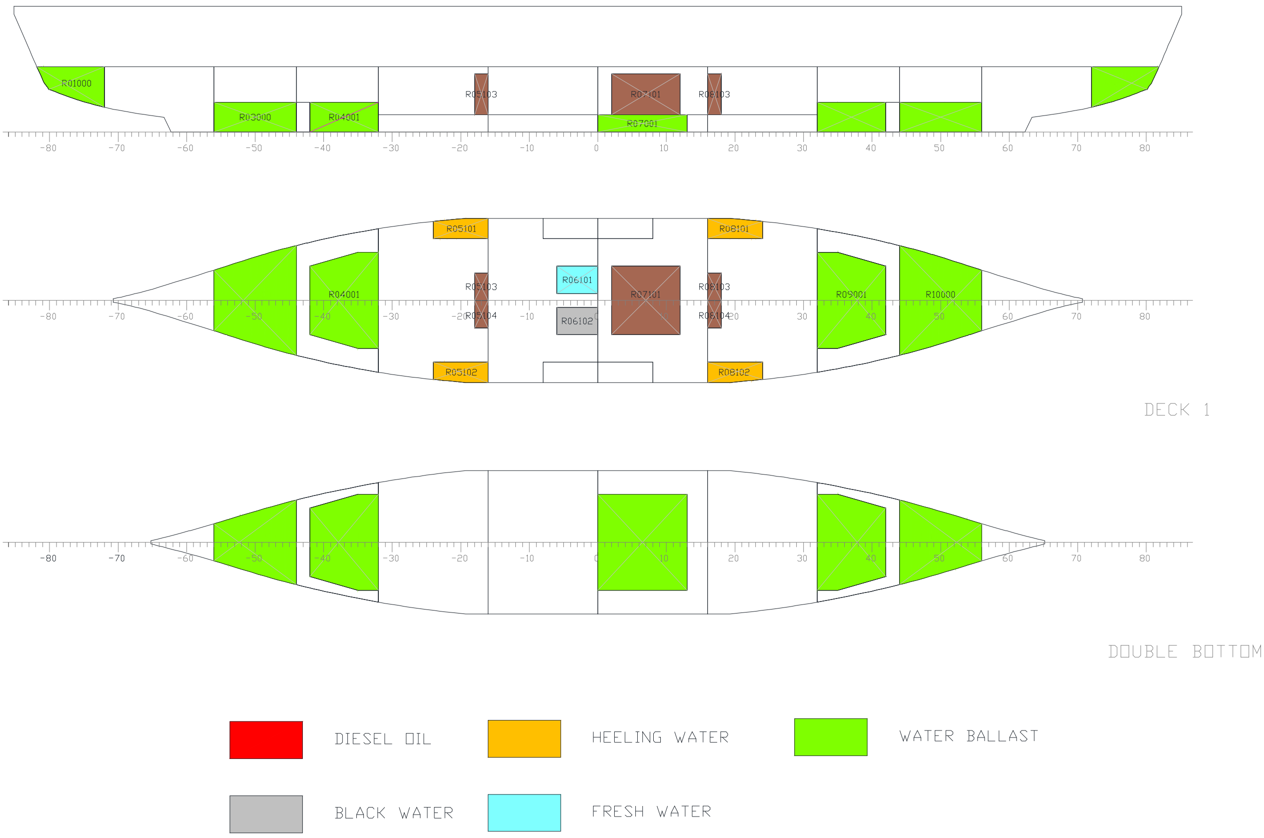


Figure 8-44 Tank Plan- Double end Ferry

The following capacities are achieved for the various purposes:

Table 8-28 Tank capacities- Double end Ferry

Description	RHO tonnes/m^3	Volume m^3	Weight tonnes
Diesel Oil	0.86	168	145
Lub Oil	0.90	11	10
Heeling Water	1.025	215	220
Fresh Water	1.00	30	30
Water Ballast	1.025	631	647

8.6.8 Subdivision

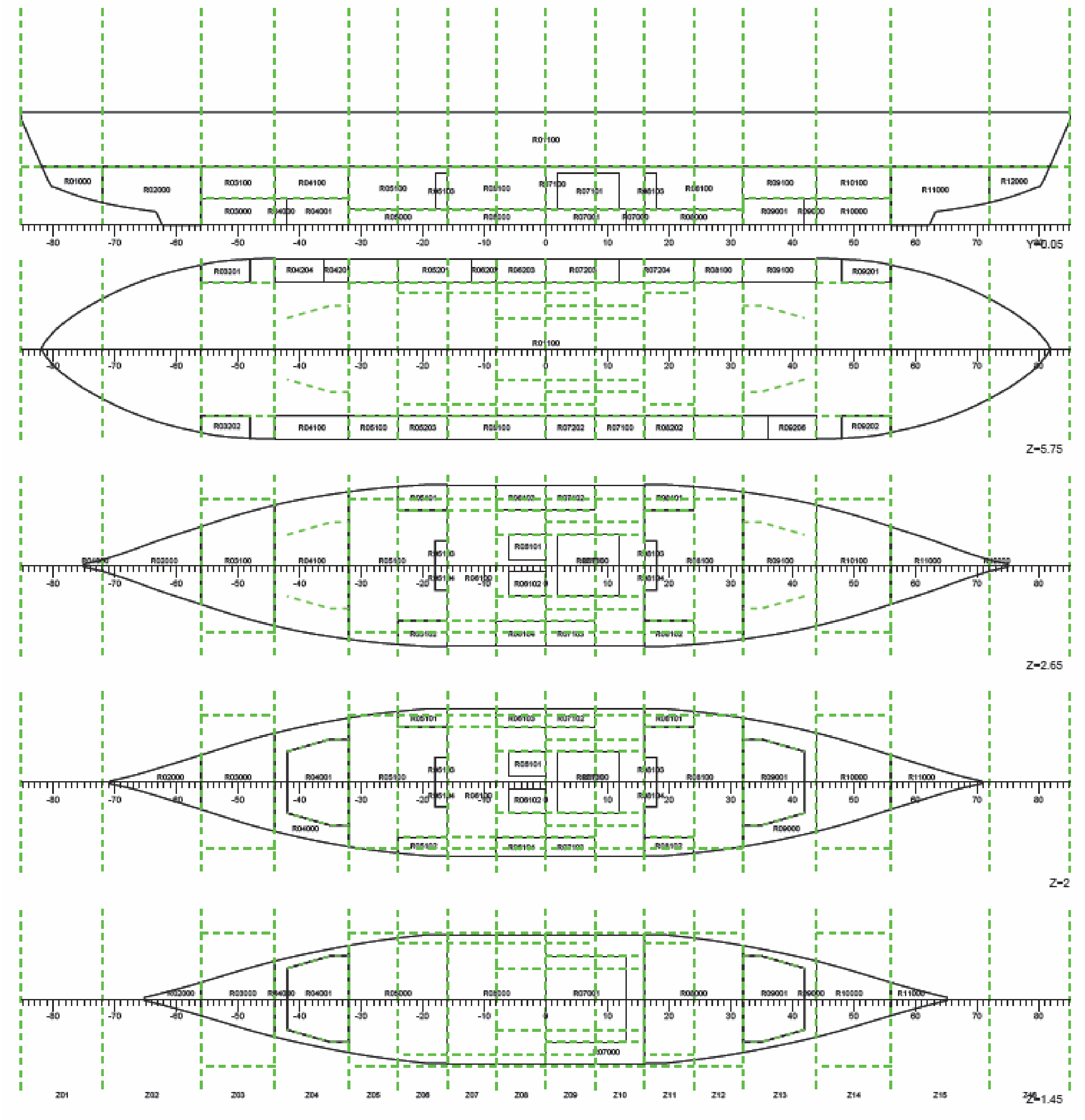


Figure 8-45 Subdivision- Double end Ferry

8.6.9 Hydrodynamics

8.6.9.1 Speed power performance

Necessary delivered power (Pd) at 16 knot = 3390 kW (no seamargin)

Necessary installed power (Pi*) at 16 knot = 4660 kW

Pi* is based on following efficiencies / coefficients:

Seamargin:	15 %	MCR:	90 %
Shaft eff.:	95 %	Gear Eff.:	98 %
El.motor loss	0 %	Conv. Loss:	0 %

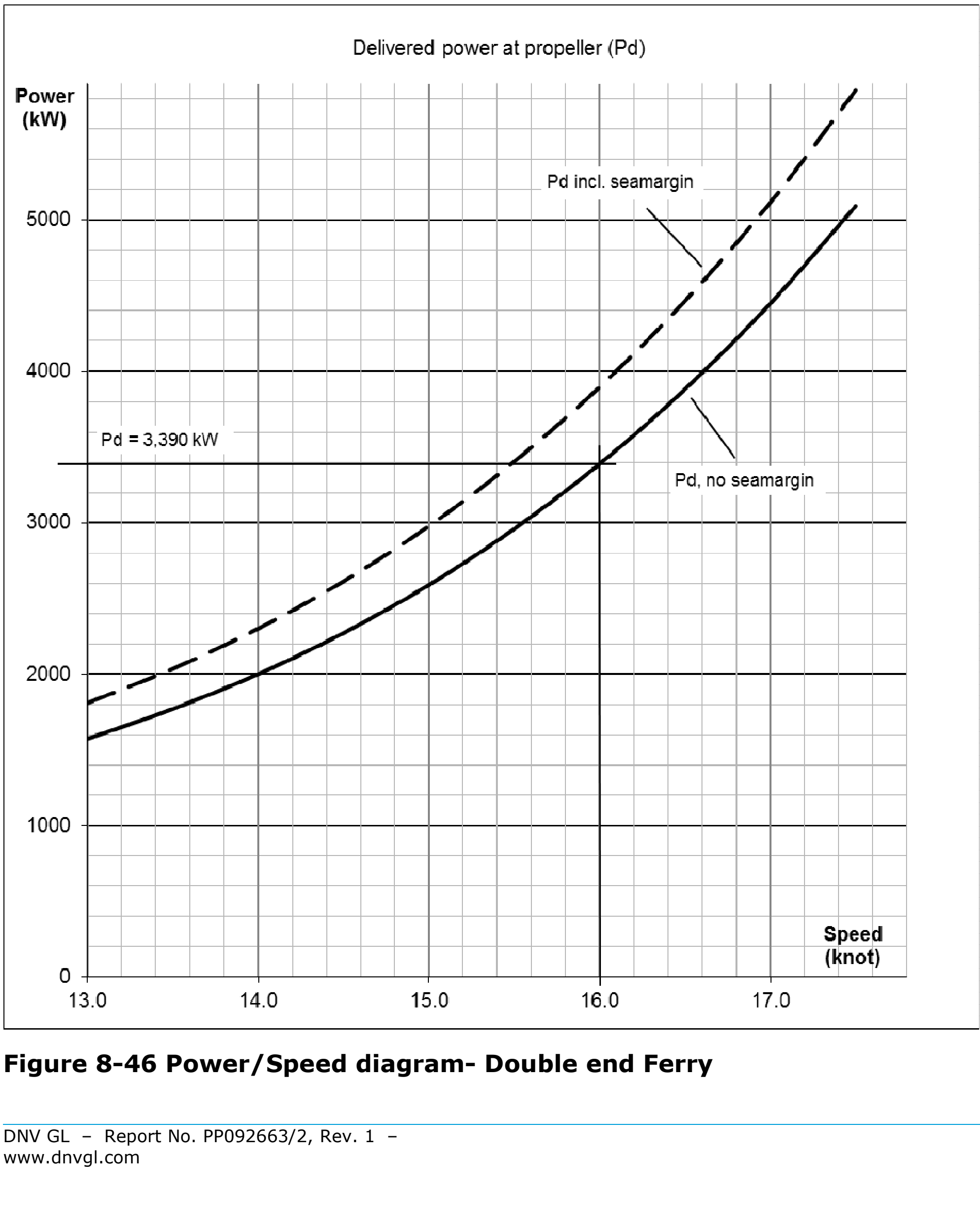


Figure 8-46 Power/Speed diagram- Double end Ferry

8.6.9.2 Manoeuvrability

The vessel is fitted with four directional propellers which can be used for manoeuvring there are no additional rudders or tunnel thrusters fitted.

8.6.10 Intact Stability

8.6.10.1 Loading Conditions

The following table details the loading conditions considered for this design.

Table 8-29 Loading conditions- Double end Ferry

ID		Draught mld (m)	Trim (m) (+ve by bow)	GMf (m)
Con01	Design Load Departure	3.99	0.03	2.008
Con01	Design Load Arrival	4.01	0.01	1.902
Con03	Ballast Arrival	3.39	0.02	3.128
Con04	Scantling Draught Departure	4.30	0.03	2.220
Con05	Full Pax No Cargo Departure	3.54	0.08	2.465
Con06	Full Pax No Cargo Departure	3.44	0.01	2.355

The design condition assumes a total load of 715 tonnes of trucks and cars along with 600 passengers.

8.6.10.2 GM Limiting Curve

GM limit curves have been generated to the requirements of the 2008 Intact Stability Code and SOLAS 2009. The following diagram illustrates the GM limit curves with the loading conditions described above plotted to show compliance with both the intact and damage stability requirements.

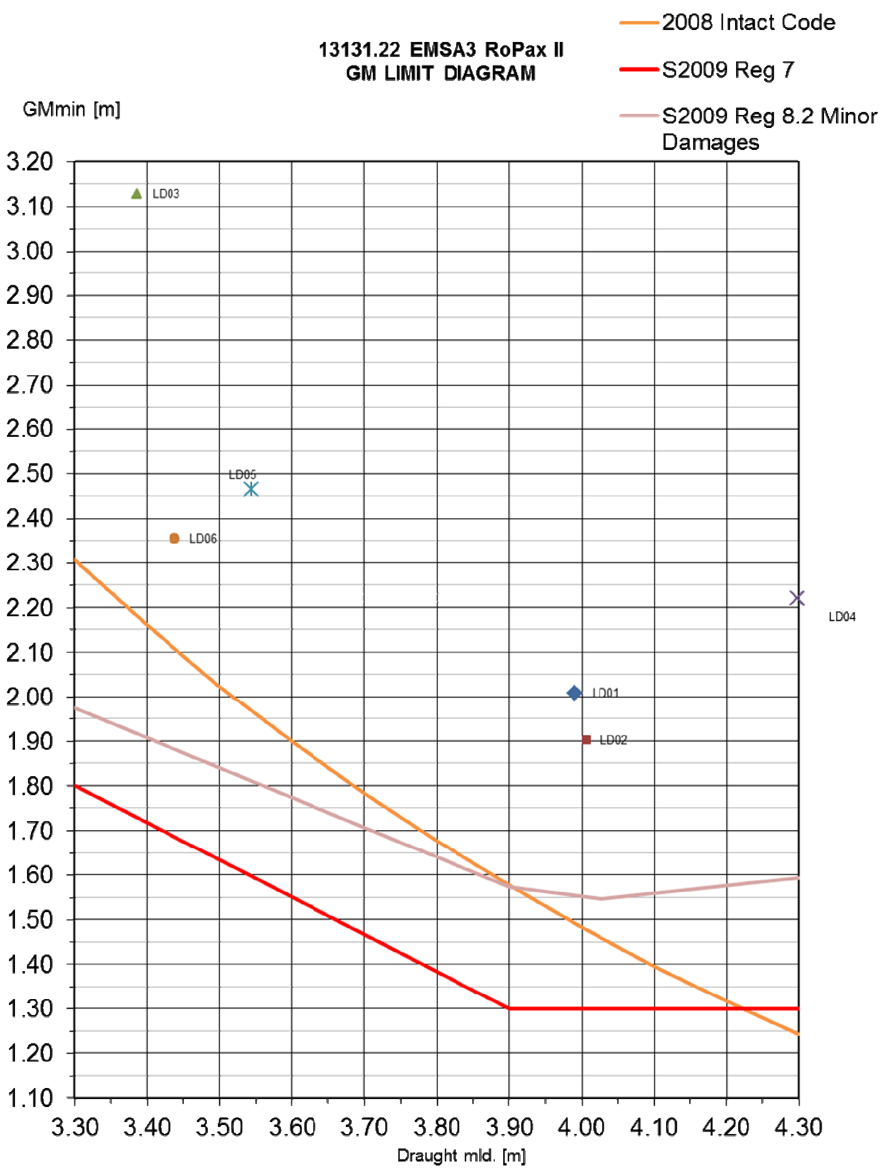


Figure 8-47 GM limit diagram- Double end Ferry

8.6.11 Results of Damage Stability Calculation

Damage stability has been assessed to the requirements of SOLAS 2009 Chapter II-1. This has included the calculation of the attained index in accordance with Regulation 7 and the assessment of damage cases required by Regulation 8.

8.6.11.1 Attained index vs R

The following table shows the results of the calculations carried out to derive the Attained index. The damage assessment has included port and starboard damages with the values below showing the combined results.

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	102.219 m
Breadth at the load line	17.189 m
Breadth at the bulkhead	17.188 m
deck	0
Number of persons N1	610
Number of persons N2	

Required subdivision index R = 0.72792
Attained subdivision index A = 0.76478
Attained subdivision index A_{WOD}[6] = 0.74911

Table 8-30 Summary of index calculations- Double end Ferry

INIT	T (m)	GM (m)	A/R	A	A*WCOEF	WCOEF
DP	3.300	1.800	1.18	0.85830	0.17166	0.200
DP	3.900	1.300	1.04	0.75471	0.30188	0.400
DS	4.300	1.300	1.00	0.72810	0.29124	0.400

8.6.11.2 Reg 8 and 9.8 Results

It was found that the assessment of damage in accordance with Regulation 8 derived more onerous limiting GM values than those necessary to achieve the Required Index alone. The initial GM values listed in the calculation of the Attained Index above were those derived from the requirements of Regulation 8.2. The full range of limiting GMs derived from Regulation 8.2 is as follows (Table 8-31):

[6] AWOD denotes use of the formulations for s agreed at SLF55 for cases when ro-ro deck is open to sea

Table 8-31 Limiting GM according to SOLAS Reg.II-1/8.2

Draught (m)	Minimum GM (m)
3.300	1.974
3.900	1.573
4.027	1.545
4.300	1.593

Using these GM values, the attained index A is 0.85227 and A_{WOD} is 0.841231. The summarised results are shown in Table 8-32 below

Table 8-32 Summary of index calculation based on limiting GM according to Reg.8.2

INIT	T (m)	GM (m)	A/R	A	A*WCOEF	WCOEF
DP	3.300	1.974	1.25	0.90741	0.18148	0.200
DP	3.900	1.573	1.18	0.85810	0.34324	0.400
DS	4.300	1.593	1.12	0.81887	0.32755	0.400

Given the double bottom arrangement of the design it was not considered necessary to assess any damage stability cases to meet the requirements of Regulation 9.

9 CONCLUSIONS

The first part of this report includes a review of FSAs previously carried out in the SAFEDOR project for cruise and RoPax as well as the FSA carried out for safety of navigation NAV49/INF.2. In addition, examination of data on accidents occurred since 2005 have been carried out focusing on collision and grounding. Analysis of causes and contrasting with causes included in the HAZIDs have been carried out when possible, however this is only possible for a limited number of accidents. It is concluded that the causes included in the HAZIDS cover a much wider range of possibilities than which can be extracted from the accidents that have occurred. It is concluded that the causes of the accidents occurred are also covered by the three HAZIDs that were carried out.

The second part of this report includes the updated collision risk model which shall be used in the further studies. The risk model takes into account uncertainties and the sensitivity of the model is discussed. The risk model will be used in the Cost Benefit Assessments that will be documented in the next report.

Finally the last part of the report includes documentation on the sample ships that have been developed for the purpose of having a distribution of ship types and sizes that are representative for the world fleet. The sample ships will be the basis for investigating effect of design modifications in the Cost Benefit Analysis.

10 REFERENCES

GOALDS, 2011: GOAL based **D**amage **S**tability – Deliverable D5.1.

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MSC 83/INF.2, 2008: FSA – Cruise ships - Details of the SAFEDOR Formal Safety Assessment. Marine Saftey Committee, International Maritime Organisation, London.

MSC 83/INF.3, 2008: FSA – RoPax ships - Details of the SAFEDOR Formal Safety Assessment. Marine Saftey Committee, International Maritime Organisation, London.

NAV 51/10, 2005: PASSENGER SHIP SAFETY: EFFECTIVE VOYAGE PLANNING FOR PASSENGER SHIPS - FSA - Large Passenger Ships - Navigational Safety. Subcommittee Navigation, International Maritime Organisation, London.

SOLAS, 2009: Safety of Life at Sea. International Maritime Organisation, London.

APPENDIX A

Description of Collision & Grounding Incidents, 2005 onwards (Source: IHS-SeaWeb)

Visible only for internal review.

APPENDIX B

Description of Collision & Grounding Incidents, 2005 onwards (Source: IMO GISIS and EMSA Website) Contrasting with Causes included in the HAZIDs

Appendix B1: Cruise Ships - Groundings

Cruise Ships – Groundings (3)

#	IMO No. Name Incident Date	Incident Description *IMO GISIS (with additional information from EMSA website, where available)*	Comments – Contrasting with causes included in HAZIDs
1	8406731 SEA DIAMOND 05/04/2007	The Sea Diamond, a Greek-flagged passenger cruise ship, hit a reef near the port of Santorini late Thursday 05 April, and sank at dawn on Friday, 6 April 2007. In total, 1,156 passengers and 391 crew were on board at the time of the collision. All but the two passengers, whom were unaccounted for, were evacuated and removed to safety. An oil slick approximately 100 m wide appeared on Thursday, in the aftermath of the collision. An immediate response was launched and all the initial oil was recovered. A remotely operated submarine was launched, in an attempt to locate the two lost passengers, as well as to conduct an overall assessment of the current state of the sunken vessel. Estimates indicate that some 50 tonnes of oil have leaked out. In spite of clean-up efforts have been 2 km of pebbled shoreline has been oiled on Santorini. Passenger cruise ship "SEA DIAMOND", sailed from the port of "HERAKLION" (Crete Island, Greece) on April 05, 2007 with 1155 passengers and 391 crewmembers. At the same day and while the above ship was navigating near the west coast of Santorini Island, Greece, in order to proceed in the port of "FIRA" (Santorini Island, Greece), at 15.40 hrs (L.T.) approximately, ran aground. The next morning, April 06, 2007, she sunk. All the passengers and the crew were rescued except of two passengers who are still reported missing. The above incident is under investigation.	No mention of causes, incident is under investigation. Hazards 8-1 and 8-2 of the SAFEDOR RoPax HAZID refer to emergency evacuations when the ship is trimmed and heeled and to evacuation equipment failure. It should be highlighted that hazard 8-2 was the top-ranked hazard in this HAZID. The causes for these hazards included in the HAZID are: difficulties in launching lifeboat and MES; slow reaction/awareness by passengers; inappropriate assistance to passengers from crew; lack of plans, training and experience; poor maintenance; lack of training; faulty equipment; too extreme heel and trim; human error.
2	8506373 ASTOR 15/05/2009	During unmooring operations/departure from the pier Nordre Toldbod (Port of Copenhagen) the vessel touched bottom by aft starboard quarter, causing no damage to the hull or propulsion system. The Master informed the Authorities immediately and they prohibited any further attempt to move the vessel. After agreement with the towage company was reached, the tugboat pulled the vessel from the seabed and the ship was moored at another berth for diver's inspection. On completion of diver inspection the vessel was cleared for sailing by Port Authorities and finally left the port in the early morning of 16/05/09.	For Hazard 2.3 (grounding) in the SAFEDOR Cruise HAZID one of the possible causes included is “lack of pilot knowledge/VTS information”. Also, in NAV49/INF.2 – Hazard No. 43 “difficult local conditions (poor quay, port layout, marking, anchoring conditions, etc.)” Causes of the incident not mention. All HAZIDs include a

		The major reason for grounding seems to be human error. The Master did not position the vessel towards outbound direction on arrival and did not use tug or pilot service for departure due to good weather conditions. However, the area of shallow water of 6 metres depth at the north area of the pier was not safeguarded by any navigational means, which actually had a negative impact on the conditions of unmooring operations.	great variety of possible causes for incidents when navigating in restricted waters.
3	9320544 COSTA CONCORDIA 13/01/2012	On 13th January 2012 the Italian passenger ship Costa Concordia departed Civitavecchia en route to Savona, Italy, where it was scheduled to arrive the following morning. A few hours and 40 miles later, the ship struck a rock formation about 450 feet from the coast of Giglio in Tuscany. It began taking on water at about 9:45 pm local time. The rocks left a 165-foot gash on the port side of Concordia's hull; after the impact, the ship listed at 20 degrees before partially sinking on Saturday morning. Some passengers jumped into the water and swam to safety, but there were delays in getting others into life boats, especially as the vessel had by then rolled over onto her side and many of the lifeboats were inaccessible. Thirty two lives were lost. Some reports indicated that the ship had also suffered a major electrical fault. There are 2,500 tonnes of oil on board, and booms have been placed around the vessel to contain any leaks, but worsening weather conditions and the shifting of the vessel will render these measures less effective. Offloading the fuel cannot be initiated until all rescue operations have been completed. **Violations and error types:** Violation (deliberate decision to act against a rule or plan): Routine (cutting corners, taking path of least effort, etc...) Lapse (unintentional action where failure involves memory): Other Mistake (an intentional action where there is an error in the planning process; there is no deliberate decision to act against a rule or procedure): Error in judgement; Inappropriate choice of route; Other **Underlying factors:** Psychological: Standards of personal competence; Lack of familiarity or	Hazards 8-1 and 8-2 of the SAFEDOR RoPax HAZID refer to emergency evacuations when the ship is trimmed and heeled and to evacuation equipment failure. It should be highlighted that hazard 8-2 was the top-ranked hazard in this HAZID. The causes for these hazards included in the HAZID are: difficulties in launching lifeboat and MES; slow reaction/awareness by passengers; inappropriate assistance to passengers from crew; lack of plans, training and experience; poor maintenance; lack of training; faulty equipment; too extreme heel and trim; human error. NAV49/INF.2 – Hazard No. 30 "technical failure of power supply" SAFEDOR Cruise HAZID –under the "planning, departure/arrival & voyage" section, HAZARD A is "black-out" Hazards included in NAV49/INF.2 • Hazard No. 1 – "OOW distractions", one of the causes mentioned is "human: telephone calls, other crew members, passengers" • Hazard No. 10 – "poor company policy/culture" • Hazard No. 19 – "communication between navigators, misunderstandings" • Hazard No. 32 – "large vessels, difficult to manoeuvre" • A number of hazards relating to use of bridge equipment: No. 15 "incorrect use of equipment", No. 29 "poor quality

		training; Boredom Software: Company policy and standing orders; Less than adequate operating procedures and instruction; Other **Principle findings and form of casualty investigation:** 1. Poor route planning and navigation direction; 2. BTW management shortcomings; 3. Poor management of emergency evacuation procedures; 4. EDG functionality Criticalities. **Action taken:** • More detailed passengers info; • Voyage plan requested by Solas R V/34 should be made available by the Master to the Company prior ship's departure; • Instructions to passengers to be implemented; • Muster of passengers to be performed in each port for embarking passengers; • Company Audit follow up as a consequence of the casualty; • Amending procedures (Emergency instructions / Decision support system for Master); • Creation of a new Maritime Development & Company Dept by the Company; • Implementation of "High Tech Safety Monitoring System"; • Dedicated Fleet Operations Centre in Genoa; • Deck Officers training implementation. **Findings affecting international regulations:** 1. Double-skin for protecting the WTCs containing equipment vital for the propulsion and electrical production; 2. Limiting of the down flooding points on the bulkhead deck; 3. Provision of a computerized stability support for the master in case of flooding; 4. Interface between the flooding detection and monitoring system and the on board stability computer;	of equipment", The SAFEDOR Cruise HAZID includes a whole section for hazards relating to Voyage Planning. We can highlight the following hazards included: • 1.4 – navigational failure with causes mentioned "unreliable electronic charts" • 1.8 – crew resource management • 3.7 – humar error – two of causes included are inappropriate watch changeover and complacency Another section of the SAFEDOR Cruise HAZID is on "Emergency Operations" with hazards included 5.1 "crew ability/training", 5.3 "crew behaviour/reaction/emergency handling", 5.7 "knowledge of emergency procedures", 5.14 "ship movement (list/trim)"; etc. SAFEDOR Cruise HAZID, Workshop II risk register. Hazard on "Grounding" – ship at full speed hitting hard sea-bottom (rock), as causes the following are mentioned: navigational equipment, updated and appropriate sea-charts, trained and competent officer on watch.

		5. Discontinuity between compartments containing ship's essential systems; 6. More detailed criteria for the distribution, along the length of the ship, of bilge pumps and requirement for the availability of at least one pump having the capacity to drain huge quantities of water; 7. Relocation of the main switchboard rooms above the bulkhead; 8. Relocation of the UHF radio switchboard above the bulkhead deck; 9. Increasing the emergency generator capacity to feed also the high capacity pump(s); 10. Provision of a second emergency diesel generator located in another main vertical zone in respect to the first emergency generator and above the most continuous deck; 11. Provision of an emergency light (both by UPS and emergency generator) in all cabins in order to directly highlight the life jacket location; 12. Bridge management, considering aspects such as the definition of a more flexible use of the resources; 13. Bridge Team Management course for certifications renewal should be mandatory by the 1st January 2015; 14. Principles of Minimum Safe Manning (resolution A.1047(27) as amended by resolution A.955(23)) that should be updated to better suit to large passenger ships; 15. Muster list, showing the proper certification/documentary evidence necessary for crew members having safety tasks; 16. Inclusion of the inclinometer measurements in the VDR; 17. SAR patrol boat supplied with fix fenders, blocked in the upper side of the hull, to approach safe other ships/boats in case of extraordinary evacuation of persons. This should be able to load at list 100 passengers in their deck; 18. Divers speleologist, able to rescue, even in dark condition, persons standing into the ravines of ships/wrecks. **ACCIDENT ANALYSIS BY ITALY IN THE 22ND WORKING GROUP** **Event and Consequences:** Grounding of passenger vessel. The master ordered the navigating	

		officer to change the passage plan to allow for the vessel to pass close to the entrance to a port. The master agreed to the navigating officer's amended plan for the vessel to alter course to starboard and then pass 0.5 mile clear of land near the port entrance. The first officer on watch did not voice his concern to the master over the proposed plan. The first officer altered the vessel's course to starboard but did not continue the turn onto the planned track. The master took the con from the first officer before gaining full situation awareness. After a delay, the master resumed altering the vessel's course to starboard. The vessel deviated inshore of the planned track and grounded. Emergency generator power was automatically activated but was then quickly lost. Sounding of the emergency signal, transmission of a distress message and broadcast of an order to abandon ship were delayed. Consequential underwater damage resulted in the vessel flooding and grounding a second time, after which she was abandoned. A total of 32 passengers and crew died, 157 persons were injured. A total of 2,042.5 cubic metres of oil was spilt. **Contributing factors:** Insufficient risk assessment and passage planning. Illusion of control. Distraction caused by presence of additional persons on the bridge and a mobile telephone call. Insufficient bridge resource management. Lack of appropriate large-scaled chart. Insufficient position monitoring. Damage in excess of survivability standard. **Issues Raised/Lessons Learned:** Need for comprehensive risk assessment, passage planning and position monitoring.	

		Need to remove distractions. Need for effective bridge resource management. Need to consider protection of propulsion and electrical production compartments. Need to consider functional integrity of essential systems. Need to consider improvement and redundancy of emergency power generation. Need to consider detection and monitoring system interfacing with on board stability computer. Need to consider inclusion of inclinometer measurements within VDR. Need to consider more detailed assessment criteria for recognising Manning Agencies. Need to assign appropriately trained crew to emergency duties. **Observations on the Human Element:** Illusion of control. Distraction caused by presence of additional persons on the bridge and a mobile telephone call. Insufficient bridge and emergency resource management.	

Appendix B2: Passenger Ships - Groundings

Passenger Ships – Grounding (1)

#	IMO No. Name Incident Date	Incident Description *IMO GISIS (with additional information from EMSA website, where available)*	Comments – Contrasting with causes included in HAZIDs
1	8913916 OCEAN NOVA 17/02/2009	At approximately 01.30 hours LT on February 17th 2009 the passenger ferry OCEAN NOVA grounded on the rocks in Marguerite Bay, west of Debenham Island, approximately two kilometres from the Argentine research station San Martin. An initial assessment of damage indicated that there was no imminent danger, and no threat to lives. There was no sign of leakage from the vessel. No evironmental damage was caused. As a precaution, the Captain issued a distress signal which was picked up by the Argentine emergency services. The vessel, with 74 passengers on board, was waiting for high tide in the hope that the vessel could be floated off the rocks without damage. Preparations were made to evacuate the passengers and 30 crew members to Argentina's Ushuaia, the world's southernmost city. Three vessels were en route to assist, if required. ***Investigation report by Bahamas not available for download.***	No mention of causes.

Appendix B3: Passenger-RoRo Ships (Vehicles) – Collision and Grounding

Passenger-RoRo Ships (Vehicles) – Collision (1)

#	IMO No. Name Incident Date	Incident Description *IMO GISIS (with additional information from EMSA website, where available)*	Comments – Contrasting with causes included in HAZIDs
1	9293404 NURAGHES 21/06/2006	On June 21st 2006, at 12:56 pm a collision occurred between M/V Moby Fantasy and M/V Nuraghes. Weather conditions were: absence of wind, calm water, and strong fog (visibility < 100 metres). The M/V Moby Fantasy had just left from Olbia Port and was proceeding to Civitavecchia Port at a speed of 18.2 knots, and M/V Nuraghes was on the opposite route at a speed of 25 knots. M/V Moby Fantasy's bow hit the Nuraghes' starboard side. Heavy damages resulted to the hulls and superstructures of both ships. The M/V Nuraghes was able to enter Olbia Port using its own means of propulsion, while M/V Moby Fantasy has to be towed to Golfo Aranci Port by a local tug boat. **On Moby Fantasy:** Number of crew being seriously injured in the casualty: 4 Number of passengers being seriously injured in the casualty: 1 Internal causes (related to the ship where the casualty occurred): Yes Human violations or errors by the crew: Human violations; Human error Structural failures of the ship: No External causes (outside the ship): Yes Another ship or ships (improper actions, etc.): No	No details for causes included. From the descriptions available we can only deduct that the collision occurred in strong fog due to human violations and errors of the crew of one of the ships involved.

Passenger-RoRo Ships (Vehicles) – Grounding (1)

#	IMO No. Name Incident Date	Incident Description *IMO GISIS (with additional information from EMSA website, where available)*	Comments – Contrasting with causes included in HAZIDs
1	9372987 ILE DE GROIX 28/07/2008	Le lundi 28 Juillet 2008, à 07:48 heures, les transbordeurs Ile de Groix et Saint Tudy assurant les liaisons Ile de Groix –Lorient, entre en collision entre la Citadelle de Port-Louis et la bouée N°1, dite «bouée de	No details for causes included.

		l'Amiral». ***Google Translation***: On Monday, July 28, 2008 at 7:48 pm ferries Ile de Croix and St. Tudy ensuring the Ile de Croix links -Lorient collided between the Citadel of Port Louis and Buoy No. 1, known as "life Admiral". ***Investigation report by IMO Secreteriat not available for download.***	

Appendix B4: RoPax Ships – Collisions

RoPax Ships – Collisions (10)

#	IMO No. Name Incident Date	Incident Description *IMO GISIS (with additional information from EMSA website, where available)*	Comments – Contrasting with causes included in HAZIDs
1	9162150 PANSTAR DREAM 03/11/2005	At 05:00 hours LT on 3rd November 2005 the passenger Ship Panstrar Dream (registered Republic of Korea, 9690 gt, built 1997), with 42 crew members on board (South Korean: 23, Filipino: 19), and general cargo ship Korex Incheon (2658 gt, built 1995), with 12 crew members on board (South Korean: 8, Myanmarese: 4), were in collision in Kanmon Passage, Kanmon Port, Japan. Panstrar Dream sustained damage to its shell plate of port quarter, and all passengers had to disembark at Kanmon Port. Ship rendered unfit to proceed. The starboard bow of Korex Incheon was destroyed. For Panstar Dream: Internal causes (related to the ship where the casualty occurred): Yes Human violations or errors by the crew: human error Violations and errors types: Mistake (an intentional action where there is an error in the planning process; there is no deliberate decision to act against a rule or procedure): error in judgement Principle findings and form of casualty investigation: (Principle findings) Panstar Dream attempted to overtake the Korex Incheon Investigators investigated the casualty, and then brought the case to the Japan Marine Accident Inquiry Agency. As a result of the court of inquiry, a judgment was pronounced.	No details for causes included, only human error by the crew is mentioned as cause.
2	8401444 FINNSAILOR 13/11/2005	The ro-ro passenger ship Finnsailor, en route from Travemünde, Germany, to Malmö, Sweden, was approaching the traffic separation scheme rounding the Gedser Reef. In good time before entering the separation scheme the Officer of Watch (OOW) on the bridge of the	The look-out on board the Finnsailor, and to some extent on board the General Grot-Rowecki was inadequate.

		Finnsailor observed, visually and on the radar, three ships on a parallel course heading east in the separation scheme. The OOW steered aft of the three ships and laid the Finnsailor on a parallel course between the northernmost ship and the one in the middle. In his mind all three ships would continue in the direction of the separation lane and turn where the direction changes from approximately east-west to approximately northeast-southwest. The southernmost of the four ships, the General Grot-Rowecki began to turn to port in order to continue along the new running of the separation lane. The new course pointed in the front of the stem of the second southernmost ship, Dana 1, which was forced to turn also to port. Since the attention of the OOW of Finnsailor was completely focused on the northernmost ship, Protector, he did not notice until late that the General Grot-Rowecki had turned to port with her course in front of the stem. When Finnsailor realised that a hazardous close-quarters situation was a fact, the OOW tried to turn away by hard to port rudder. The manoeuvre failed and the starboard quarter of the Finnsailor hit the port side of the General Grot-Rowecki in way of hatch no. 6. The hulls of the two ships were seriously damaged and both had to proceed to a shipyard for repairs. ***For General Grot-Rowecki:*** Internal causes (related to the ship where the casualty occurred): Yes Human violations or errors by the crew: Human error Violations and error types Mistake (an intentional action where there is an error in the planning process; there is no deliberate decision to act against a rule or procedure): Error in judgement Underlying factors Psychological: Standards of personal competence Software: Management and supervision **Principle findings and form of casualty investigation:** This casualty has been classified as serious, in accordance with MSC-MEPC.3/Circ.1 – Reports on Marine Casualties and Incidents. A safety	The Finnsailor, which was overtaking the other three ships, sailed into a hazardous close-quarter situation at a speed, which was high for the prevailing situation and cannot be considered to be a safe speed in accordance with Rule 6 of the collision regulations. Although not necessarily a contributing factor to the collision, the hours of rest on board the General Grot-Rowecki were not in accordance with the requirements of the STCW Convention. SAFEDOR RoPax FSA – Hazard 4.2 – collision, listed current safeguards include adherence to COLREG and STCW provisions. NAV49/INF.2 includes the following relevant hazards: • 5 – tired crew, under pressure, not sufficient rest • 9 – high speed – one of the causes mentioned is attitude • 18 – misjudgement of traffic situations – unpredicted action by other vessel

		investigation was carried out in accordance with the guidelines prescribed in the IMO Assembly Resolution A.849(20), as amended. Sweden acted as the lead investigating State, following consultation with Malta and Germany, which were substantially interested States. The principle findings presented in this Annex, which have been extracted from the Swedish Maritime Safety Inspectorate accident report, were gathered by the Swedish Maritime Safety Inspectorate, the Malta Maritime Authority and the German Federal Bureau of Maritime Casualty Investigation. 1. The main cause of the collision was the turn to port of the General Grot-Rowecki ahead of a ship, being overtaken and going in the same direction. The port turn caused a collision with another ship, also going in the same direction and at a speed higher than that of the General Grot-Rowecki. 2. The General Grot-Rowecki did not adjust her speed in accordance with Rule 6 of the Collision Regulations. Instead, she turned to port ahead of the bows of the vessel being overtaken, in such a way that the latter had to make an evasive manoeuvre. 3. The look-out on board the Finnsailor, and to some extent on board the General Grot-Rowecki was inadequate. 4. The OOW of the General Grot-Rowecki did not appreciate the importance of Rule 10(a) of the Collision Regulations. 5. The Finnsailor, which was overtaking the other three ships, sailed into a hazardous close-quarter situation at a speed, which was high for the prevailing situation and cannot be considered to be a safe speed in accordance with Rule 6 of the collision regulations. 6. The OOW of the Finnsailor was not aware of the change of course of the General Grot-Rowecki until at a very late stage. 7. Two other vessels, the Dana 1 and the Protector were leaving the TSS to maintain their original intended courses against Rule 10(b)(iii). 8. The Finnsailor and the General Grot-Rowecki did not imagine that the Dana 1 and the Protector were to leave the TSS rather than proceed in the traffic lane. 9. Although not necessarily a contributing factor to the collision, the hours of rest on board the General Grot-Rowecki were not in accordance with the requirements of the STCW Convention.	

		Investigation report from Maltese Authority not available for download.	
3	9220330 OLYMPIA PALACE 07/12/2005	On December 7th 2005 at 14:15 hrs, during mooring operation at the Port of Ancona, the stern of M/N "Olympia Palace" collided with the portside of the tug "Conero" moored at Berth No. 3 which suffered serious damages with the subsequent introduction of a considerable quantity of water. Ship rendered unfit to proceed. **Action taken:** called the firemen for assistance. Assistance given (SAR operations) coastguard patrol boat in assistance to the tug.	No details for causes included.
4	8611685 MERCANDIA IV 11/09/2006	In dense fog Mercadia IV had just left Helsinore and Sundbuss Pernille was on her way to enter the port. The port bow of Mercadia IV hit the port side of Sundbuss Pernille. Mercadia IV had some scratches and a dent and fracture in the port bow port. She returned to Helsingoer. Sundbuss Pernille had a dent in her port side and her wheelhouse smashed. 4 passenger got minor injuries when the vessel heeled over when being hit. Sundbuss Pernille sailed into the port on her own. ***Investigation report from Danish Authority not available for download.*** **SUMMARY INFORMATION FROM EMSA's WEBSITE** Mercadia IV departed the berth in Helsingor at 06:15 hours as normal and with 12 passengers and 9 vehicles on board. The master and the chief officer were on the bridge. The visibility was very poor and the master could not from the berth see the two lights on the jetty. Before the departure the master had on the radar detected an echo approx. ¾ miles from the port entrance in ESE direction. The master assumed the echo to be Sundbuss Pernille (in the following Pernille), because normally a sundbus will enter the port just after the departure of the HH-ferry at 0615 hours. The master transmitted the departure on channel K and transmitted again, when the ferry was between the jetties. From the port entrance the course was set to 065°-70° to give more	Relevant hazards included in NAV49/INF.2 HAZID include: • 19 – communication between navigators, misunderstandings • 28 – insufficient radar functionality • 31 – communication equipment failure • 39 – poor bridge design, physical work conditions

		room for Pernille. The current was north about 1 ½ - 2 knots. Shortly after the passage of the entrance the master suddenly saw Pernille head on. The master turned on starboard, but immediately after the ships collided. Pernille departed Helsingborg on 11 September at 0605 hours as normal on the first tour of the day with 52 passengers on board. The master, a helmsman and a look-out were in the wheelhouse. It was foggy and the fog became more and more dense on approaching Helsingor. After having passed 0.35 miles north of the Disken buoy, the course was set towards the entrance to Helsingor. Shortly after they saw Mercadia IV approx. 20° on the port bow and they were not in time for a reaction before ships collided. Pernille was hid in port side around the wheelhouse. The master had not heard the departure transmissions from Mercadia IV on channel K, and he had not detected it on the radar. Pernille got some dents in port side and the port side of the wheel-house was smashed. 4 passengers got minor injuries. Pernille had no leakages and proceeded into port by its own means. Mercadia IV got a minor dent and scratches in the bow. Mercadia IV returned to Helsingor. **Safety Recommendations:** • H-H ferries A/S is recommend to initiate a discussion between the lines on the HH-passage concerning a more secure communication on channel K in whether with restricted visibility including a direct contact between an ingoing and an outgoing ferry. • H-H Ferries is further recommended to initiate a revision of the “Seglationhandboken”, in order to bring the book’s recommendations on navigation in coincidence with the actual used practice. • The Sundbuss-owner is recommended to change the position of the AIS-display from the aft bulkhead of the wheel-house to besides the radar.	
5	8503797 PRIDE OF BRUGES 13/11/2007	At 16:01 hours on 13 November 2007 the roll on, roll off (ro-ro) ferry Ursine made contact with the passenger ferry Pride of Bruges while manoeuvring onto a berth in King Georges Dock, Hull, causing damage to both ships. Ursine was rendered unfit to proceed.	Hazard 3.2 – collision (SAFEDOR RoPax FSA) includes as probable causes improper training on use of bridge equipment and communication problems. Also, hazard 5.3 – human error

		Investigation report from UK Authority not available for download. **ACCIDENT ANALYSIS BY UK IN THE 18TH WORKING GROUP** **Event and Consequences:** Ro-Ro Ferry "Ursine" manoeuvring to berth alongside in King Georg Dock at Hull, collided with passenger ferry Pride of Bruges. Damage was caused to both vessels. **Contributing Factors:** 1. PEC holder was not a fully integrated member of the bridge team and lacking skills and necessary training for handling the vessel. 2. Breach of the condition by CHA ensuring that Art. 8(1) of the UK Pilotage Act 1987 was respected and the vessel added to the PEC holder's certificate. **Issues Raised/Lessons Learned:** 1. The PEC holder was not trained or experienced in handling the vessel and the work he carried out and the CHA did not ensure any verification of his required skill before issuing his certificate. 2. The inner harbour (dock area) is not part of the PEC examination process by the CHA and therefore the vessel should have taken a pilot for berthing. 3. Unawareness of the allocated berth, a procedure should be put in place confirming the berth prior going alongside. 4. The PEC holder was unfamiliar with the handling of the vessel. His presence on board was not in line with the requirements of the CHA. 5. Master and Chief Officer were not familiar nor trained in handling the Ursine, Furthermore no briefing about berthing techniques were carried out. 6. Absence of a valid passage plan. Though existing the SMS checklist for berthing was not used	and lack of training. Relevant hazards included in NAV49/INF.2: • 8 – insufficient training • 12 – unfamiliar with vessel/bridge • 16 – misjudgements when approaching quay • 19 – communication between navigators, misunderstanding • 20 – communication with pilot

		7. Little was known about the handling skills of similar vessels from the Master and Chief Officer at former assignments. The Charter inspection did not assess if Master and Ch. Mate were able to manoeuvre the Ursine effectively in port areas. **Observations on the Human Element:** The bridge team lacking experience and qualification in handling the vessel effectively. **SUMMARY INFORMATION FROM EMSA's WEBSITE** At 1601 on 13 November 2007 the roll on, roll off (ro-ro) ferry Ursine made contact with the passenger ferry Pride of Bruges while manoeuvring onto a berth in King George Dock, Hull, causing damage to both vessels. Ursine was on her first voyage into Hull, having recently been chartered by P&O Ferries Holdings Ltd (P&O) to undertake a service between Hull and Rotterdam (Europort). In accordance with the terms of the charter party agreement, P&O had placed its representative on board to perform the pilotage duties for both ports. He joined Ursine the evening before the accident, in Europort, but was not signed on the crew agreement. In accordance with local regulations the P&O representative, who held a Pilotage Exemption Certificate (PEC) for the river Humber, was on Ursine's bridge with the vessel's bridge team when the vessel entered the river. As Ursine approached Hull, the PEC holder gave a briefing to the rest of the bridge team on the approach and entry into the lock for King George Dock. The master, who was not experienced in handling ro-ro vessels, assumed that the PEC holder would be in control. However, the PEC holder, who was not an experienced ship handler, assumed that the master would take charge of the manoeuvre. Eventually, with both men involved in the ship handling, Ursine berthed in the lock.	

		In the lock, the PEC holder and the master, who had not been to Hull before, discussed the required approach for berthing at the P&O terminal. Again, there was no clarification as to who would be in control of the vessel. Once the lock had filled, Ursine proceeded stern first towards the berth, with both men handling the controls. From the conning position, on the port bridge wing, neither of them could see the P&O terminal. In the absence of any formal berth allocation, the PEC holder directed Ursine towards the berth which he assumed had been allocated to the vessel. This berth, 5 Quay Middle, was adjacent to the one regularly used by Pride of Bruges. However, on this occasion, for operational reasons, Pride of Bruges had been berthed on 5 Quay Middle. In the confusing situation, during which key bridge team members found themselves undertaking tasks for which they were nadequately prepared, Ursine was manoeuvred stern first towards the berth already occupied by Pride of Bruges until contact was made between the two vessels.	
6	9086588 SKANIA 17/02/2009	At about 01:41 hours on 17 February 2009, the Ro-Ro ferry Skania, sailing under the flag of the Bahamas, collided with the fishing ship Gitte, registered in the Federal Republic of Germany, while en route from Swinoujscie, Poland, to Ystad, Sweden. At the time, the fishing ship anchored approximately 13 n, east of Rügen because of engine failure. For unknown reasons, the watchkeepers on the bridge of the ferry failed to notice the fishing ship, which anchored on the ferry's course line, collided with the starboard forecastle and then dragged the fishing with her anchor line until it broke shortly afterwards. The Gitte was damaged above the waterline, however, she remained buoyant and sailed to the port of Sassnitz under her own steam after the engine was repaired. The ferry also continued her voyage after communicating briefly with the Master of the fishing ship. There were neither injuries nor environmental pollution. ***Investigation report from German Authority not available for download.***	Hazard 3.2 – collision (SAFEDOR RoPax FSA) includes as probable causes improper training on use of bridge equipment and communication problems. Also, hazard 5.3 – human error and lack of training. SAFEDOR RoPax FSA – Hazard 4.2 – collision, listed current safeguards include adherence to COLREG and STCW provisions. Also, in Hazards 3.2 and 4.2 (SAFEDOR RoPax FSA) listed causes of collisions include "improper training on use of bridge equipment", "communication problems – sometimes hard to reach the other ship on radio". Relevant hazards included in NAV49/INF.2: • 8 – insufficient training

		ACCIDENT ANALYSIS BY GERMANY IN THE 19TH WORKING GROUP **Type of Casualty:** Less serious casualty: Collision between Ro-Ro ferry under way and anchored fishing vessel **Event and Consequences:** At 0141 hrs (UTC+1) on 17 February 2009 , the northwards Ro-Ro Ferry Skania collided with the fishing ship Gitte anchored approximately 13 nm east of island of Rugen . As a result of the collision the Skania reported some paint abrasions and scratches on the port side of the stem and the Gitte suffered no serious damage to the starboard bow and to the waterline . Neither injuries nor environmental pollution. **Contributing Factors:** As the VDR data has not been obtained, in order to check the data to help the investigators to find the cause of the collision, many questions remain open. But it is clear that the human elements have been a determining contributing factor, e.g. VHF communications between both side, the inadequacy in watch-keeping of both vessels that not took the due attention required in that area considered. The fishing vessel was with an engine failure anchored in position on the track of the ferry and other ships. It was not prohibited to anchor there, but the choice of the anchor position itself posed a hazard, especially during night time. **Issues Raised/Lessons Learned:** Personnel on watch on both ships did not observe several COLREG 72 rules: Look-out (rule 5); Risk of collision(rule 7); (additionally on the F/V) not under command and anchor lights (rules 27, 30 and 36)	• 10 – poor company policy/culture • 15 – incorrect use of equipment • 18 – misjudgement of traffic situations • 19 – communication between navigators, misunderstanding • 22 – interaction, minor/leisure/fishing traffic • 28 – insufficient radar functionality

		Personnel on watch on both vessels did show inadequate knowledge of procedures, instructions and bridge instruments (proper use of the radar, including long range scanning). **Observations on the Human Element:** The Officers on Watch on both ships should have a good knowledge of the contents of COLREG 72 and of all electronic navigation apparatus; The ship management company should make sure that OOWs would comply strictly with the specified operating procedures in the area of radar observation. **SUMMARY INFORMATION FROM EMSA's WEBSITE** At about 0141 on 17 February 20091, the Ro/Ro ferry2 SKANIA, sailing under the flag of the Bahamas, collided with the fishing vessel GITTE, registered in the Federal Republic of Germany, while en route from Świnoujście, Poland, to Ystad, Sweden. At the time, the fishing vessel anchored approx. 13 nm east of Rügen because of engine failure. For unknown reasons, the watchkeepers on the bridge of the ferry failed to notice the fishing vessel, which anchored on the ferry's course line, collided with the starboard forecastle and then dragged the fishing vessel with her anchor line until it broke shortly afterwards. The GITTE was damaged above the waterline; however, she remained buoyant and sailed to the port of Sassnitz under her own steam after the engine was repaired. The ferry also continued her voyage after communicating briefly with the Master of the fishing vessel. There were neither injuries nor environmental pollution. **Safety Recommendations:** Following the internal investigation of the accident, the measures shown below were recommended for the shipping company: 1. Implementation of additional training programmes for all Masters and Officers on Watch in the area of bridge watch duty and preventing collisions in relation to small vessels; 2. Implementation of additional training programmes in the area of radar observation for all Officers on Watch.	

7	9223796 GOTLAND 23/07/2009	On 23 July 2009 the roro cargo ferry Gotland was outbound from Nynäshamn when she collided with the inbound roro cargo ferry Gotlandia 2 at 11.20 hours LT. The accident was investigated by the Swedish Accident Investigating Board and the report will be forwarded to IMO. Internal causes (related to the ship where the casualty occurred): Yes Human violations or errors by the crew: Human error Structural failures of the ship: No ***Investigation report from Swedish Authority available for download. (Report in Swedish).***	No details for causes included, only human error by the crew is mentioned as cause.
8	9435454 SCOTTISH VIKING 05/08/2010	At 19:46 hours on 5 August 2010, the Italian registered ro-ro passenger ferry Scottish Viking was in collision with the UK registered fishing vessel Homeland about 4 miles off St Abb's Head. As a result of the collision the fishing vessel sank. The skipper was recovered from the sea but, despite an extensive search by the rescue services and a large number of local fishing vessels, the remaining crew member, was lost. **For Scottish Viking:** Internal causes (related to the ship where the casualty occurred): Yes Human violations or errors by the crew: human error Underlying factors: Psychological: Standards of personal competence **Principle findings and form of casualty investigation:** Factors that led to the collision included: • Scottish Viking's watchkeeper did not: determine at an early stage if there was a risk of collision with Homeland; sufficiently monitor or plot Homeland's track; and, once a risk of collision was deemed to exist, take sufficient action to avoid collision. • Homeland's watchkeeper did not: determine at an early stage if there was a risk of collision with Scottish Viking; maintain a proper lookout from the wheelhouse; or detect or recognise a risk of collision with Scottish Viking until it was too late to take effective	Hazard 3.2 – collision (SAFEDOR RoPax FSA) includes as probable causes improper training on use of bridge equipment and communication problems. Also, hazard 5.3 – human error and lack of training. SAFEDOR RoPax FSA – Hazard 4.2 – collision, listed current safeguards include adherence to COLREG and STCW provisions. Also, in Hazards 3.2 and 4.2 (SAFEDOR RoPax FSA) listed causes of collisions include "improper training on use of bridge equipment", "communication problems – sometimes hard to reach the other ship on radio". Relevant hazards included in NAV49/INF.2: • 1 – OOW distractions (too many tasks for navigators, high stress level) • 8 – insufficient training • 10 – poor company policy/culture • 14 – incapacitation (illness, intoxicated, asleep, absorbed in other tasks, etc.) • 15 – incorrect use of equipment

		action. • The investigation identified the following other contributing factors: Scottish Viking – complacency and lack of precautionary thought; ineffective implementation of the company's navigation policy and procedures. • Homeland – restricted all-round visibility from the aft deck; conflicting task priorities and possible lack of watchkeeping proficiency. **Action taken:** The manager of Scottish Viking has taken a number of actions aimed at improving the performance of the company's bridge teams. These include: reiterating the importance of following the company's navigational procedures; introducing a procedure for masters to report on the competence of a newly joined officer; carrying out unscheduled navigational audits at sea; and randomly scrutinising VDR data to verify compliance with its procedures. Both the International Chamber of Shipping (ICS) and the MAIB have distributed the safety lessons arising from this investigation to the merchant shipping and fishing industry sectors respectively. In view of the actions that have been taken, the MAIB has issued no safety recommendations. **Assistance given (SAR Operations):** Yes. The skipper was recovered from the sea but, despite an extensive search by the rescue services and a large number of local fishing vessels, the remaining crew member was lost. ***Investigation report from UK Authority not available for download.*** **ACCIDENT ANALYSIS BY UK IN THE 22ND WORKING GROUP** **Event and Consequences:**	• 18 – misjudgement of traffic situations • 19 – communication between navigators, misunderstanding • 22 – interaction, minor/leisure/fishing traffic

		Collision between RoRo passenger ship and fishing vessel due to poor lookout and collision avoidance. One crewmember of the fishing vessel remained missing **Contributing Factors:** Both watchkeepers did not determine at an early stage if there was a risk of collision with the other vessel. No proper lookout was maintained and no sufficient action taken to avoid a collision. Company procedures and legislation in respect to safe navigation were not followed. The fishing vessel had a restricted all-round visibility from the aft deck. No lifejackets were worn by the fishing vessel crew, lowering the chance of survival once in the water. **Issues Raised/Lessons Learned:** Though the company had provided comprehensive guidance and well-documented procedures for the vessel to maintain a safe navigational watch. Internal audits were held to determine compliance. In practice it has turned out that the navigation procedures were not always followed in practice. It is concluded that the operational procedures of a navigational nature are best audited while the vessel is underway, providing a better opportunity to assess if the company's policies and procedures are being followed and, if not, to identify appropriate corrective action. **Observations on the Human Element:** The events that led to the collision may have been influenced by task priorities and possible lack of watchkeeping proficiency.	
9	9136022 STENA FERONIA 07/03/2012	The outbound vessel Union Moon collided with the inbound ferry Stena Feronia in the vicinity of the fairway buoy. Ship rendered unfit to proceed. Internal causes (related to the ship where the casualty occurred): Yes Human violations or errors by the pilot: Yes	Hazard 3.2 – collision (SAFEDOR RoPax FSA) includes as probable causes improper training on use of bridge equipment and communication problems. Also, hazard 5.3 – human error and lack of training.

		Structural failures of the ship: No **Violations and errors types:** Mistake (an intentional action where there is an error in the planning process; there is no deliberate decision to act against a rule or procedure): error in judgement **Underlying factors:** Software: Company policy and standing orders **SUMMARY INFORMATION FROM EMSA's WEBSITE** At 18:58 on 7 March 2012, the outbound general cargo vessel Union Moon collided with the inbound ferry Stena Feronia, in the vicinity of the fairway buoy that marks the harbour limit of Belfast Harbour. Both vessels suffered major structural damage; however, there were no injuries or pollution and each vessel managed to proceed into port without assistance. Once alongside in Belfast, both vessels were visited by officers from the Police Service of Northern Ireland, who breathalysed the bridge teams. Union Moon's master was found to have an alcohol level of 123µg of alcohol per 100ml of breath, in breach of the permitted maximum of 35µg of alcohol per 100ml of breath. He was arrested and, on 31 May 2012, was sentenced to 1 year's imprisonment for breaching the Railways and Transport Safety Act 2003. The investigation found that although Union Moon's master had been under the influence of alcohol and had altered course to port resulting in a collision course with Stena Feronia, several other factors contributed to the accident, including: • A lack of clear guidance regarding traffic flow around the fairway buoy. • No action taken by the bridge teams of either vessel to prevent a close quarters situation from developing. • Action taken on board Stena Feronia to avoid collision. • Sub-standard VHF communications.	SAFEDOR RoPax FSA – Hazard 4.2 – collision, listed current safeguards include adherence to COLREG and STCW provisions. Also, in Hazards 3.2 and 4.2 (SAFEDOR RoPax FSA) listed causes of collisions include "improper training on use of bridge equipment", "communication problems – sometimes hard to reach the other ship on radio". Relevant hazards included in NAV49/INF.2: • 8 – insufficient training • 10 – poor company policy/culture • 15 – incorrect use of equipment • 18 – misjudgement of traffic situations • 19 – communication between navigators, misunderstanding • 28 – insufficient radar functionality

		Belfast Harbour has reviewed the accident with its Safety, Environmental and Security Committee, harbourmasters, Vessel Traffic Services staff and a representative of the Belfast pilots. It has taken measures to ensure its required radio procedures are followed, and has changed the point at which pilots disembark outbound vessels. As part of its comprehensive review of port operations, which was ongoing at the time of the accident, Belfast Harbour has since laid four new buoys which address the pinch point at the fairway buoy, introduced new routeing advice for mariners approaching Belfast Harbour, updated its Navigational Risk Assessment, and incorporated the findings of this report into its regular programme of Vessel Traffic Services emergency training. Northern Marine Management Ltd has issued a fleet guidance notice to its masters, reminding them of the importance that al deck officers have a clear understanding of the International Regulations for Preventing Collisions at Sea and of the manoeuvring characteristics of their vessels. Continental Ship Management AS has, inter alia, reviewed the manning levels of its vessels and issued a circular letter to its fleet to reiterate its instructions on watchkeeping, including the need to ensure the bridge is manned by an additional lookout during the hours of darkness. Northern Marine Management Ltd has been recommended to amend its safety management system to provide clarity on the roles and responsibilities of the bridge team when a Pilotage Exemption Certificate holder is acting solely as a pilot. **Safety Recommendations:** 2012/149 Amend its SMS to make clear the roles and responsibilities of the bridge team when conducting pilotage with a PEC holder who is not part of the normal ship's complement and is performing an act of pilotage.	
10	9217230 NILS HOLGERSSON 03/05/2012	On the evening of 3 May 2012, the German-flagged ferry Nils Holgersson sailed into the port of Travemunde, where she was to make fast with her stern at pier 6a of the Skandinavienkai. The turning manoeuvre in the Siechenbucht (turning basin) necessary for this failed	The SAFEDOR RoPax HAZID includes the following causes relevant to this incident:

		because the two pod propulsors were still being operated in "Sea mode". Because only one hydraulic pump was activated per propulsor, instead of two. The ship's command was unable to stop in the turning basin and the ferry headed towards the opposite pier at a speed over ground of 6.51 kts. The Danish ferry URD, whose crew was occupied with making proparations for the scheduled voyage to Liepaja, was made fast there at pier. Most of the passengers and the cargo were already on board. The collision occurred at 18:14 hrs. The port side of the URD was pressed in by the bow of the Nils Holgersson, causing the URD to take on water and heel to port. It was possible to stabilise the ship by flooding the forward ballast water tanks, which enabled the evacuation of people and much of the cargo via stern ramp. The Nils Holgersson was able to move to her berth under her own power after the controls were switched to harbour mode. Nobody came to physical harm and the environment was not damaged due to the collision. ***Investigation report from German Authority not available for download.*** **SUMMARY INFORMATION FROM EMSA's WEBSITE** On the evening of 3 May 2012, the German-flagged ferry Nils Holgersson sailed into the port of Travemünde, where she was to make fast with her stern at pier 6a of the Skandinavienkai. The turning manoeuvre in the Siechenbucht (turning basin) necessary for this failed because the two pod propulsors1 were still being operated in 'Sea mode'. Because of that, the rudder angle was limited to +/- 35° and the rotation of the pods retarded because only one hydraulic pump was activated per propulsor, instead of two. The ship's command was unable to stop in the turning basin and the ferry headed towards the opposite pier at a speed over ground of 6.51 kts. The Danish ferry Urd, whose crew was occupied with making preparations for the scheduled voyage to Liepaja, Latvia, was made fast there at pier 3. Most of the passengers and the cargo were already on board. The collision occurred at 1814372. The port side of the Urd was pressed in by the bow of the Nils Holgersson, causing the Urd to take on water	• 3-2 – collision when arriving/departing from port – technical and human failure, improper training on use of bridge equipment (maybe too much equipment on bridge) • 8-3 – human error and lack of training – improvements in company policy, error The NAV49/INF.2 HAZID also includes causes relevant to this incident: • 15 – incorrect use of equipment – new, difficult equipment • 27 – wrong procedures – procedures not adapted to current ship • 8 – insufficient simulator training – insufficient training with respect to emergency situations

		and heel to port. It was possible to stabilise the ship by flooding the forward ballast water tanks, which enabled the evacuation of people and much of the cargo via the stern ramp. The Nils Holgersson was able to move to her berth under her own power after the controls were switched to 'Harbour mode'. Nobody came to physical harm and the environment was not damaged due to the collision. **Safety Recommendations:** The following safety recommendations do not constitute a presumption of blame or liability in respect of type, number or sequence. 6.1 TT-Line The Federal Bureau of Maritime Casualty Investigation recommends that TT-Line document the regular manoeuvres for operation of the various emergency steering systems for ships with pod propulsor that have been introduced and implement the regular training for improvement of communication and teamwork that is planned accordingly. 6.2 L-3 SAM Electronics The Federal Bureau of Maritime Casualty Investigation recommends that L-3 SAM Electronics work toward eliminating interference identified when testing bridge microphones in the course of the VDR's annual performance test.	

Appendix B5: RoPax Ships – Groundings

RoPax Ships – Groundings (5)

#	IMO No. Name Incident Date	Incident Description *IMO GISIS (with additional information from EMSA website, where available)*	Comments – Contrasting with causes included in HAZIDs
1	9246061 HAMNAVOE 16/05/2006	The Ro-Ro ferry was leaving Stromness in the Orkney islands with 31 passengers and 40 crew onboard. The only electrical power source was provided by a single shaft generator. As the ship entered the channel the shaft generator supply breaker failed while port helm was applied. Pitch was taken off the twin controllable pitch propellers but the vessel's stem touched the bottom. About 30 seconds later the emergency generator was connected to the switchboard and electrical power was re-established. The master took the ship out into the channel and then returned to port. Once secured alongside a divers inspection was conducted, the only damage recorded was superficial paint detachment. Internal inspections revealed no damage. The cause of the breaker failure has not been determinate and the failure could not be replicated. The management company are reviewing their guidance on the electrical generation configuration on entering confined navigational areas. The Ro-Ro ferry was leaving Stromness in the Orkney islands with 31 passengers and 40 crew onboard. The only electrical power source was provided by a single shaft generator. As the ship entered the channel the shaft generator supply breaker failed while port helm was applied. Pitch was taken off the twin controllable pitch propellers but the vessel's stem touched the bottom. About 30 seconds later the emergency generator was connected to the switchboard and electrical power was re-established. The master took the ship out into the channel and then returned to port. Once secured alongside a divers inspection was conducted, the only damage recorded was superficial paint detachment. Internal inspections revealed no damage.	SAFEDOR RoPax HAZID, hazard 3.1 – grounding, one of the causes included is propulsion or steering failure (technical) during acceleration or deceleration

		The cause of the breaker failure has not been determinate and the failure could not be replicated. The management company are reviewing their guidance on the electrical generation configuration on entering confined navigational areas. Subsequent inspection and testing of the electrical breaker failed to identify any defects.	
2	7907245 STENA DANICA 10/01/2008	On 10th January 2008 the roro cargo ferry Stena Danica was outbound from Gothenburg when she grounded at Gaveskar at 19.20 hours LT. The accident was investigated by the Swedish Accident Investigating Board and the report will be forwarded to IMO. Internal causes (related to the ship where the casualty occurred): Yes Human violations or errors by the crew: human error ***Investigation report from Danish Authority available for download. (Report in Danish).***	No details for causes included, only human error by the crew is mentioned as cause.
3	9007295 PRIDE OF CANTERBURY 31/01/2008	On 31st January 2008 the port of Dover was closed during a period of high winds Force 10/11. The ro-ro cargo ship Pride of Canterbury was inbound at the time the port closed, and deviated to The Downs to steam round awaiting the port to re-open. During the morning the vessel made three circuits of the area, but on the last circuit she went further North than planned, and on making the turn to go South struck a charted wreck at approximately 12.50 hours LT. Internal causes (related to the ship where the casualty occurred): Yes Human violations or errors by the crew: Human violations; Human error **Violations and error types:** Violation (deliberate decision to act against a rule or plan): Routine (cutting corners, taking path of least effort, etc...); Necessary(due to inadequate tools or equipment, improper procedures or regulations) Mistake (an intentional action where there is an error in the planning process; there is no deliberate decision to act against a rule or procedure): Error in judgement; Inappropriate choice of route **Underlying factors:**	Hazards 2-2 and 3-1 (SAFEDOR RoPax FSA) include as causes of grounding presence of current and wind, swell and bad weather (possible effects of leeway) and human error on the interactions between captain and other members of the crew. As existing safeguards, the following are listed: ISM (familiarisation) and passage planning. Hazard 3-10 (SAFEDOR RoPax FSA) errors due to inadequate display of navigational information (ECDIS/ARPA). Hazard 9-1 (SAFEDOR RoPax FSA) irrational behaviour by crew – lack of training, stress, fatigue, communication problems, all resulting in wrong operation of equipment Relevant hazards included in NAV49/INF.2: • 1 – OOW distractions (captain became distracted whilst on phone for a non-navigational issue) • 8 – insufficient simulation training

		Physiological: Stress Psychological: Boredom Hardware: Ergonomics Software: Company policy and standing orders; Less than adequate operating procedures and instruction Environment: Ship movement/Weather effects **Principle findings and form of casualty investigation:** Use of non approved ENC (VMS) as primary means of navigation. No training in use of VMS No passage plan made after vessel deviated Lack of Bridge Team Management training Master influences OOW actions even though OOW has officially got the con **Action taken:** Company recommended to re introduce training in BTM and ECDIS Also to review passage plans for waiting areas when ports are closed. Flyer to be issued highlighting the issues. ***Investigation report from UK Authority not available for download.*** **ACCIDENT ANALYSIS BY UK IN THE 19TH WORKING GROUP** **Event and Consequences:** The vessel was on her way from Calais to Dover on a scheduled crossing in severe weather. During this crossing the vessel was informed that the Port of Dover would be temporarily closed due to severe weather conditions and seas. Under the instructions of the Master the vessel proceeded to The Downs and commenced 'slow steaming' while waiting for the port to reopen. The vessel had been in the area for about 4 hours and while approaching a turn at the northern extremity there was a fire alarm and a number of telephone calls to the bridge of a non-navigational nature. Due to these distractions the vessel overshot the northern limit of the safe area before	• 10 – poor company policy/culture • 15 – incorrect use of equipment

		the turn was even started. At 12:51 on January 31st 2008 the vessel struck a charted wreck which had been wire swept to a depth of 1.8m. The location was at Lat 51 14.48N Long 001 28.7E. The vessel had 275 Passengers on board and 101 Crew. There were no injuries or fatalities. The vessel was subsequently able to berth at Dover later in the day when the Port reopened. Weather conditions at the time of accident were as follows: Wind SW 10 to 11 Sea/Swell High Tide: 1.5-2.0 kts from the north-east Visibility: Fair with sea spray A divers survey reported severe damage to the port CPP. After approval by Class the vessel proceeded to Falmouth and an inspection revealed: Loss of the port CPP hub Loss of about 1 m of the port tail shaft Port after stern tube, centre stern tube, stern tube bearings-all damaged and misaligned. Two sections of the port intermediate tail shaft bent. Misalignment of associated framing, extending to gearbox and main engines. Port rudder stock bent. **Contributing Factors:** The basic cause of the grounding: (Root Cause) Lack of effective Bridge Team Management. Contributing factors • Distractions to the Bridge Team. The bridge team was distracted several times, including a request from a driver of a refrigerated truck to run his engine so the truck could run its cooling plant. The exhaust from the truck led to the activation of the fire detection system, which then cascaded into further distractions to the bridge	

		team, including discussions on starting up the ventilation system so that the truck's exhaust does not keep setting off the fire alarm. A series of telephone calls to the bridge took place and the Master himself took another 4 telephone calls to the bridge, before returning to the important aspect of navigating the vessel. • Use of non-approved ENC (Electronic Navigation Chart)—Voyage Management System (VMS) as primary means of navigation. The navigation during the period was almost entirely carried out with reference to the Sperry Voyage Management System (VMS) and by eye. The lack of proper training in the use of ECDIS possibly led to the wreck being undetected, and the paper chart, which was marked with "no go" areas, was never re-assessed or amended. • No training in use of VMS. Subsequently it was revealed that the bridge officers had received no training on the VMS system. • Master influences OOW actions even though OOW has officially got con. • No passage plan made after vessel deviated. • The bridge team was never on stand by or "red bridge" operating condition. **Issues Raised/Lessons Learned:** • The Bridge team members were required to provide administrative information and respond to non-navigational issues at a time when the Bridge team's attention should have been solely focussed on the navigation of the vessel. • Contingency Planning: There was no contingency plan onboard. The company provided plans for normal operations. However, a contingency plan in the actions that the vessel would require during port closure, slow steaming would have been very helpful. • Bridge teams were not on standby or "red bridge" operating condition. This is important and is fairly standard operating procedure to have the bridge on stand by during slow steaming, especially where manoeuvres are required. • Similarly, watch handing over procedures were done on an as need basis. Basically to conform to meal times or additional duties that officers were performing. Therefore, handovers were not structured	

		and important information was not passed along. Nonchalance and malaise was tolerated. Strict rigorous procedures must always be followed, especially when operating in close quarters. • Electronic chart systems or other such navigational aids should be used as aids and not as the primary navigational tool. In addition specific training should be provided to all navigational officers at regular intervals, so that they have a thorough understanding of the equipments functionality. • The vessels speed was adjusted, on an ad hoc basis. The criteria being to maintain steerage. Therefore, at a critical moment when danger was imminent, the vessels speed was increased, thus giving the crew less time to react. • Between 1995 and 2008 at least 4 similar incidents have been reported within these waters. Therefore; the lessons learned must be promulgated aggressively to vessel operators. In addition further analysis of similar accidents should be initiated world wide. **Observations on the Human Element:** • The investigation has revealed the importance of training, drills and contingency planning to handle emergencies including false alarms. In this accident the Bridge Management Team (BTM) was ineffective and training was discontinued. It is well known that training, drills and effective contingency planning increase the likelihood of efficient and rational action if a real emergency or near emergency should occur. • Lack of awareness, knowledge, education (ignorance), malaise and overconfidence may have caused the information exchange at watch handovers to be not performed in a systematic way. Similarly, the vessels position was not systematically plotted on the paper chart. • Although fatigue has not been identified in this case as a cause, it could be a contributory factor given the fact anecdotally that the officers were at the end of their 7 day duty period. This extra day of duty and increased workload due to discussions with contractors could have contributed towards fatigue. • The Master took several phone calls on the bridge during the lead	

		up to this situation; similarly the Officer on Watch was also dealing with a situation on the trailer deck which would have resulted in lower situational awareness to the primary duty function of navigating the vessel. **SUMMARY INFORMATION FROM EMSA's WEBSITE** On 31 January 2008, the Roll on Roll off Passenger ferry, Pride of Canterbury, grounded on a charted wreck while sheltering from heavy weather in an area known as 'The Downs' off Deal, Kent. The vessel suffered severe damage to her port propeller system but was able to proceed unaided to Dover, where she berthed with the assistance of two tugs. The vessel was on a scheduled crossing from Calais to Dover in severe weather when she learned that Dover Port was to be temporarily closed due to the weather and sea conditions. She proceeded to The Downs to wait for the reopening of the port. The master instructed the bridge team to slow steam in the area and he gave verbal instructions on the geographic limits to be imposed. No formal passage plan was formulated and nothing was marked on the paper or electronic chart. The vessel had been in the area for over 4 hours when, while approaching a turn at the northern extremity, the bridge team became distracted by a fire alarm and a number of telephone calls for information of a non-navigational nature. The vessel overshot the northern limit of the safe area before the turn was started. The officer of the watch (OOW) became aware that the vessel was passing close to a charted shoal, but he was unaware that there was a charted wreck on the shoal. The officer was navigating by eye and with reference to an electronic chart system which was sited prominently at the front of the bridge, but he was untrained in the use and limitations of the system. The wreck would not have been displayed on the electronic chart due to the user settings in use at the time. A paper chart was available, but	

		positions had only been plotted on it sporadically and it was not referred to at the crucial time. The vessel's owner has reviewed its training programme and implemented a number of measures to prevent a re-occurrence of the accident. The MAIB has published a Safety Flyer, for circulation to ferry and other ship operators, which details the lessons learned from the accident and advises operators: • To review their training requirements/provision with respect to the use of electronic chart systems, especially where a system that is not approved as the primary means of navigation is provided and sited prominently on the bridge. • Where navigating bridges are the focus for frequent requests for nonnavigation related information, to ensure that systems are in place to prevent watchkeepers from becoming distracted at critical times. • To ensure that plans are in place to identify likely contingency areas in advance of the intended voyage, and that any dangers or hazards within these areas are clearly identified. • Of the need to ensure that the principles of effective bridge team management are understood and practised by bridge teams at all times. **Safety Recommendations:** Interferry and the International Chamber of Shipping are recommended to: 2009/101 Promulgate to ship owners/managers the MAIB Safety Flyer describing this accident and the principal lessons to be learned from it.	
4	8323161 PRINCESS OF THE STARS 21/06/2008	The ro-ro ferry Princess of the Stars departed Manila, Philippines, on the evening of 20 June 2008, bound for Cebu City, Philippines, with hundreds of passengers on board. The ferry sent a distress signal at midday on 21 June 2008 when its engines stalled in rough seas near Sibuyan. The ship capsized at the height of the typhoon "Frank"	No details for causes included, only that the incident occurred at the pick of a typhoon.

		(International Code Name: Fengshen) in an area approximately 1,500 metres off the coast of Sitio Cabitangahanan, Barangay Taclobo, San Fernando, Romblon, Philippines, with the loss of many lives.	
5	8219554 ISLE OF ARRAN 28/03/2009	The inter island ro-ro passenger ferry Isle of Arran was operating a route on which she was not normally engaged. Weather conditions over the preceding two days had been poor and resulted in a disturbed sleep pattern for the crew. The vessel arrived in port and sailed about five minutes late on the allocated 25 minute turnaround time, with 19 passengers on board. The bridge organisation consisted of the master on the port bridge wing with the con, the second officer as the officer of the watch, and a quartermaster stood by the helm. The master manoeuvred the vessel clear of the berth and headed out towards a reef, five cables away, marked by north and south cardinal marks. Speed was increased to 4 knots. The second officer was monitoring the master's actions in case of error and, was responsible for monitoring the vessel's position. The master then instructed that control of engines, bow thrust, and helm, be taken inside the bridge. Once inside the master stood behind a dirty bridge window and with the sun directly ahead his vision was obscured and he arranged for the window to be cleaned but became distracted whilst in conversation; speed was increased to 8 knots. With the window still dirty, but the buoy visual, he then altered course to port with the intention of leaving the reef and the south cardinal mark to starboard. Inexplicably the turn was stopped early, possibly to counter the effects of leeway, with the buoy still on the port bow. Fast approaching the reef, the master was alerted to the danger by the second officer who questioned his intentions. The master immediately recognised the danger and applied full astern pitch and full port thrust. Unfortunately his actions were too late. The vessel momentarily grounded on the reef only six minutes after slipping from the berth.	Hazards 2-2 and 3-1 (SAFEDOR RoPax FSA) include as causes of grounding presence of current and wind, swell and bad weather (possible effects of leeway) and human error on the interactions between captain and other members of the crew. As existing safeguards, the following are listed: ISM (familiarisation) and passage planning. Relevant hazards included in NAV49/INF.2: • 1 – OOW distractions (captain became distracted whilst in conversation) • 4 – Time pressure – keep schedule • 5 – Tired, pressure, not sufficient rest • 14 – incapacitation (absorbed in other tasks) • 16 – misjudgements when approaching quay, in narrow waters • 19 – communication between navigators, misunderstandings

		The vessel suffered substantial hull damage but was able to return to her berth without assistance. Internal causes (related to the ship where the casualty occurred): Yes Human violations or errors by the crew: human violations External causes (outside the ship): Sun directly in the line of sight **Violations and error types:** Violation (deliberate decision to act against a rule or plan): Routine (cutting corners, taking path of least effort, etc...) Slip (unintentional action where failure involves attention): Failure to report due to distraction Lapse (unintentional action where failure involves memory): Forgetting to report information Mistake (an intentional action where there is an error in the planning process; there is no deliberate decision to act against a rule or procedure): Error in judgement; Deciding not to pass on information; Failure to respond appropriately **Underlying factors:** Physiological: Stress Hardware: Ergonomics Software: Management and supervision Environment: Ship movement/Weather effects **Principle findings and form of casualty investigation:** Distraction of the master. Vision hindered by salt water on the bridge window and direct sunlight in the master's line of sight. Passing of information from the OOW delayed. No proper monitoring of the passage plan.	

Appendix B6: RoPaxRail Ships – Collision

RoPaxRail Ships – Collision (1)

#	IMO No. Name Incident Date	Incident Description *IMO GISIS (with additional information from EMSA website, where available)*	Comments – Contrasting with causes included in HAZIDs
	9151539 SCHLESWIG-HOLSTEIN 24/08/2009	At 04:00 hours on 24 August 2009, the Schleswig-Holstein, a Roro-Ferry flying the flag of Germany, which was sailing on a north-easterly course towards Rödby (Denmark) collided with the American yacht Mahdi about 15 minutes after departing from Puttgarden ferry port. The yacht was proceeding under sail on a westerly course towards Kiel with two people on board. Her skipper observed the departure of the ferry, but saw only her green sidelight up until the very last. Therefore, in spite of the approaching and planned close quarter situation, he was confident that the ferry would observe his right of way and realised they were on a collision course only second before the impact. Accordingly, he did not have sufficient time for the usual procedure in critical situations of illuminating his sail with spotlights and calling over VHF. The hazardous approach was only recognised just before the collision, at the moment that the yacht was first identified visually, on the bridge of the ferry as well. In spite of the last-moment action initiated on each ship, there was not enough time left (approximately 30 seconds) until the collision to avoid the accident. The fore section on the port side of the Mahdi was hit with considerable force by the bow of the ferry. The yacht heeled very quickly and heavily to starboard side of the ferry and righted herself after parting from the ferry. The skipper, who along with the female co-sailor did not suffer any injuries, managed to start the engine and put the bilge pump into operation. A general alarm was sounded on the Schleswig-Holstein and a lifeboat was lowered into the water. Contact between the crew of the lifeboat and the yacht revealed the people on board had survived the accident unhurt and that the yacht was still buoyant in spite of strong deformations on her outer skin. There was no environmental pollution. A search and rescue ship, the Emil Zimmermann, and a Danish tug, the	Hazard 3.2 – collision (SAFEDOR RoPax FSA) includes as probable causes improper training on use of bridge equipment and communication problems. Also, hazard 5.3 – human error and lack of training. SAFEDOR RoPax FSA – Hazard 4.2 – collision, listed current safeguards include adherence to COLREG and STCW provisions. Also, in Hazards 3.2 and 4.2 (SAFEDOR RoPax FSA) listed causes of collisions include “improper training on use of bridge equipment”, “communication problems – sometimes hard to reach the other ship on radio”. Hazard 2.1 (SAFEDOR RoPax FSA) as cause of collision includes poor knowledge of presence of pleasure craft. Relevant hazards included in NAV49/INF.2: • 1 – OOW distractions (too many tasks for navigators, high stress level) • 8 – insufficient training • 10 – poor company policy/culture • 15 – incorrect use of equipment • 18 – misjudgement of traffic situations • 19 – communication between navigators, misunderstanding • 22 – interaction, minor/leisure/fishing traffic

		Baltsund, promptly sailed from Puttgarden to the scene of the accident. The Baltsund, accompanied by the search and rescue ship, then towed the yacht to Puttgarden. Internal causes (related to the ship where the casualty occurred): Yes Human violations or errors by the crew: Human violations; Human error Violations and error types: Violation (deliberate decision to act against a rule or plan): Routine (cutting corners, taking path of least effort, etc...) Slip (unintentional action where failure involves attention): Other ***Investigation report from German Authority not available for download.*** **ACCIDENT ANALYSIS BY GERMANY IN THE 20TH WORKING GROUP** **Type of Casualty:** Serious marine casualty Collision between a Ro-Ro ferry and a sailing yacht **Event and Consequences:** The ferry, which operates between Puttgarden and Rodby, was on a north-easterly course after departing from Puttgarden port at night, while the yacht was proceeding under sail on a westerly course crossing the ferry route. The visibility was good and the sea was calm. It was not until just before the collision that the yacht was identified visually by the ferry. The echo of the yacht on the radar display was weak and not visible at times. The ferry crew heard the yacht asking an east-bound vessel on VHF if she could see the yacht, but there was no answer. The ferry also had no idea where the yacht was. Suddenly, a high red light was detected at a distance of about 200 meters. The crew of the yacht observed the busy traffic and tried to make	

oncoming vessels aware of their presence on VHF at different times but did not receive an answer. They also observed the departure of the ferry and saw only her green sidelight up until the very last. They thought the ferry would give way to the yacht and did not realise both vessels were on a collision course until a few seconds before the collision.
The fore section of the port side of the yacht was hit by the bow of the ferry with considerable force. The yacht heeled heavily to starboard and took on a large amount of water, but the crew did not suffer any injuries. There was no environmental pollution.

Contributing Factors:

Vessels were coming from both the east and the west. In addition, a drilling platform together with auxiliary vessels was in close proximity to the ferry. The yacht approached the ferry in the shadow of the drilling platform.
It can be assumed that the ferry crew focused primarily on other vessels, and the yacht's tricolour light was apparently overlooked.
The echo of the yacht was hardly distinguishable from radar interference on both the X-band radar and the S-band radar on the ferry, and no attention was paid to the weak echo on the displays.
None of the radar settings on the ferry were changed apart from the range.
The yacht gave no information about her own position when asking another vessel on VHF if she could be seen.

Issues Raised/Lessons Learned:

- Effective lookout and radar observation
- Better understanding of the other vessel's perspective
- Risk of passing large vessels in their immediate vicinity
- Detectability of a small vessel; it would be increased by providing information about her own position on VHF communication or by being equipped with AIS or a radar reflector.

Observations on the Human Element:

The human eye focuses more or less inevitably on very bright spots in

		darkness. A light mounted at the top of the mast of a sailing boat nearby is easily confused with a navigation light much further away on the horizon. The current coexistence of vessels with and without AIS increases the risk of the radar operator's attention being focused too much on clearly identifiable objects. **SUMMARY INFORMATION FROM EMSA's WEBSITE** At 04:01 on 24 August 2009, the Schleswig-Holstein, a ro/ro ferry2 flying the flag of Germany, which was sailing on a north-easterly course towards Rödby (Denmark), collided with the American yacht Mahdi about 15 minutes after departing from the Puttgarden ferry port. The yacht was proceeding under sail on a westerly course towards Kiel with two people on board. Her skipper observed the departure of the ferry, but saw only her green sidelight up until the very last. Therefore, in spite of the approaching and planned close quarters situation, he was confident that the ferry would observe his right of way and realised they were on a collision course only seconds before the impact. Accordingly, he did not have sufficient time for the usual procedure in critical situations of illuminating his sail with spotlights and calling over VHF. The hazardous approach was only recognised just before the collision, at the moment that the yacht was first identified visually, on the bridge of the ferry as well. In spite of the last-moment action initiated on each vessel, there was not enough time left (approximately 30 seconds) until the collision to avoid the accident. The fore section on the port side of the Mahdi was hit with considerable force by the bow of the ferry. The yacht heeled very quickly and heavily to starboard, took on a large amount of water in the process, scraped along the starboard side of the ferry and righted herself after parting from the ferry. The skipper, who along with the female co-sailor did not suffer any injuries, managed to start the engine and put the bilge pump into operation. A general alarm was sounded on the Schleswig-Holstein and a lifeboat was lowered into the water. Contact between the crew of the lifeboat and the yacht revealed the people on board had survived the accident unhurt and that the yacht was still buoyant in spite of strong deformations on her outer skin. There was no environmental pollution.	

		A search and rescue vessel, the Emil Zimmermann, and a Danish tug, the Baltsund, promptly sailed from Puttgarden to the scene of the accident. The Baltsund, accompanied by the search and rescue vessel, then towed the yacht to Puttgarden. **Safety Recommendations:** The BSU has already commented at length in an investigation report on the use of active or passive radar reflectors to increase safety for pleasure craft.27 Therefore, the publication of safety recommendations can be dispensed with. Instead, the BSU is limiting itself to publishing a summary investigation report on the accident.	

ABOUT DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.