MARITIME SAFETY COMMITTEE
88th session
Agenda item 19

MSC 88/INF.6
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GENERAL CARGO SHIP SAFETY

IACS FSA study – Steps 3 and 4 (Risk control options and Cost benefit assessment)

Submitted by the International Association of Classification Societies (IACS)

SUMMARY

Executive summary:	This document provides at the annex a copy of the final version report of Steps 3 and 4 (Risk Control Options and Cost Benefit Assessment) from an FSA study that has been conducted by IACS regarding general cargo ships
Strategic direction:	12.1
High-level action:	12.1.1
Planned output:	12.1.1.2
Action to be taken:	Paragraph 3
Related documents:	MSC 77/25/4; MSC 85/19/1; MSC 86/INF.4; MSC 87/INF.3; MSC 87/20/1; MSC 87/INF.4 and MSC 88/19/2

1 At MSC 77, the issue of general cargo ship safety was brought to the attention of the Committee by RINA (MSC 77/25/4). IACS has been carrying out an FSA study on general cargo ships. The results of step 1 (Evaluation of Historical Data, MSC 85/19/1, MSC 86/INF.4, MSC 87/INF.3) and step 2 (Risk Analysis, MSC 87/20/1; MSC 87/INF.4) have previously been reported to the Organization.

2 In conjunction with what is stated in document MSC 88/19/2, subsequent to undertaking steps 1 and 2, the identification of risk control options and their cost benefit/effectiveness assessment (steps 3 and 4 of an FSA) are provided in detail in the annex to this document. Further, as reported in document MSC 87/INF.4, the quantification of property related consequences is carried out as part of step 4.

Action requested of the Committee

3 The Committee is invited to note the report as set out in the annex and take it into account, as appropriate, in its further consideration of this issue.

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ANNEX

FSA General Cargo Ship

Step 3 & 4: Risk Control Options & CBA

Version 1/2010-07-14

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Date 2010-07-14

Contents

1 Introduction

The issue of general cargo ship safety was noted at IMO in 2006 in the submission by Russia (MSC 82/21/19, 2006). This submission highlights the disparity between the fraction of general cargo ships of the world fleet (17 % in number of ships) and the share of this ship type of all total losses (42 %) and of all fatalities (27 %) for the period 1999 to 2004. At MSC 83 several additional papers that focus on general cargo ship safety were submitted. In these submissions the safety with respect to other ship types (MSC 83/20/1, 2007; MSC 83/20/5, 2007), the causes of total losses of general cargo ships and the causes of fatalities on general cargo ships (MSC 83/20/3, 2007) are further highlighted. According to the cited submissions, occupational risk contributes with 63 % (MSC 83/20/3, 2007) to the total risk.

The importance of general cargo ship safety was also highlighted by the EMSA *Maritime Accident Review 2008* (EMSA, 2009).

To bring forward the discussion of general cargo ship safety, IACS started a project on the statistical analysis of general cargo ship safety and submitted the results of the preparatory step to IMO (MSC 86/INF.4). The report summarised the results of the initial review of accident data and fleet data which provide the basis for further analyses within a FSA. This analysis was performed on basis of the sample specified as follows:

- All ships specified as general cargo ships in Lloyds Register Fairplay (LRF) database;
- Ships "due or delivered" after 1981-12-31 and before 2009-01-01 (corresponding to a maximum ship age of 27 at the end of the investigation period);
- A gross tonnage greater than 499;
- Classed by IACS society (based on the assignment in LRF 2009);
- Casualty reports for IACS classed ships and classified as "severe" accident.

In order to determine the statistical parameters like fleet at risk, number of accidents etc., the LRF database is used. The information provided by the LRF database was checked or amended by GISIS (Global Integrated Shipping Information System) data.

In 2009 this investigation was updated to consider the casualty reports for the period 1997 to 2008 and was submitted to IMO (MSC 87/INF.3).

The FSA was continued by developing the high-level generic risk models for general cargo ships. The risk model covers the accident categories collision, contact, fire & explosion, foundering, hull, machinery as well as wrecked/stranded (MSC 87/INF.4).

This report is aimed at presenting in a concrete way the results of step 3 (Risk Control Options – RCOs[1]) and Step 4 (Cost-Benefit Assessment – CBA) of the conducted FSA on general cargo ships (GCSs) safety.

The purpose of step 3 is to propose effective and practical RCOs and comprises the following stages:

a. Focus on risk areas needing control;
b. Identify potential risk control options (RCOs);

[1] FSA Guidelines distinguish Risk Control Measure and Risk Control Option. In context of this investigation this categorisation is not taken into consideration and only the term Risk Control Option (RCO) is used.

c. Evaluate the cost-effectiveness of the RCOs in reducing risk by re-evaluating risk with the RCOs implemented;
d. Group RCOs into practical regulatory options.

In this report, items a to c are addressed, whereas item d will be postponed to the work of step 5. Initially, the effort is focused on the areas with the highest risk contribution, by considering the frequency of occurrence and together with the severity of the outcomes. Structured thought process techniques (i.e. causal chains which can be expressed as: causal factors → failure → circumstance → accident → consequences) are utilised to identify new RCOs for risks that are not sufficiently controlled by existing measures. Furthermore, the produced list includes RCOs which could be introduced by considering future technology advancements or new methods of operation and management.

The purpose of step 4 is to identify and compare benefits and costs associated with the implementation of the RCOs decided to be considered further. The following stages are included:

a. RCOs are arranged in a way to facilitate understanding of the costs and benefits resulting from their adoption;
b. The pertinent costs and benefits of the RCOs are estimated;
c. The cost-effectiveness of each RCO is estimated and is compared in terms of the cost per unit risk reduction by dividing the cost values by the risk reduction achieved as a result of implementing the RCO;
d. RCOs are ranked from a cost-benefit perspective in order to facilitate the decision-making recommendations in step 5, i.e. those RCOs which are not cost-effective or impractical are not recommended.

All costs should be expressed in terms of life-cycle costs and may include initial, operating, training, inspection, certification, decommission, etc. For the lifecycle costs of an RCO the net present value is calculated. The benefits may include reductions in fatalities, injuries, casualties, etc. and an increase in the average life of ships (IMO 2007).

The investigation with respect to the accident causes of *Collision*, *Foundering* and *Wrecked/Stranded* were supported by Germany and Norway providing access to the GISIS investigation reports with restricted access.

The cost estimations performed for the cost-effectiveness evaluation were supported, among others, by:

- Shipping Company Peter Döhle Schiffahrts-KG (Hamburg)
- Association of Hanseatic Marine Underwriters (Hamburg)

2 Identification of risk control options

2.1 Determination of areas needing control

In order to prepare the expert brainstorming session for identification of risk control options, the results of step 1 and step 2 were reviewed to identify the areas most needing control.

The FSA Guidelines recommend identifying the main risk contributors by a screening with respect to the following topics:

- Risk levels, by considering frequency of occurrence together with the severity of outcomes. Accidents with an unacceptable risk level become the primary focus;
- Probability, by identifying the areas of the risk model that have the highest probability of occurrence. These should be addressed irrespective of the severity of the outcome;
- Severity, by identifying the areas of the risk model that contribute to highest severity outcomes. These should be addressed irrespective of their probability; and
- Confidence, by identifying areas where the risk model has considerable uncertainty either in risk, severity or probability. These uncertain areas should be addressed.

The results of step 2 of the FSA for GCS are summarised in Table 2-1.

With respect to crew safety the areas with highest risk contribution are *Collision*, *Foundering* and *Wrecked/Stranded.* The fatality rate per ship year is about one order of magnitude higher than for the other accident categories. This group of accident categories represents more than 85 % of all crew fatalities (from ship accidents). With respect to the number of accidents *Machinery Damage* contributes nearly 37 % to all accidents. However, the fatality rate is significantly lower than for the three categories mentioned above.

For the risk category environmental pollution (Potential Loss of Oil, PLO), again, the three accident categories *Collision*, *Foundering* and *Wrecked/Stranded* are the main risk contributors:

- Collision: 0.232 tonne/ship year
- Foundering: 0.158 tonne/ship year
- Wrecked/Stranded: 0.044 tonne/ship year

Following the data summarised above, the risk to GCSs is mainly safety related and the environmental risk is relatively small.

Even if these results show clearly that the risk of general cargo ships result from *Collsion*, *Foundering*, *Wrecked/Stranded* the project team decided to consider all accident categories in the experts brainstorming session. However, in the expert session emphasis was placed on the major risk contributors.

Table 2-1: Casualty statistics and accident frequencies for general cargo ships (1997-01-01 to 2008-12-31)

Accident category	Casualties	Ship years[2]	Frequency per ship year	Consequences				
				Fatalities	Fatalities per ship year	Pollution events	Days out of service[3]	General Cargo Ship losses
Collision (CN)	238	43,222	5.5 E-03	99.7	2.3E-03	2	1~45	22
Contact (CT)	99	43,222	2.3 E-03	12.1	2.8E-04	2		2
Foundering (FD)	64	43,222	1.5 E-03	220	5.1E-03	1	--	59
Fire/explosion (FX)	116	43,222	2.7 E-03	20.2	4.7 E-04	1	1~10	11
Hull damage (HD)	86	43,222	2.0 E-03	12.2	2.8 E-04	0	1~14	1
Wreck/Stranding (WS)	325	43,222	7.5 E-03	61	1.4E-03	9	2~16	22
Machinery damage (MD)	533	43,222	1.2 E-02	13.1	3.0 E-04	1	1~21	1
TOTAL	1,461			438.3				

2.2 Accident causes

In order to provide information with respect to the accident causes to the experts in the session for identification of risk control options the casualty reports of LRF as well as the additional information found in GISIS (Global Integrated Shipping Information System) were reviewed. The results of this review are summarised in the sections below for different accident categories. The information was also used to review and update the fault trees already provided with the risk model (step 2 of the FSA, MSC 87/20/1 and MSC 87/INF.4).

2.2.1 Collision (CN)

By the analysis of the GISIS database two new casualties were identified and were added to the sample. In total the sample contains 240 collisions. Of these, 80 accidents are also reported in GISIS. The GISIS database investigation for these 80 accidents yields 22 investigation reports providing more detailed information with respect to accident causes.

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[2] Number of ship years determined in step 1 of the FSA (MSC 87/20/INF.3)

[3] Number of days out of service as provided by the casualty reports. Only 14 % of casualty reports provide information with respect to the time out of service.

In Figure 2-1 the generic scenario aspects to be considered including a fault tree collecting the main causes of collision accidents is shown. For 33 of the 240 accidents the cause could be identified by the LRF report or by the information provided in the GISIS database:

- Human (18 or 55 % of all accidents with specified causes)
- Steering (4 or 12 % of all accidents with specified causes)
- Machinery/Engine (3 or 9 % of all accidents with specified causes)
- Anchor (4 or 12 % of all accidents with specified causes) / Mooring (3 or 9 % of all accidents with specified causes)

As shown above, the majority of the known accident causes are human related, often in combination with other effects like bad weather conditions or low visibility. In this context bad weather means low visibility due to fog or fog and night time. Eight accidents or 44 % of the human related accidents took place in fog/low visibility.

It might be notable that 27 of 240 collisions (11 %) took place in fog/mist/poor visibility.

Human errors as navigational errors are often promoted by high work load causing reduced attention of the OOW (officer of watch). Some examples are summarised below:

- The C/O (Chief Officer) was facing the chart table, checking his vessel position, because the vessel was nearing a course-alteration point and, as a result, failed to monitor the movement of the M/V Y sufficiently.
- … Negligence to keep a sufficient lookout;
- The lookout on the bridge of M/V Y had been sent to carry out cleaning duties elsewhere on the ship.
- The primary cause of the collision is that both of the two vessels involved violated the COLREG 1972 while sailing in fog with the negligence of keeping proper lookout, proceeding at safe speed, making full and accurate appraisal of the existing risk of collision, and failure to take timely anti-collision actions.

Another contributing factor to human errors is low risk awareness. The analysis of the casualty reports gave indications that the risk of operation in restricted waters was not adequately taken into consideration during berthing, take over or give way manoeuvres. For instance, manoeuvres were carried out without consideration of tidal effects or accurate weather report. 31 % of all collisions were reported for River/Canal. River/Canal are high traffic areas, however, these areas are also equipped with risk control measures like VTS, pilotage etc. But without sufficient preparation of the ship and the crew the effectiveness of these measures is reduced.

In some of these accidents the pilot or onshore VTS (Vessel Traffic Service) support are the root cause of the accident.

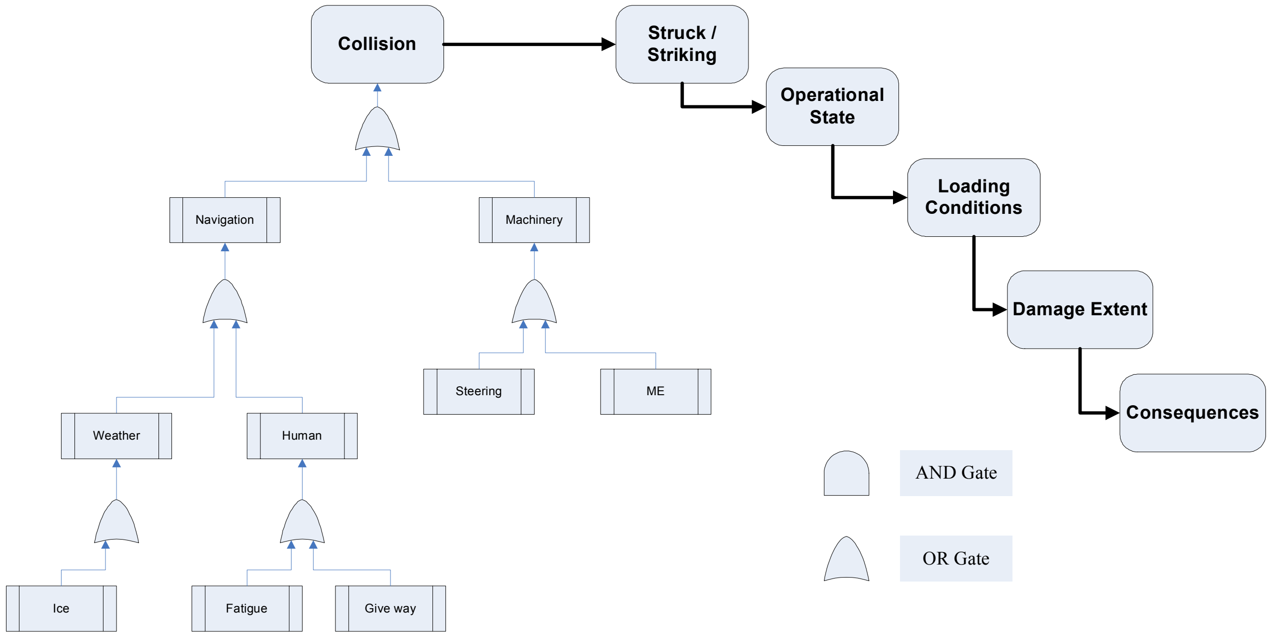

Figure 2-1: High-level generic scenario aspects for *Collision*.

2.2.2 Foundering (FD)

After the critical review of the casualty reports 64 casualty reports for the accidents category *Foundering* remain. In Figure 2-2 the generic scenario aspects including a fault tree collection of the main causes of foundering accidents is shown. The frequency of the initiating event of the Event Tree *Foundering* is determined to 1.5 10^{-3} (Table 2-1). In 60 % of the casualty reports information with respect to the accident cause are provided, which are

- Capsize: 8 % corresponding to a frequency 6.9 10^{-5} per ship year;
- Loading error: 5 % (4.6 10^{-5} per ship year);
- Cargo shift (including listing): 45 % (3.9 10^{-4} per ship year);
- Water ingress (also due to structural failure): 42 % (3.7 10^{-4} per ship year).

About 50 % of all foundering accidents are reported to happen in heavy weather conditions like hurricane, strong winds or heavy swell.

The majority of accidents were reported for ships built before 1990 (47 of 64). The relation between the number of accidents of ships built in one specific year and the number of ship years for this year was investigated. As shown in Figure 2-3 the frequency for ships built after 1991 is lower than for the ships built before. The average foundering frequency for ships built between 1981 and 1992 is about five times higher than for the ships built between 1991 and 2009. Additionally, Figure 2-3 contains the 95 % confidence interval for each year. These intervals increase after the year 2001 due to the decreasing number of ship years for younger ships. The decrease in the accident frequency could be the result of new SOLAS regulations for ships longer than 100 m coming into force after 1991 that require a damage stability calculation and double bottom. The latter is required also for ships below 80 m.

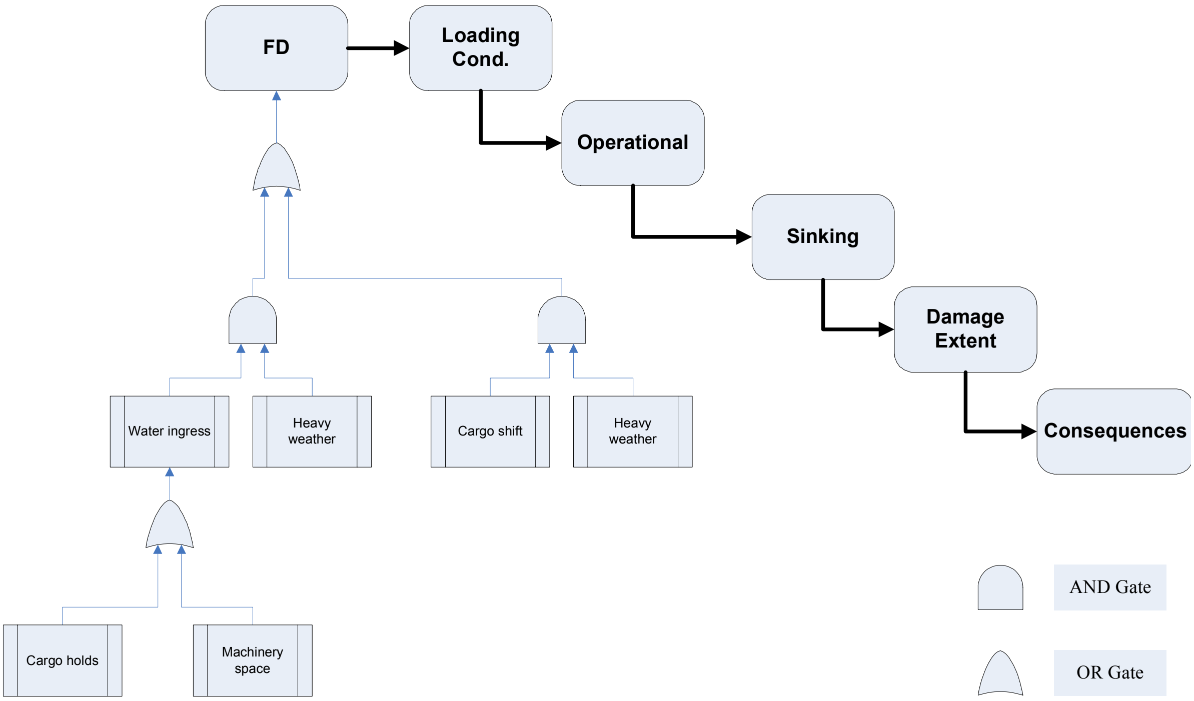

Figure 2-2: High-level generic scenario aspects for *Foundering*.

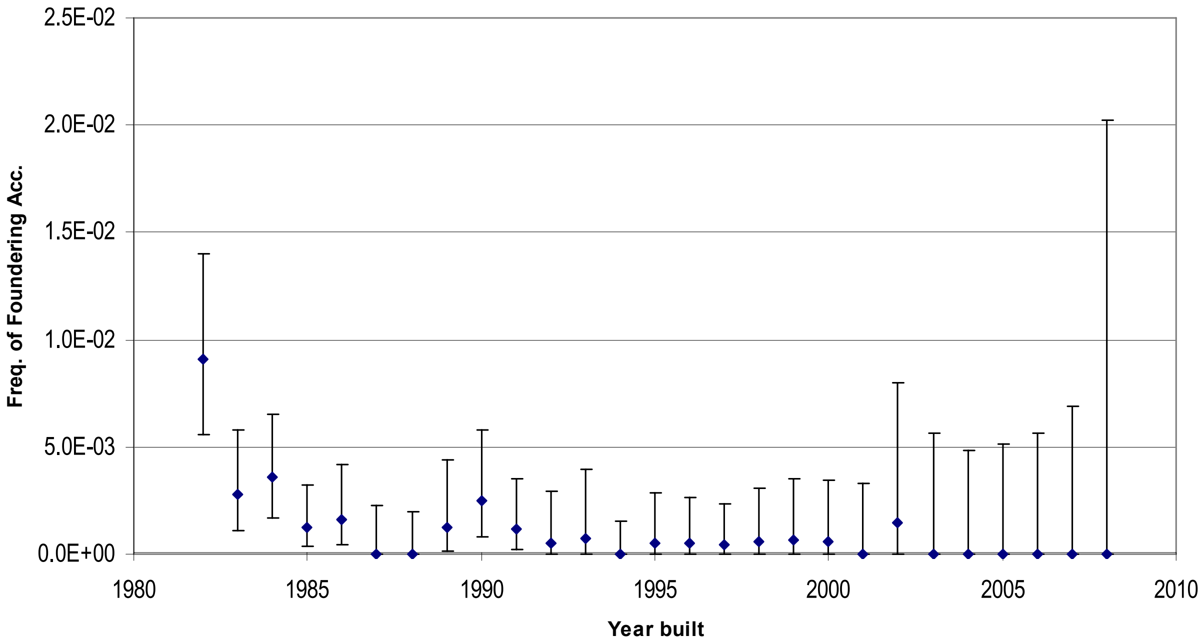

Figure 2-3: Accident frequency per year built

2.2.3 Wrecked/Stranded (WS)

The casualty reports from LRF were revised by a comparison with the information stored in GISIS. No new accidents were found. For 109 of 325 LRF casualty reports a notice was also found in GISIS. Information with respect to the course of events leading to the accident is not always provided. For 24 accidents listed in LRF GISIS contains detailed investigation reports. These reports were analysed with respect to accident causes and to provide more information useful for the identification of RCOs.

For 92 of the 325 accidents causes are known either by information in LRF or in GISIS.

The high-level generic scenario aspects that contain also accident causes is shown in Figure 2-4. An updated and more detailed fault tree is shown in Figure 2-5. The main causes of a wrecked/stranded accident are:

- Human related influences (31 accidents corresponding to ~34 % of accidents with known causes): the additional details provided by the GISIS investigation reports show that human errors are a significant cause for wrecked/stranded accidents. The human errors lead to navigational errors that are promoted by other effects, human related effects and environmental effects. As mentioned in the GISIS investigation reports these other effects are, for instance, fatigue, violation of regulations and rules (insufficient watch, handover of watch), lack of training, lack of attention and alcohol. Fatigue itself is a result of the watch planning as well as the workload. Both lead to a lack of rest which reduces the attention of the OOW especially during night time between 4 and 6. Additionally, it is indicated that the 6/6 watch system is not appropriate for navigation in coastal waters or on river/canal but is used on ships operating in these areas. Environmental effects are low visibility (fog, snow), bad weather (storm) or icy conditions.

  In several cases the provided safety measures to mitigate the influences mentioned above are not used, e.g. watch alarm in case of fatigue, GPS for positioning or the crew is not trained in the correct usage of the measures, e.g. ECDIS.

  In detail the following WS accidents causes were mentioned in the reports:
    - Fatigue (13 % of all)
    - Wrong positioning or missing course change (9 % of all);
    - Wrong usage of ECDIS (2 % of all)

- Machinery (23 of accidents corresponding to ~25 % of accidents with known causes) and steering failures (10; ~11 %): machinery or mechanical failures and steering failures cause a loss of manoeuvrability and, hence, easily lead to grounding when they took place in coastal waters, on river/canal or in harbour. Details of the root causes for machinery and mechanical failures were neither provided by LRF nor by GISIS. For steering some details could be found, e.g. in some cases the steering problems were caused by contacts of the rudder.

- Anchor dragging (19 of accidents corresponding to ~21 % of accidents with known causes): anchor dragging typically took place in combination with strong wind. The anchor is dragged and, if the crew did not pay sufficient attention, the drifting was not discovered. In one case it was reported that anchor and machine full ahead were not sufficient to avoid grounding due to a typhoon.

Other causes are

- Development of list (4 accidents): list is caused by cargo shift or water ingress. In order to save the ship it was beached in two of these four accidents.
- Autopilot failure (1 accident): technical failure in the autopilot.
- Leakage (1 accident): water ingress during typhoon.
- Mooring failure (1 accident): ropes fail during hurricane.
- Struck of object (1 accident): water ingress after striking a rock.

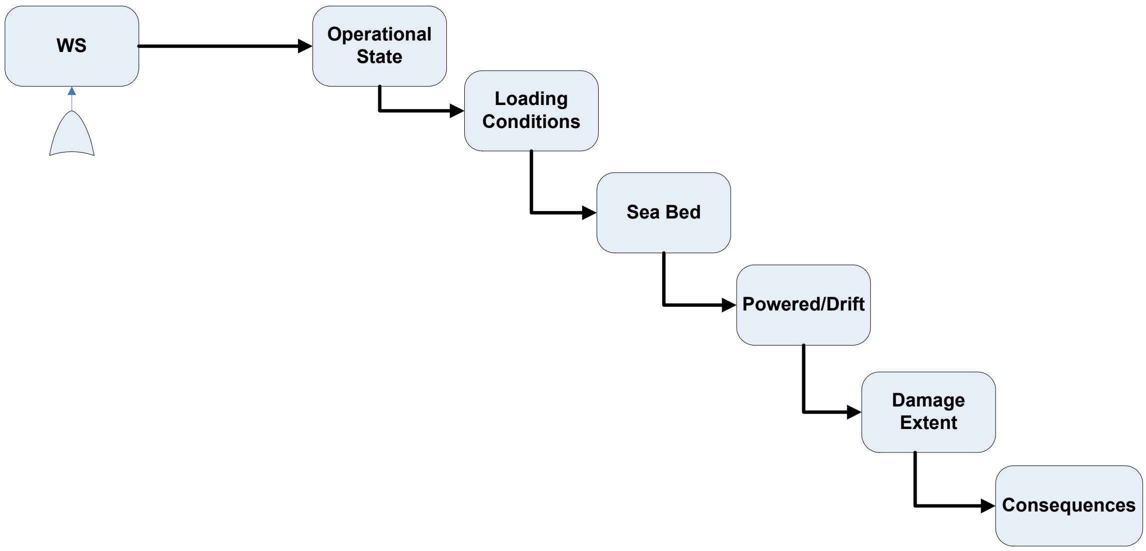

Figure 2-4: High-level generic accident scenario aspects for *Wrecked/Stranded*

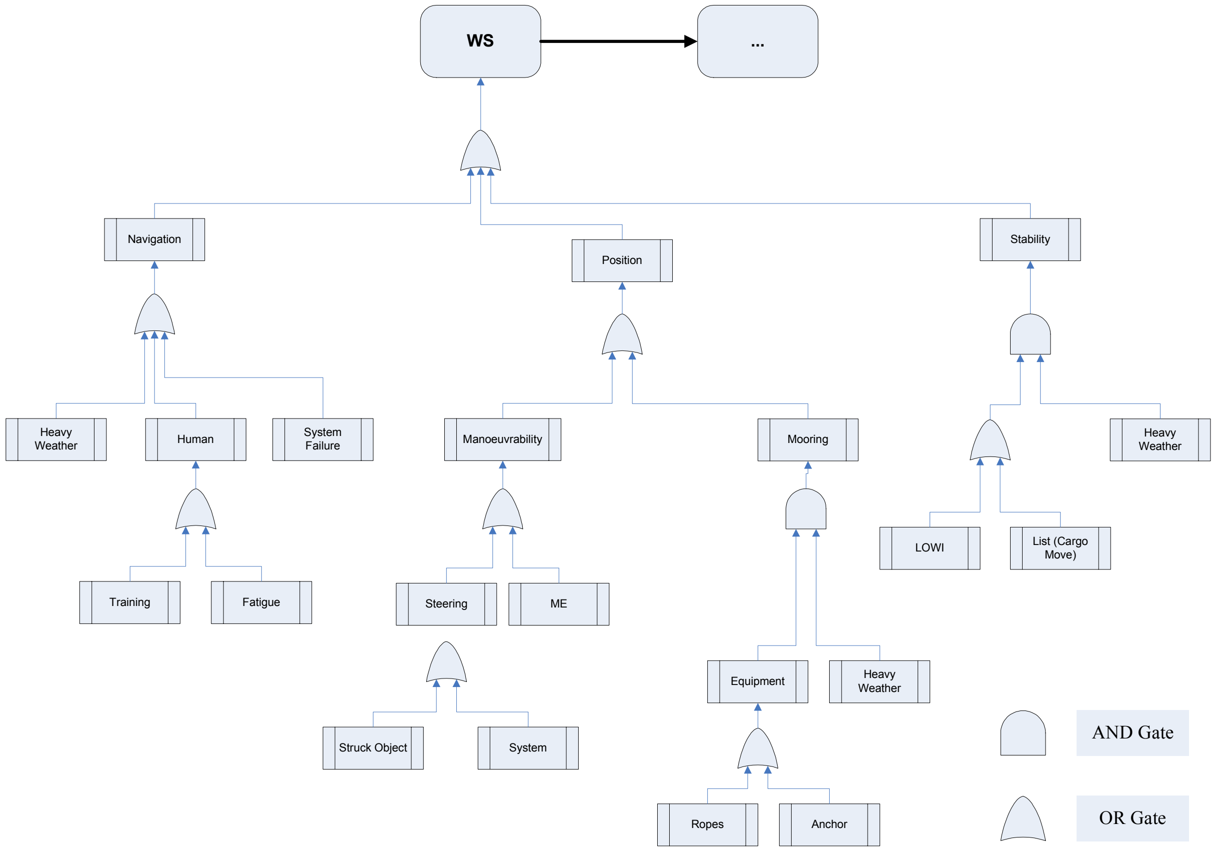

Figure 2-5: High-level generic fault tree for causes of *Wrecked/Stranded* accidents (updated)

2.2.4 Machinery damage (MD)

Out of the 533 records in LRF, 132 were also reported in GISIS, out of which additional information was provided for 21 cases. The high level accident scenario, containing also the causes is shown at Figure 2-6. Major points from the causes are summarised below:

i. Blackout affecting all engines
ii. Intermediate shaft was cut off
iii. Propulsion system not maintained and diesel generator broken down
iv. After a main engine oil mist detection alarm, it was found that both No4 piston and cylinder liner had shattered and the crankcase was full of debris. The piston crown was jammed solidly in the remains of the cylinder liner and there was a hole about d=14 cm in the entablature passing from the jacket cooling water space to the charge air manifold
v. Leaking valve in the main control air start system which caused excessive wear on the air distributor
vi. Bolts holding the piston crown and skirt together had come undone and this caused the skirt to drop down, seizing the engine

vii. Piston rings were broken
viii. Lubrication system failure
ix. Main engine cooling system had leaked into 3 of 8 cylinders in way of exhaust valves
x. Main engine auxiliary blower stator coils were burnt
xi. Engine oil had become water contaminated. Problem was located on a cylinder head and water was seen to transfer to the head valve operating gear into the sump
xii. Fortuitous structural yielding of a mechanical component of No2 cylinder
xiii. Damaged crankpin
xiv. Lost rudder due to metal fatigue
xv. Connection rod between steering machine and rudder stock was damaged

Based on the aforementioned, it should be noted that this accident category is associated with the interface between human and machinery and not in the reliability of individual components.

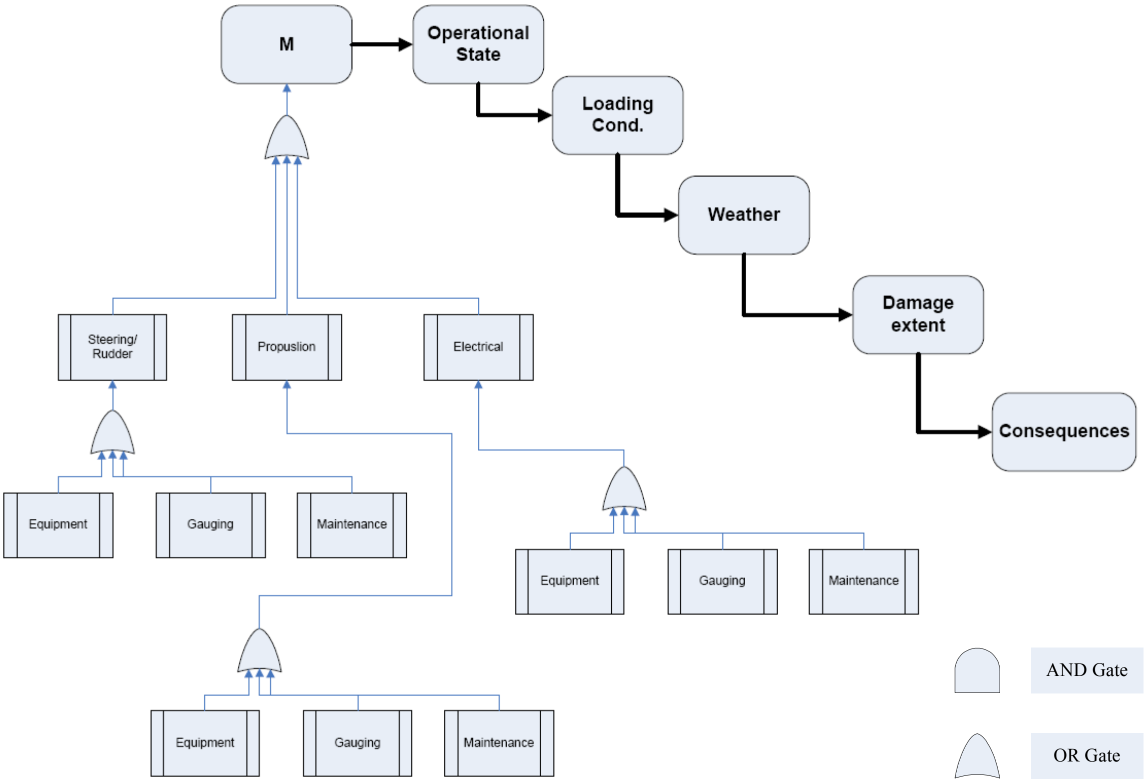

Figure 2-6: High level accident scenario for Machinery damage

2.3 Identification of potential risk control options

A two-day brainstorming session was carried out (18th and 19th March 2010) to identify potential risk control options. In this session, the results of step 1 and 2 as well as the information summarised above were explained. The findings for each accident category with respect to sample, databases, consequences and causes for the accidents were presented. Possible RCOs were discussed and collected including a brief explanation.

The following potential RCOs were identified by the experts and the expected areas of effect were assigned:

1. **ECDIS for smaller ships (new) in the current implementation plan (<3,000 GT), retrofit ECDIS in old ships (<10,000 GT).**

   ECDIS is already required for new ships GT ≥ 3000 and old vessels of GT ≥ 10,000. However, there is a question for the "paragraph" ships, i.e. for ships below the GT limit for installing ECDIS (Appendix A.2). It is anticipated that ECDIS would result in better voyage planning, monitoring, provision and updating of chart information. Hence, this could reduce the risk of grounding (WS) and could have smaller effect on collisions (CN)

2. **The previous integrated with AIS and RADAR (only for new ships).**

   ECDIS in combination with AIS would provide information of surrounding vessels including their size, speed, direction, etc. All information about voyage planning and monitoring are displayed in ECDIS. Most, importantly, the Officer Of Watch (OOW) must pay attention only to "one" display not jumping between three displays. Follow up investigations showed that ECDIS is always equipped with AIS and RADAR information, and therefore RCO 2 is merged with RCO 1. It is anticipated that the risk of grounding (WS) and collision (CN – smaller effect) could be reduced.

3. **2nd RADAR for ships within 500~3,000 GT.**

   This will provide redundancy and the option for two resolutions (near/far) without changing displays. It is anticipated that the risk of collision (CN) and grounding (WS – smaller effect) could be reduced.

4. **At least 1 electronic plotting aid device.**

   Electronic plotting device would improve actuality of charts. It is anticipated that the risk of collision (CN) and grounding (WS – smaller effect) could be reduced; however, the effect is expected to be smaller than for ECDIS. If ECDIS is already in place electronic plotting aid would have no effect as long as ECDIS is working. Some administration already stipulate electronic plotting device as stand alone or integrated with radar.

   This RCO was not considered in the cost-effectiveness evaluation because this RCO seems to be technical outdated by ECDIS.

5. **Increased manning requirements (Officer Of Watch-master (OOW master) + 2 BWO for ships >500 GT (Reference is made to STCW 95 Section A-VIII/1 & B-VIII/1 + ILO Conv. No 180 Articles 5 & 7. The survey and control of current requirements should be correctly implemented).**

   Increased manning would allow shorter watch shifts (especially during night) with the possibility of a three-watch system; less fatigue problems/increased performance; redundancy in case of sickness. Several groundings took place during early morning watch. An investigation report noted that the two-watch scheme is inappropriate for operation in coastal waters during night time. A shorter watch scheme would only be possible with increased manning. Reference to this issue can be made to Allen et al. (2007), Kahveci (1999), Houtman et al. (2005), Smith (2007), Hetherington et al. (2006). It is anticipated that the risk of collision (CN) and grounding (WS) could be reduced.

6. **Optimised/reviewed bridge design arrangement and equipment (Proper conning position of bridge visibility: visibility could be improved if all ships fulfil MSC/Circ.982 which presently is a guideline and not a requirement).**

   This will result in better access to available information/less distraction of attention; instruments should be installed in the place with maximum visibility; specific definition of conning position would lead to general improvement of visibility. The guideline is only optional and it should be made mandatory by a regulation. It is anticipated that the risk of collision (CN), contact (CT) and grounding (WS) could be reduced.

7. **3D RADAR**

   With reference to eNavigation strategy of IMO, new and improved navigation equipment requirements will be brought up, i.e. elaboration of 3D RADAR. However, this is currently beyond the scope of the present FSA and therefore this RCO was not considered in the cost-benefit assessment.

8. **Improve preparation and handling of ship for manoeuvring in restricted waters (crew & pilot preparation).**

   Pilot is required for navigation in restricted waters (river, canal, harbour) and hence the use of pilot depends on the operational scheme of the vessel. The better preparation would result in better co-operation between pilot and captain (if pilot is required). Additionally, the pilot has improved knowledge about ship behaviour. In the case that pilot is required; there would be better consideration of all environmental effects. It is anticipated that the risk of collision (CN), contact (CT) and grounding (WS) on river/canal/harbour could be reduced.

9. **Pilot simulator training.**

   Training through a simulator would result to better preparation with respect to emergency situation; improved consideration of ship behaviour (training for different ship types), as well as the specific environmental conditions of the harbour/river/canal. It is anticipated that the risk of collision (CN), contact (CT) and grounding (WS) could be reduced.

10. **Pilot for smaller ships.**

    The group of experts had no information about the number of accidents of ships that need no pilot. However, the group of experts was of the opinion that a pilot could reduce collision (CN) and grounding (WS) accidents on river/canal or in harbour.

    After the expert session the situation with respect to pilotage requirements was briefly investigated by the example of the river Elbe. It turned out that the present development is focused on a reduction of pilotage. Due to the fact that it is not clear how many accidents may be caused by lack of pilot and the aforementioned, it was decided not to consider this RCO.

11. Information card on the bridge for pilots.

This will improve the information provided for pilots. Follow up investigation showed that information on pilot card must be provided on completion, in order for the vessel registration to be efficient. Hence, RCO 11 and RCO 8 are merged (only RCO 8 is considered in CBA). It is anticipated that the risk of collision (CN), contact (CT) and grounding (WS) could be reduced.

12. Voyage Data Recorder for small vessels (500~3,000 GT).

The communication on the bridge is recorded and it can be used in case of accident. The effect of observation/recording could lead to higher awareness and attention in performing the crew's tasks/job. The communication between pilot and OOW or between OOWs during watch handover is recorded and can be checked if the requirements are implemented correctly. It is anticipated that the risk of collision (CN), contact (CT) and grounding (WS) on river/canal/harbour could be reduced.

13. Weather routing.

Weather routing would allow better preparation of the journey taking into consideration the weather forecast especially for smaller ships with less damage stability requirements, less freeboard etc. It is anticipated that the risk of foundering (FD) could be reduced.

14. Life boats for smaller vessels (L<85 m).

On small vessels only rafts are required, crew cannot enter the rafts directly from the ship; it is expected that lifeboats would provide higher survival probability in case of evacuation. It would be reasonable only for new vessels since retrofitting old vessels hardly possible. Even though for new buildings it is questionable if installation is feasible due to dimensions of the ship. It is anticipated that life boats could have an effect to all accident which lead to abandoning the ship.

15. Water ingress alarm for No1 cargo hold.

Small ships have only one cargo hold; water ingress in this cargo hold leads to decreased stability or loss of stability. Water ingress alarm would lead to early notice and will increase the available time for corrective actions or abandoning the ship. It is anticipated that the risk of foundering (FD) could be reduced with little effect on collision (CN) and grounding (WS). Rules already require a water ingress alarm for ships with one cargo hold only.

16. Increased R index or stability criteria/requirements

The R value depends on ship length whilst for a small ship the R value is only 0.4~0.5. Furthermore, damage stability calculation does not consider dynamic effects of waves, and covers only CN scenarios. Higher R values would increase the probability of survival of a water ingress or cargo shift. It is anticipated that the risk of foundering (FD) could be reduced as well as the consequences of collision (CN) and contact (CT).

Calculations were performed by Sigmund Rusås[4] (DNV) and are included in Appendix A.3.

17. Improvement of cargo stowage especially bulk (other than grain) and heavy items.

Cargo shift decreases the stability and can also lead to damage to the ship hull with water ingress; especially in heavy weather a higher probability for cargo shift is observed. These observations may be caused by inadequate stowing requirements (lashing, stowage of bulk). Improved stowing as well as dividing the cargo hold would reduce the probability of cargo shift in bad weather. It is anticipated that the risk of foundering (FD) and hull damage (HD) could be reduced.

18. Coating requirements for areas of low accessibility.

Improved coating, especially for areas with reduced accessibility, may extent the coating life and hence decreases the probability of corrosion. Coatings with life of 15 years are already available. It is anticipated that leakage could be reduced and therefore this could have a reduction effect to foundering (FD).

19. Extended survey on GCS

An extended survey reduces the probability of hidden deficiencies that may cause hull damage with water ingress. From 2003 it has been agreed within IACS not to implement the documentation requirements of ESP, but to conduct extended surveys on GCS. As unified requirements (UR-Z10) exist for bulk carriers and chemical and oil tankers, additional text for GCS could be provided. It is anticipated that the risk of foundering (FD) and hull damage (HD) could be reduced.

20. PSC inspector training on GCS.

Training of PSC inspectors would increase their technical knowledge, e.g. with respect to problematic arrears in relation to ship type. Additionally, training could improve the exchange of information with respect to deficiencies and hence would focus the attention to most problematic arrears. It is anticipated that the risk of foundering (FD) and hull damage (HD) could be reduced.
Even if the training of PSC inspectors is not an IMO matter, it is considered in this FSA.

21. Reduced BWT (Ballast Water Tank Size) size.

Reduced BWT size may decrease the free surface effect and hence the probability of dangerous situation in cases when ballast water exchange is performed in inadequate weather conditions (instability with possibility of capsizing or heel with cargo shift). It is expected that this can have a positive effect on subdivision index. It is anticipated that the risk of foundering (FD) could be reduced.

22. Extended inspection/survey on hatch covers and deck/shell openings.

Several accidents were caused by loss of watertight integrity of the vessel, which may have been caused by defected hatch covers or wrong closure of the hatch covers or deck/shell openings. Water ingress leads to reduced stability which may cause capsizing

[4] The project manager of HARDER

or heel leading to cargo shift. According to IACS Rec.15 and UR Z4 the scope of hatch cover survey (conditions for annual survey) is described. During special/renewal survey, the operation and strength assessment of hatch covers are considered. Hence, RCO 22 is merged with RCO 19 into extended surveys applicable to GCS (only RCO 19 is considered in CBA). It is anticipated that the risk of foundering (FD) could be reduced.

23. Simulator training for increasing situational awareness (i.e. anchor dragging).

Anchor dragging is a one of the mayor causes for WS. The anchor is not designed to keeping the ship position in heavy weather; but it seems that crew is not aware of this. Therefore, training with on-board simulator may improve risk awareness. It is anticipated that the risk of grounding (WS) could be reduced.

24. Increased design requirements for anchor holding power (inclusion of dynamic effects on Equipment Nr).

The equipment Nr formula is an international standard. A separate project should be established for possible/proposed changes in deriving a formula including dynamic effects. In such a case, the design weight of the anchor as well as the improvement of the functional anchoring which depends on the seabed could be investigated. It is anticipated that the risk of grounding (WS) could be reduced.

25. Watch scheme every 4 hrs.

Follow up investigations showed that RCO5 and RCO25 should be merged. It is anticipated that the risk of collision (CN), contact (CT) and grounding (WS) could be reduced and in particular human fatigue related accidents.

26. ECDIS training of all OOW.

Crew do not use all features of ECDIS (example: wrong resolution and setting for grounding alarm). It is expected that all OOWs should hold a valid ECDIS certificate. It is anticipated that the risk of collision (CN) and grounding (WS) could be reduced.

27. Anchoring watch alarm integrated in ECDIS.

This would avoid anchor dragging to go undetected. Software should be developed in a way that the setting of unrealistic thresholds is impossible. It is anticipated that the risk of grounding (WS) could be reduced.

28. Checklist for maintenance procedures.

Fire and explosion accidents occur often during harbour stays. It was concluded that these accidents may be caused by inadequate maintenance work, e.g. welding in oily areas, not properly installed flanges. Presently no information is available if a checklist to prepare maintenance work exists or if HazIds are performed to identify hazards (similar to ISM or TMSA requirements). It is anticipated that the risk of machinery damage (MD) failures could be reduced with small effect on fire/explosion (FX) events.

29. Effect of regulations on engine room fire suppression

See discussion section 5.1.

30. Sprinkler in the accommodation area of cargo ships.

Some fire incidents had their origin in the accommodation (12%), thus sprinkler would provide immediate fire fighting capacity and it is expected that the consequences could be reduced.

31. Smoke detector in cabins

Smoke detectors are installed in the corridors, but not in the cabins. As smoking is permitted in the whole accommodation block, having smoke detectors installed in each cabin would allow earlier warning of an ignition source. It is anticipated that the fire risk in accommodation area could be reduced.

32. Combine watch alarm with autopilot

By modification of watch alarm system a switch off of watch alarm is prevented when autopilot is activated. It is anticipated that the risk of collision (CN) and grounding (WS) could be reduced with small effect on contact (CT)

2.4 Evaluation of risk reduction capacity of risk control options and method of work

The risk reduction capabilities of the risk control options were estimated by a comprehensive analysis of the casualty reports and estimation of the effect of the risk control option on the accident causes. Afterwards all information was summarised and was distributed to the experts for collecting the expert opinion. This information is associated with the estimated number of accidents which could have been avoided when a particular RCO is implemented. These values are used for updating the risk models and providing an estimation of the reduced potential loss of life and property. More information with respect to the specific data as well as the assumptions made are summarised in Annex A.6 on page 79.

The result is summarised in Figures 2-10 and 2-11 showing the average avoidance effectiveness as well as the deviation in the expert opinions (error bar) and all broken down into the accident categories. For instance, RCO 1 (ECDIS) should be effective for Collision (CN) and grounding (WS) accidents. The experts are of the opinion that on average 30 % of the collisions caused by human related navigational errors in poor visibility conditions could be avoided by the introduction of this RCO. The minimum value of effectiveness is 15 % and the maximum value 45 %. As shown in Figure 2-7 the effect on grounding (WS) accidents is expected to be higher (30 % to 55 %). Moreover, according to the ECDIS/ENCs FSA study (MSC 81/24/5, Denmark and Norway) estimated effect on grounding accidents was 36%.

Following the fault tree of the risk model these effectiveness values were combined with the percentage of accidents and/or percentage of fleet influenced by the risk control option to get the overall effect of the risk control option onto the accident frequency.

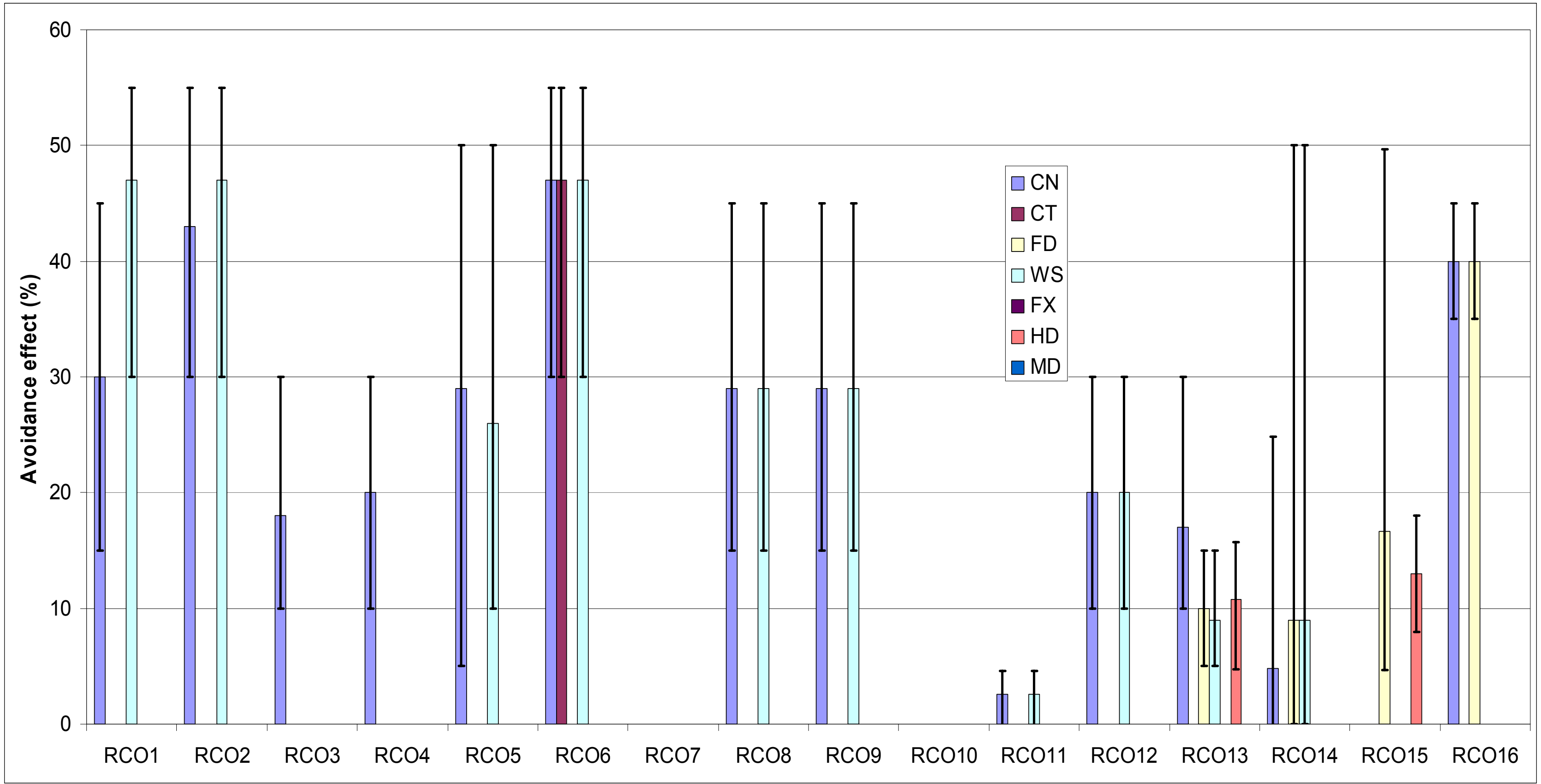

Figure 2-7: Effectiveness of risk-control options and broken down into the accident categories.

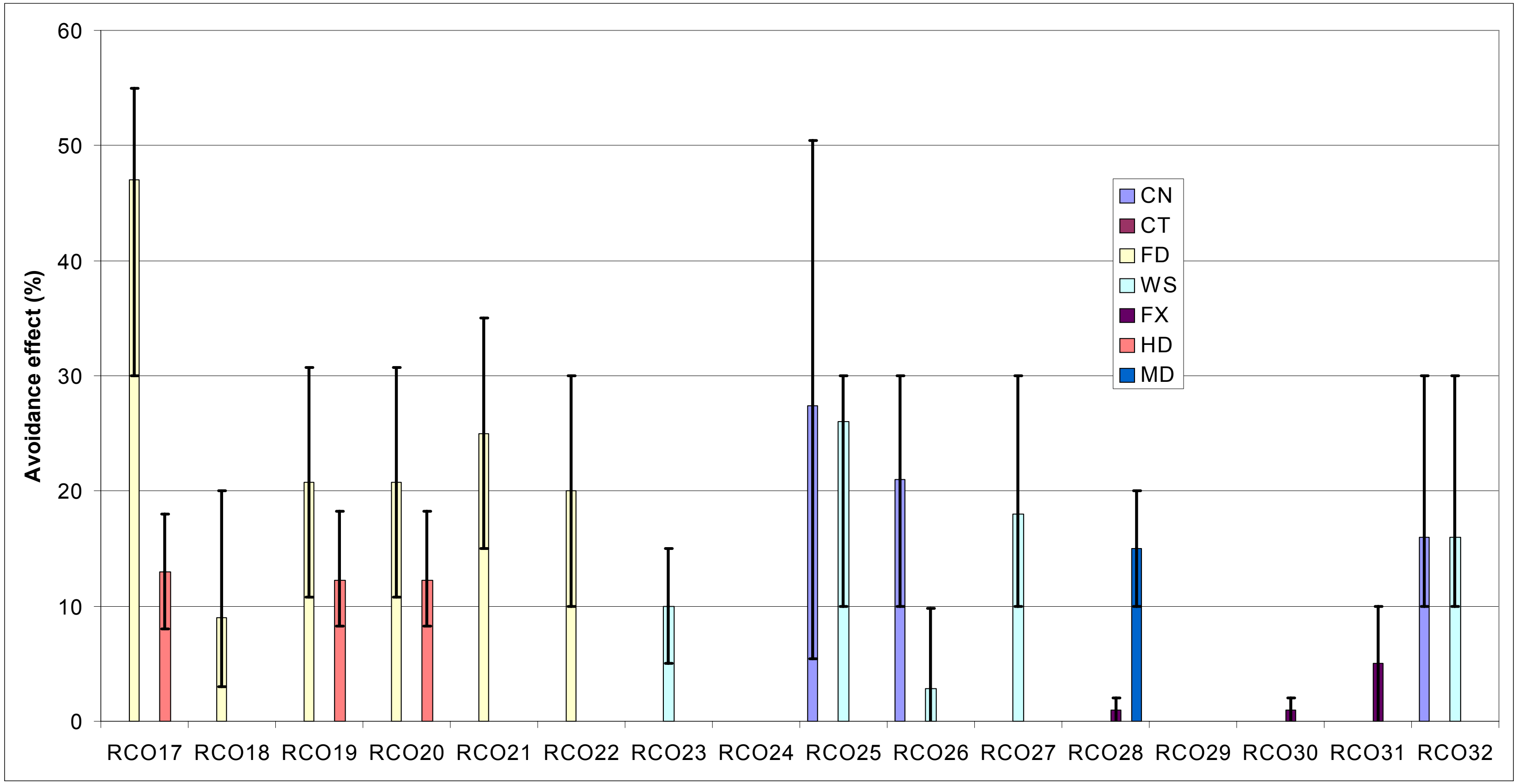

Figure 2-11: Effectiveness of risk-control options and broken down into the accident categories.

2.5 Costs of risk control options

The installation and possible maintenance costs for the different risk control options were determined (Table 2-2) in order to provide the required input data for the cost-effectiveness evaluation. Understandably, these costs vary, for instance, with respect to the manufacturer, equipment accessories, provider and also country. Within the scope of this FSA the determination of the costs could only be an estimation of significant characteristic values. As far as possible cost ranges and average values are specified. The latter ones are used in the cost-effectiveness evaluation.

The determination of costs is also used to collect more information with respect to the risk control options. In some cases these information lead to the decision to combine risk control options. This is also highlighted in Table 2-2.

Additionally, it turned out that for some risk control options the required information could not be collected in the time frame of this assessment; or the information lead to the valuation of the authors that this risk control option would have no effect. Therefore these risk control options were not considered in the cost-effectiveness assessment which is indicated, too.

Table 2-2: Costs for risk control options

No	RCO	Remarks	Cost Estimate		
			Av.	Min	Max
2	ECDIS integrated with AIS and RADAR for smaller ships (new) in the current implementation plan (<3,000 GRT), retrofit of ECDIS in old ships (<10,000 GRT)	Hardware:~31,000 $[5] Installation: 3,750 $ Licence: ~ 750 $ minimum fee applies to each licence ~24 $ individual charts ~1,625 $ indiv. area disk ~8,750 $ all area disk annual basis Alternatively:	Hardware: 31 k$ Installation/Training: 3.8 k$ Annual costs for charts, etc.: 2.5 k$	19 k$ 2.9 k$ 1.9 k$	38.8 k$ 4.8 k$ 3.1 k$

[5] Price information received in Euro. Exchange rate: 1 € = 1.25 $

No	RCO	Remarks	Cost Estimate		
			Av.	Min	Max
		"Pay Per View": charts on short term licence (3 months) as and when they are required → Rumours of price dumping are spreading (not confirmed): Hardware ~ 18.750 $			
3	2nd RADAR for ships within 500~3,000 GRT	X-Band 250mm PPI: ~15,000 $ (makes sense if blind sectors like the superstructure or cranes are to be blinded out) S-Band 250mm PPI: ~22,500 – 32,500 $ (far better, e.g. when raining)	X-Band Variant a) Hardware & installation: 15 k$ Annual costs for maintenance, etc.: 625 $ S-Band Variant b) Hardware & installation: 27.5 k$ Annual costs for maintenance, etc.: 625 $	11.3 k$- 500 $ 20.6 k$- 500 $	18.8 k$- 780 $ 34.4 k$- 780 $
4	At least 1 electronic plotting aid device	Technically outdated. Integrated in Radar.			
5	Increased manning requirements and a three-watch scheme	Assuming one additional crew per ship for all ships	Variant a) new building 45.5 k$ for crew (no depreciation rate for crew costs) plus additional cabin: 45 k$ Variant b) retrofitting 45.5 k$ for crew (no depreciation rate for crew costs) plus additional	Crew: 43 k$ Cabin: 34 k$ Crew: 43 k$ Cabin: 86 k$	Crew: 48 k$ Cabin: 56 k$ Crew: 48 k$ Cabin: 144 k$

No	RCO	Remarks	Cost Estimate		
			Av.	Min	Max
			cabin: 115 k$		
6	Optimised/reviewed bridge design arrangement and equipment		Variant a) Standard: 80 k$ Variant b) Over SOLAS: 200 k$ Annual cost: 2 k$	60 k$ 150 k$ 1.5 k$	100 k$ 250 k$ 2.5 k$
7	3D RADAR	**Not considered in CBA**			
8	Improve preparation and handling of ship for manoeuvring in restricted waters (crew & pilot preparation) & improve information card for pilots	Fees vary significantly between locations, e.g. Kiel Canal 5200 GT ~ 2,200 $; Elbe 915 $; Kieler Förde 625 $; Panama Canal ~ 5000 $; Harbour in Suez Canal ~90 $ to 130 $. Not all ships require always pilotage. Assuming an average GCS with 24 annual harbour approaches yielding 48 pilotages at 300 $ plus ten times canal à 2,000 $. Total annual costs: 34,400 $. The costs of this RCO are estimated to 1 % of the annual	344 $ per ship year (no depreciation rate for this cost) Review of information card 100 $	177 $ 0 $	688 $ 200 $

No	RCO	Remarks	Cost Estimate		
			Av.	Min	Max
		pilotage costs.			
9	Pilot simulator training	Rent for simulator ~ 3,750 $/day. Independent of number of participants; If a one day training of two pilots is assumed the costs should be about 2500 $/day and pilot. Assuming one training per year. Similar to RCO 8 it is assumed that the annual pilot costs will increase by 2 %	688 $ per ship year (no depreciation rate considered)	344 $	1366 $
10	Pilot for smaller ships	Presently, there is a trend to reduce the usage of pilots on the river Elbe. Costs are specified by means of RCO 8.	**Not considered in CBA**		
12	Voyage Data Recorder for small vessels (500~3,000 GRT)	Voyage Data Recorder: ~25,000 $ Simplified Voyage Data Recorder: ~14,300 $ Package of Hardware, implementation and yearly inspection: ~21,250 $	Hardware: 19.7 k$ Annual: 600 $	11. k$ 450 $	25 k$ 750 $

No	RCO	Remarks	Cost Estimate		
			Av.	**Min**	**Max**
13	Weather routing	Technical/software solution to assist crew during voyage: basic equipment 44 k$ to 56 k$. Additional costs for deviation: assume one day operational costs (charter): 15 k$/a (software reduces the unnecessary deviations compared to manual) Manual planning: weather report 1.5 k$/a ship. Additional costs for deviation: assume two days operational costs (charter): 30 k$/a	Variant a) Technical: 50 k$ plus maintenance 300 $/a plus 15 k$/a (no depreciation) Variant b) Manual: 1.5 k$/a plus 30 k$/a (no depreciation)	 44 k$ 230 $ 11 k$ 1.1 k$ 20 k$	 56 k$ 380 $ 19 k$ 1.9 k$ 38 k$
14	Life boats for smaller vessels (LBP<85 m)	~125,000 $ per ship	**Not considered in CBA: Not clear if installation is possible.**		
15	Water ingress alarm for No1 cargo hold	Rules already require a water ingress alarm for ships with one cargo hold only. 25 k$ ~ 90 k$ average: 57.5 k$	**Not considered in CBA: Already requirement.**		
16	Increased R index or stability	Cost estimates as a function of steel:	Variant C2 (Annex A.3)		

No	RCO	Remarks	Cost Estimate		
			Av.	Min	Max
	criteria/requirements	3 k$/t (New-building) 6.5 k$/t (Retrofitting)	90 k$ 124 k$	32 k$ 65 k$	189 k$ 370 k$
17	Improvement of cargo stowage especially bulk (other than grain) and heavy items	Cost estimates as a function of steel: 3 k$/t (New-building) 6.5 k$/t (Retrofitting)	Variant D (Annex A.3) 75 k$ 163 k$	 42 k$ 85 k$	 119 k$ 240 k$
18	Coating requirements for areas of low accessibility	Example: coating of ballast tanks about 250 k$ per ship. Typical prize easy access (paint, blasting, painting): ~ 17 $/m^2 Assuming: special coating of ballast water tanks for an average GCS yields 170,000 $ Maintenance: 10 % of repair after 5 and 10 years; 20 % after 15 and 20 years.	Initial: 170 k$ plus 10 % of repair after 5 and 10 years; 20 % of repair after 15 and 20 years.	Initial: 130 k$ plus 10 % of repair after 5 and 10 years; 20 % of repair after 15 and 20 years.	Initial: 213 k$ plus 10 % of repair after 5 and 10 years; 20 % of repair after 15 and 20 years.
19	Extended surveys applicable to GCS	Increases the average annual survey costs by 3 k$ to 5 k$. Average 4 k$	Annually: 4 k$ (without depreciation)	3 k$	5 k$
20	PSC inspector training on GCS	The number of inspectors hardly to determine. For Paris MoU the number of inspectors is 1,600. Assuming ~ 8,000 inspectors world wide. Training for one	125 $ (no depreciation rate considered)	63 $	188 $

No	RCO	Remarks	Cost Estimate		
			Av.	**Min**	**Max**
		inspector 1.5 k$. Assuming that 5 % of these were trained each year yields 600 k$ per year. World IACS fleet ~ 4,800 ships. Costs per ship and year 125 $.			
21	Reduce BWT size	Cost estimates as a function of increased steel weight: 3 k$/t (New-building) 6.5 k$/t (Retrofitting)	Variants A and E (Annex A.3) 66 k$ 143 k$	 15 k$ 30 k$	 171 k$ 330 k$
23	Simulator training for increasing situational awareness (anchor dragging)	Crisis management course for crew, partly coupling with the machine simulator. Costs are ~ 680 $ per day and participant. Typical labour costs ~ 150 $/day. Additional costs 700 $ (travel, accommodation). Assuming one day training for one crew per ship every five years.	1400 $/ship initial and than after 5; 10; 15; 20 years	1050 $	1750
24	Increased design requirements for anchor holding power (inclusion of dynamic effects on Equipment Nr)		**Not considered in CBA**		

No	RCO	Remarks	Cost Estimate		
			Av.	Min	Max
26	ECDIS training of all OOW	Certified ECDIS course: 3 days; ~ 1,250 $ per participant. Assume training of one crew per year on average.	1.25 k$ per year	940 $	1.6 k$
27	Anchoring watch alarm integrated in ECDIS	Probably free of charge when integrated in radar (it seems that it is already integrated in radar)	0 $	0 $	1000 $
28	Checklist for maintenance procedures		5 k$ Annual cost: 700 $	3.8 k$ 525 $	6.3 k$ 875 $
29	Effect of regulations on engine room fire suppression	See discussion (section ??)			
30*	Sprinkler in the accommodation area of cargo ships	Initial/fixed cost: 150,000 USD Annual maintenance: 1,500 USD	**Not considered in CBA because negligible risk reduction**		
31*	Smoke detector		Smoke detection: Initial/fixed cost: 30,000 $ Per cabin: 130 $/cabin	22.5 k$	37.5 k$

* Cost estimates were kindly provided by Lars Elsrud (Autronica Fire and Security AS) and Markku Miinala (Marioff Corporation OY)

No	RCO	Remarks	Cost Estimate		
			Av.	Min	Max
			Annual maintenance: 1,500 USD	1.1 k$	1.9 k$
32	Combine watch alarm with autopilot	Assuming 1 k$ of electronically work	1 k$	500 $	1500 $

3 Cost-effectiveness assessment

In FSA the ALARP principle is applied to evaluate the benefit or cost-effectiveness of an RCO. Following the definitions in the FSA guidelines an RCO is regarded to be cost-effective if the societal benefit is greater than the costs of the RCO. The societal benefit is defined by a threshold. In the cost-effectiveness evaluation the lifetime costs of an RCO are put in relation to the risk reduction and the result is compared with the threshold.

The cost and benefit of the RCOs will typically be spread over the lifetime of the vessel. Some RCOs might involve annual costs while others may involve costs at other intervals. In order to be able to compare the costs and benefits and calculate the NCAF and GCAF, Present Value (PV) calculations have been performed using the formulae given below:

$$PV = A + \sum_{t=1}^{T} \frac{X_t}{(1+r)^t} \qquad (1)$$

Where:
X_t = cost (or benefit) of RCO in year t
A = amount spent initially for implementation of RCO
r = depreciation rate
T = estimated usage time of risk control option, i.e. remaining operational lifetime of the vessel

For this FSA the life time of a general cargo ship is set to 25 years.

The direct costs of the measures have been divided into two parts: Initial costs and running costs over the lifetime of the vessel. The initial costs include all costs of implementing the measure, e.g. acquiring and installing equipment, writing of procedures and training of crew. Thereafter there might be additional indirect costs at regular intervals in order to maintain the effect of the measure, e.g. equipment service and refreshment courses but also replacement. The additional cost for example might occur annual, bi-annual or fifth–annual.

Cost-effectiveness is assessed in terms of Gross Cost of Averting a Fatality (GCAF) is defined by:

$$GrossCAF = \frac{\Delta C}{\Delta R} \qquad (2)$$

and Net Cost of Averting a Fatality (NCAF) by:

$$NetCAF = \frac{\Delta C - \Delta B}{\Delta R} \qquad (3)$$

Where:
ΔC is the life cycle cost per ship of implementing the RCO
ΔB is the economic benefit per ship resulting from the implementation of the RCO
ΔR is the risk reduction per ship, in terms of the number of fatalities averted, implied by the RCO

In accordance with current practice within IMO and the proposals presented in MSC 72/16 (Norway 2000), the following criteria have been adopted for this cost-effectiveness analysis: *A risk control measure will be recommended for implementation if it has notable potential for* *risk reduction, and the GrossCAF ≤ USD 3 million or NCAF ≤ USD 3 million*. For risk control options where the estimated GrossCAF/NetCAF is close to USD 3 million, further scrutiny might be required.

3.1 Cost of damage to property

The evaluation of the risk control options based on eq. (3) provides a consideration of all benefits linked to introduction of an RCO through a reduction of the total costs (for more details with respect to the cost evaluation see section above). One benefit of a prevented accident is the avoidance of costs for repair, docking, loss of charter etc. In this section the determination of the different expense loadings is explained.

The costs contributors considered are:

- Value of ship (in case of total loss)
- Loss of cargo (in case of total loss)
- The repair costs including docking time, loss of income and costs for the crew

3.1.1 Value of Ship

The actual value of a ship lost in an accident is determined taking into consideration the new building price and the salvage value using a linear decline in value between year being built and sold for scrapping. The actual value of a ship considered in the cost-benefit evaluation is determined as explained below.

For 142 ships built between 2000 and 2009 the LRF database provides the new building price of the ship in USD for the year built. This sample is regarded to be representative for the new building price of GCS. These prices are transformed into USD of 2010 based on an average rate. In order to determine this rate the price development is investigated. Figure 3-1 shows the price development for the period 1996 to 2010 for a general cargo ship of 22,000 DWT taken from Clarkson. The average annual inflation rate for this period is about 2.7 %. As shown the development of the price does not follow a continuous trend, and between 1997 and 2005 the new building prices were lower than for 1995. Another significant drop in the new building prices is observed after 2009; which is obviously an effect of present economic situation.

To fade out the effect of the present economic situation the average rate is determined on basis of the years 1995 and 2007 to 2008 that yield an average price increase of about 2.5 %. This value is only slightly lower than the average inflation rate for this period.

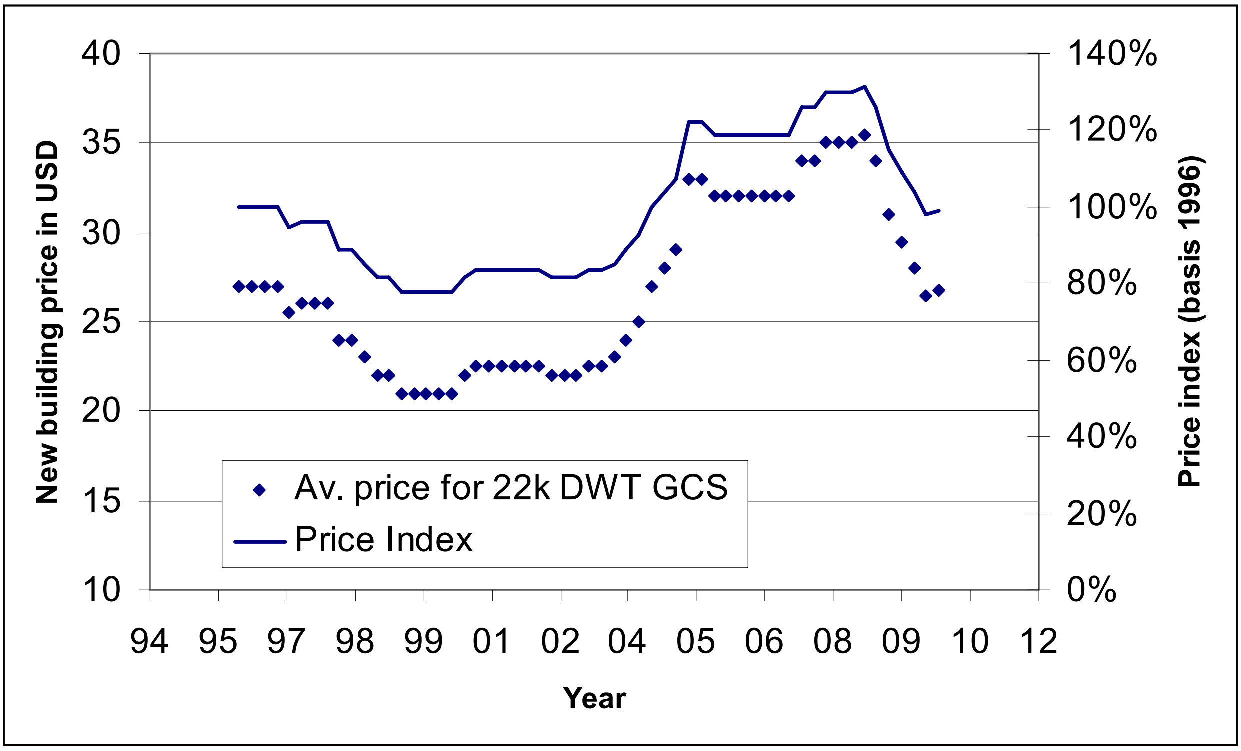

Figure 3-1: Average quarter year price for a general cargo ship of 22 k DWT and the according price index (reference year 1995 = 100 %) for 1996 till 2010 in USD (source Clarkson)

The prices specified in LRF database are transformed into the 2010 values using this average rate. In Figure 3-2 the LRF data and the 2010 values are plotted for all sizes of GCS. For ships above 25,000 DWT only few data were available. All of them were lower than the prices for ships about 25,000 DWT. Therefore, and because of the fact that the majority of ships is below 25,000 DWT (Of the whole sample for this analysis (4764 ships) only 138 ships are greater than 25,000), these ships were not taken into consideration. For ships below a deadweight tonnage of 25,000 a linear trend line for new building prices as a function of deadweight is found with a regression coefficient of 0.8[6].

Based on this data and the trend curve the standard deviation was determined for the normalised new building price (normalised with respect to the price determined with the trend curve) to 0.31.

[6] Alternatively, the relation between gross tonnage and new building price is investigated which yields a slightly lower correlation (regression coefficient 0.75).

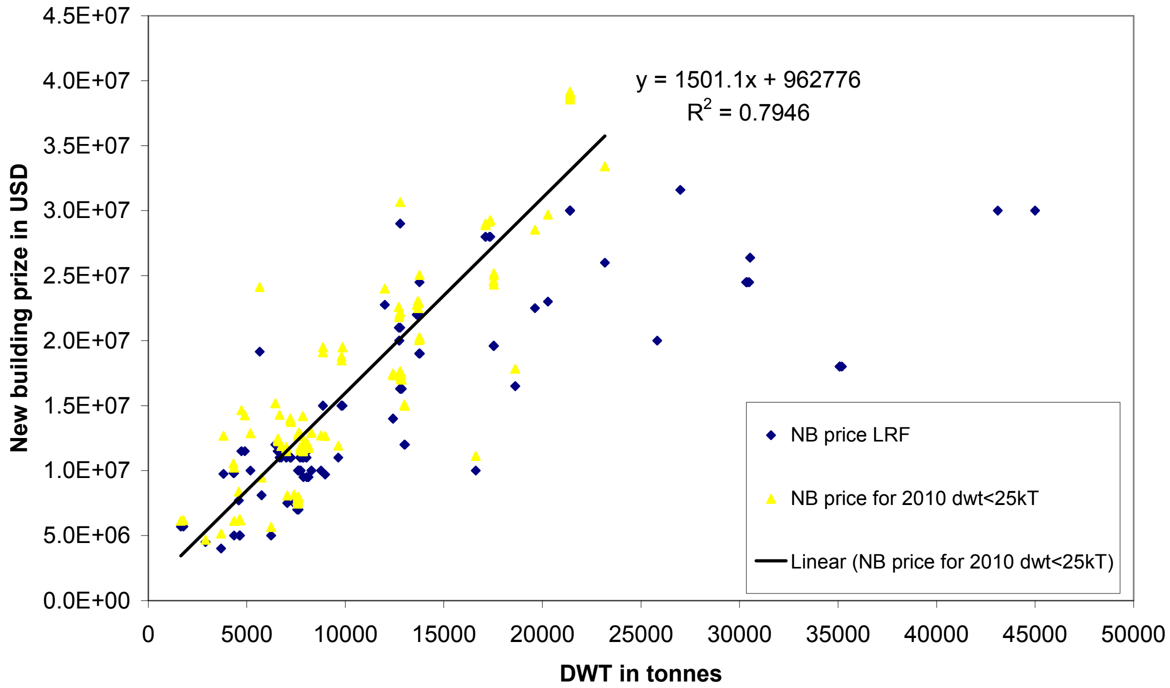

Figure 3-2: New building prices in USD (original LRF values and 2010 value) for general cargo ships up to 25,000 DWT.

The average ship size for the sample is about 7,000 DWT and the median about 5,000 DWT yielding an average new building price of about USD 11 million or about USD 8.5 million respectively.

The second point needed to calculate the actual value of a ship is the final value of the ship. This point is determined on basis of the scrapping price. For a sample consisting of ships built between 2000 and 2008 (75 ships; 1850 ≤ GT ≤ 23132) the scrapping price is determined using a steel price of 400 USD/tonnes and the lightweight of the ships. This sample is regarded to be representative for the ships being scrapped in future. The average relative scrapping revenue is about 12 % (min. 6 %; max 18 %) of the new building price.

After determining the basic data for new building prices the age at the date of loss is required to estimate the property loss (ship) for this accident consequence. It is expected that this age depends on the accident category, i.e. older ships are more likely to founder due to structural degradation than younger ships, as well as on the age distribution of the world fleet, i.e. older ships are taken out of service (or lost in accidents) and therefore the fleet size decreases with increasing age (above ~25 years).

For the accident categories collision, contact and grounding the accident frequency is regarded to be independent of the ships age. For these accident categories the average age of the present IACS GCS fleet (2008) of 13.5 years is used. This and the parameter values specified above yield an average property loss in a foundering accident of 6.3 million USD.

For the accident category foundering the average age of a ship involved in this accident type is determined on basis of the casualty reports (64) to 15.4 years. This and the parameter values specified above yield an average property loss in a foundering accident of about 5.6 million USD.

3.1.2 Costs for Loss of Cargo

In case of an accident the cargo may be damaged, e.g. due to water ingress, or lost in case of sinking of the vessel. The value of the cargo varies significantly between a few percent of the ship's value in case of sand or stones up to several times the ship's value in case of material for e.g. offshore industry or wind turbines. Accordingly, in the latter case loss of cargo is a significant contribution to the overall losses and, therefore, could have a significant influence on the result of the cost-benefit assessment (net costs).

One possibility would be to neglect the loss of cargo. This approach would be conservative with respect to the cost-benefit assessment because the benefit would be lower and therefore the NCAF value greater. However, it wouldn't represent the reality. Hence, loss of cargo is taken into consideration. As no information was available, it was assumed that on average the value of cargo is 50 % of the ship's value (the average ship value specified above). Even if in *Collision* and *Wrecked/Stranded* accidents cargo may be damaged by water ingress, loss of cargo is considered only for total loss of loaded ship.

3.1.3 Repair Costs

The repair costs consist of

- Costs for repair (steel, equipment, labour costs);
- Loss of income (loss of charter);
- Costs for crew.

These costs are determined for the different accident categories separately and will be explained in the following for each accident category separately.

All estimations summarised in the following are based on the information provided by the Association of Hanseatic Marine Underwriters and the shipping company Peter Döhle. In order to determine the repair costs different damage descriptions were discussed with respect to real damage extent and all parameters influencing the repair costs, e.g. location (Europe, Asia). The expert provided also estimations for typical docking costs, days in the dock and days out of service. The shipping company provided information with respect to annual crew costs.

The costs for docking are independent of the accident category but the docking time varies with the damage category as well as the accident category. The docking costs vary between 6,250 $[7]/d and 31,250 $/d with an average of 15,600 $/d for the ship size under consideration. Typical docking times are specified in the following.

The costs of crew were estimated on the basis of information provided by a German ship owner for ships operating not under German Flag. Following this information the average annual costs for a crew member are between $ 43,000 and $ 48,000 or 117.8 $/day to 131.5 $/day. For ships operating under German Flag crew costs are about 30 % higher. The average value for a crew member is set to 125 $/day. The number of crew was determined in step 1 of this FSA and varies between 4 and 25 with an average of 17.1. Because the whole

[7] All information provided in €; exchange rate 1 € = 1.25 $

crew need not be hired for the whole time of repair, only 80 % of the costs are considered in the cost-benefit analysis. The total costs for crew are determined using the number of days out of service which are specified in the different accident categories respectively.

3.1.3.1 Collision

The repair costs for collision are determined on the basis of the accident descriptions taken from the casualty reports (LRF and GISIS investigation reports) for the damage categories *small* and *severe*[8].

Following the discussions, the costs of the repair depend on, among others,

- The dimensions of the damage (how many tonnes of steel must be replaced);
- The shape of the parts to be replaced (bow or alongside);
- Damage to machinery equipment like winches or steering gear;
- The place of repair (e.g. steel prices as well as labour costs deviate between Europe or Far East);
- The docking time required;
- The work load of the yards (e.g. the prices for docking depend significantly on the utilisation of the yard);

The discussion showed that the available information about the damage is rather small and the two damage categories *small* and *severe* cover a wide range of possible damages and, hence, repair costs. Accordingly, some damage descriptions regarded to be representative for the collected collision accidents and the costs were estimated (average values). The basis for these estimations is an average general cargo ship between 5,000 DWT and 7,000 DWT.

For the damage category *small* the following damage descriptions were used to estimate the repair costs:

- Damage in the aft section (above waterline) including damage to poop deck, anchor, machinery equipment on aft deck, damage to aft ballast tank and deformities in way of lifeboat deck.
  Total average costs about 625 k$, even higher if machinery equipment must be replaced.

- Several square meters whole in bow section close to anchor. Due to the whole size significant damage to the internal structure of this section is expected.
  Total costs between 375 k$ and 500 k$.

- Denting of the star board bow plating.
  Total costs can vary between 75 k$, if no equipment was damaged, and 2.5 m$, if the whole forecastle including machinery equipment must be replaced.

- Damage to starboard bridge.
  In this case often damage to accommodation. Cost for sanitary block only 31.25 k$.

[8] Cost of total loss is explained in section 3.1.1.

Costs for replacement of steel lower than for hull. Total costs between 125 k$ and 250 k$.

Based on these characteristic damage descriptions the repair costs (steel, equipment, labour costs) for the damage category *small* are estimated to a range of 62.5 k$ to 625 k$ with an average value of 375 k$.

For the damage category *severe* the following damages were estimated:

- Damage in the aft section with water ingress. Damage to steering gear and accommodation assumed. Docking about ten days.
  Total average costs about 625 k$ including machinery equipment but without docking.

- Damage in aft section with water ingress to steering gear and engine room. Additionally, one cabin crushed.
  Cost for the cabin only, 62.5 k$. Total costs between 875 k$ and 1.25 m$.

- Damage to forward hull and water ingress into bow thruster room. No information of the damage steel structure available.
  Repair costs of bow thruster about 187.5 k$.

- 3 m * 3 m gash in port side midship area 12 m to 14 m below the waterline and no. 2 cargo hold flooded.
  Costs for steel work between 250 k$ and 375 k$ plus cargo.

Based on these characteristic damage descriptions the repair costs (steel, equipment, labour costs) for the damage category *severe* are estimated to a range of 500 k$ to 1.25 m$ with an average value of 875 k$.

Not yet considered are the costs for docking. Typical docking times for small damages, if required, are about five days and in case of a severe damage is about 45 days. However, the total time to return to service is longer, 45 days on average for small damages as described above and up to six months for severe damages. These long times result from the journey to the repair yard, time of waiting, repair time itself and the journey to loading harbour.

The docking costs were estimated as follows:

- Following the information, for damages of the category *small*, docking might be required for about 50 % of the accidents. The average docking time of all accidents is estimated to three days yielding ~47 k$.

- All accidents of the category *severe* require a docking which should on average last for 10 days yielding ~156 k$.

The loss of charter was estimated using a representative current daily charter of 10,000 $ which yields 450 k$ (45 days out of service) in case of small damage and 1.8 m$ (180 days out of service) in case of severe damage.

3.1.3.2 Contact

As shown by the risk model on average the damage extent for *Contact* accidents is smaller than for *Collision*. However, the repair costs for a specific damage should be the same, because these costs relate to the damage extent and not to the source of the damage. Accordingly, the authors decided to use the same cost intervals like *Collision* but to reduce the average values for both damage categories to 70 % of the values used for the accident category *Collision*.

3.1.3.3 Foundering

Foundering, in general, leads to a total loss of the ship. In some rare cases a re-floating could be successfully performed. For a re-floated ship the main cost contributors are expected to be the costs for the replacement of the machinery and electrical equipment. The replacement costs for machinery easily exceed several millions USD. For this analysis the authors decided to assume 25 % of the new building price (about $ 2.8 million) as the average repair costs exclusive additional costs for docking, loss of income etc.

3.1.3.4 Wrecked/Stranded

The costs were determined similar to the accident category collision.

For the damage category *small* no information with respect to the damage extent was available. Therefore, the authors decided to use the estimation of the accident category *Collision* because all *Wrecked/Stranded* accidents assigned to this damage category have no significant damage to the structure or water ingress.

For the damage category *severe* the following damages were estimated:

- 10 m hole from stern to astern in front section with flooded bow thruster room and starboard ballast water tank holed
  Repair costs between 500 k$ and 625 k$ because of shape of the hull and damage to thruster.

- 40 m long tear in hull with damage to three bunker tanks.
  Significant contributor to the repair costs are the costs for disposal of the bunker tank content which varies significantly between the countries, e.g. Germany: 250 k$ and China: 62.5 k$.
  Total average costs estimated to 1.25 m$ and a time of repair of 3 months.

- Fracture 7 m times 0.7 m to bunker tank and further severe damage to hull bottom. Total costs about 625 k$.

Based on these characteristic damage descriptions and the investigation for collision accidents the repair costs (steel, equipment, labour costs) for the damage category *severe* are estimated to a range of 500 k$ to 1.25 m$ with an average value of 875 k$.

In contrast to the accident category Collision docking is always required for the damage category *small*. The average docking time is estimated to six days. Typical docking times for *severe* damage is about 45 days or even longer. Again, the total time to return to service is longer, 45 days on average for small damages as described above and up to six months for severe damages. These long times result from the journey to the repair yard, time of waiting, repair time itself and the journey to loading harbour.

3.1.3.5 Costs for Machinery Damage, Hull Damage and Fire & Explosion

Based on the average days out of service, which is 7 for machinery damage, 6 for hull damage and 5 for fire incidents, and considering Spouge (2003), estimated average cost for machinery damage varies from \$ 200,000 to \$ 800,000. Hull damage costs vary from \$ 120,000 to \$ 300,000. For fire accidents in the accommodation, estimated average cost is \$ 200,000 up to \$ 400,000. Lower bound reflects *small*, whereas upper bound *severe* cases.

3.1.3.6 Summary of property related losses

Distributions were specified for the different cost parameters of the repair costs explained above. The distributions were used to determine the upper and lower bound values used in the sensitivity analysis. All distributions are briefly explained in Annex A.4. The parameters of these distributions as well as the average values are summarised in Table 3-1, Table 3-2, Table 3-3 and Table 3-4. The 5 % and 95 % percentiles were determined by means of a Monte Carlo simulation.

Table 3-1: Summary of costs for repair, docking, charter (loss of income), crew and loss of ship (Part I)											
		Repair			**Docking**						
		$			**days**			**Docking costs per day in $**			
		μ	σ	∅	μ	σ	∅	μ	σ	∅	**Product**
CN	Small	375,000	150,000	375,000	3	2	3.58	15,625	6,000	15,740	56,270
	Severe	875,000	150,000	875,000	10	4	10.13	15,625	6,000	15,740	159,412
	Loss										
CT	Small	262,500	105,000	262,500	1.5	2	2.79	15,625	6,000	15,740	43,938
	Severe	612,500	105,000	612,500	7	3	7.17	15,625	6,000	15,740	112,781
FD	Re-floated	2,800,000	1,500,000	2,800,000	20	5	20.00	15,625	6,000	15,740	314,801
	Loss										
WS	Small	375,000	150,000	375,000	6	3	6.31	15,625	6,000	15,740	99,366
	Severe	875,000	150,000	875,000	10	4	10.13	15,625	6,000	15,740	159,412
	Loss										
FIRE	Small	200,000	40,000	200,000							
	Severe	400,000	80,000	400,000							
HD	Small	120,000	24,000	120,000							
	Severe	300,000	60,000	300,000	6	4	6.82	15,625	6,000	15,740	107,291
M	Small	200,000	40,000	200,000							
	Severe	800,000	160,000	800,000							

Table 3-2: Summary of costs for charter (loss of income) (Part II)

		Charter						
		days			Charter per day in $			
		μ	σ	∅	μ	σ	∅	Product
CN	Small	45	15	45.08	1058[9]	882	13,222.2	596,072
	Severe	180	30	180.00	1058	882	13,222.2	2,379,995
	Loss							
CT	Small	31.5	10.5	31.56	1058	882	13,222.2	417,316
	Severe	126	21	126.00	1058	882	13,222.2	1,665,997
FD	Re-floated	180	30	180.00	1058	882	13,222.2	2,379,995
	Loss							
WS	Small	45	15	45.08	1058	882	13,222.2	596,072
	Severe	180	30	180.00	1058	882	13,222.2	2,379,995
	Loss							
FIRE	Small	5	3	5.54	1058	882	13,222.2	73,270
	Severe	8	4	8.36	1058	882	13,222.2	110,531
HD	Small	3	3	4.28	1058	882	13,222.2	56,619
	Severe	8	4	8.36	1058	882	13,222.2	110,531
M	Small	5	3	5.54	1058	882	13,222.2	73,270
	Severe	8	4	8.36	1058	882	13,222.2	110,531

[9] Log-normal distribution with a shift of 12,163

Table 3-3: Summary of costs for crew (Part III)

		Crew									
		days			number of crew			cost per day in $			Product
		µ	σ	∅	µ	σ	∅	µ	σ	∅	
CN	Small	45	15	45.08	17	5	16.14	100	5	100	72,768
	Severe	180	30	180.00	17	5	16.14	100	5	100	290,550
	Loss										
CT	Small	31.5	10.5	31.56	17	5	16.14	100	5	100	50,946
	Severe	126	21	126.00	17	5	16.14	100	5	100	203,385
FD	Re-floated	180	30	180.00	17	5	16.14	100	5	100	290,550
	Loss										
WS	Small	45	15	45.08	17	5	16.14	100	5	100	72,768
	Severe	180	30	180.00	17	5	16.14	100	5	100	290,550
	Loss										
FIRE	Small	5	3	5.54	17	5	16.14	100	5	100	8,945
	Severe	8	4	8.36	17	5	16.14	100	5	100	13,494
HD	Small	3	3	4.28	17	5	16.14	100	5	100	6,912
	Severe	8	4	8.36	17	5	16.14	100	5	100	13,494
M	Small	5	3	5.54	17	5	16.14	100	5	100	8,945
	Severe	8	4	8.36	17	5	16.14	100	5	100	13,494

Table 3-4: Summary of costs for loss of ship and loss of cargo (Part IV)

		Ship			Cargo			Total		
		Cost			cost				Percentile	
		μ	σ	∅	μ	σ	∅	∅	5 %	95 %
CN	Small							1.1E+06	6.9E+05	1.5E+06
	Severe							3.7E+06	3.0E+06	4.5E+06
	Loss	6,020,000	3010000	6,020,960	3,010,480	3,010,480	3,011,260	9.0E+06	3.3E+06	1.9E+07
CT	Small							6.0E+06	2.1E+06	1.3E+07
	Severe							7.7E+05	4.9E+05	1.1E+06
FD	Re-floated							2.6E+06	2.0E+06	3.1E+06
	Loss	5,250,000	3,150,000	5,264,876	2,632,438	2,632,438	2,633,385	5.8E+06	3.9E+06	8.8E+06
WS	Small							7.9E+06	2.5E+06	1.8E+07
	Severe							5.3E+06	1.5E+06	1.2E+07
	Loss	6,020,000	3,010,000	6,020,960	3,010,480	3,010,480	3,011,260	1.1E+06	7.3E+05	1.6E+06
FIRE	Small							3.7E+06	2.9E+06	4.5E+06
	Severe							9.0E+06	3.3E+06	1.9E+07
HD	Small							6.0E+06	2.1E+06	1.3E+07
	Severe							2.8E+05	2.0E+05	3.8E+05
M	Small							5.2E+05	3.8E+05	6.9E+05
	Severe							1.8E+05	1.3E+05	2.5E+05

Applying these values to the risk models for Collision, Contact, Foundering and Wrecked/Stranded yield the values for loss of property as summarised in Table 3-5. This summary is completed by the values PLL and potential loss of oil. Furthermore, the average annual values for a fleet of 5000 ships were calculated. The values summarised in Table 3-5 show, that the average number of accidents for the categories specified above is about 84 with 47 fatalities. The average annual property loss linked to these accident categories is about $ 230 million.

Table 3-5: Summary of characteristic values of the risk model

Accident category	Average annual number of accidents for a fleet of 5000 ships	PLL Potential Loss of Life per ship year Crew	Average annual human fatalities crew (fleet of 5000)	Ship damage	Loss/ per ship year	Property	Average annual property loss for a fleet of 5000	Bunker spill tonnes per ship year	Average annual tonnes of bunker spilled for a fleet of 5000 ships	PLS Potential Loss of Ship per ship year	Average annual no of losses for a fleet of 5000 ships
				$/ship year	$	$/ship year	$	tonnes/ship year			
CN	27.5	2.43E-03	1.21E+01	9,276	5,197	14,474	7.2E+07	1.77E-02	89	5.85E-04	2.9
CT	11.0	3.41E-04	1.70E+00	3,682	669	1,820	9.1E+06	3.90E-03	19	8.07E-05	0.4
FD	7.5	5.22E-03	2.61E+01	542	11,033	11,575	5.8E+07	1.58E-01	788	1.41E-03	7.0
WS	37.5	1.43E-03	7.16E+00	13,178	4,370	17,548	8.8E+07	1.35E-02	67	5.17E-04	2.6
Total	83.5		4.7E+01				2.3E+08		963		12.9

3.2 Cost-effectiveness evaluation of risk control options

The costs summarised above, the effectiveness of the risk control options (Figure 2-7) as well as the portion of fleet an RCO is acting on, were used to perform the cost-effectiveness evaluation. Similar to the FSAs submitted within the last years a depreciation rate of 5 % is considered.

The results for the RCOs are summarised in Table 3-6 in ascending order of the GCAF value. This table shows the GCAF and NCAF values for the different RCOs and additionally the risk reduction with respect to PLL and PLP. The reduction of PLP is equivalent to the economic benefit of an RCO. The GCAF threshold is specified by FSA guidelines to $ 3 million (MSC 83/INF.2). Hence, all RCOs below this threshold are regarded to be cost efficient, which are:

- RCO 27 (technical): Anchoring watch alarm integrated in ECDIS (no additional costs if ECDIS is already integrated into Bridge):
  Even if the risk reduction for crew is relatively small this RCO is cost-effective because no or only minimal costs would be observed if ECDIS is already installed on a ship. The benefit of this RCO is relatively big because of the high damage costs in case of WS accidents. ECDIS (without anchoring alarm) is evaluated to be cost-effective with respect to NCAF. If RCO 27 is considered in RCO 2 the NCAF value of RCO 2 is further reduced (to -$ 1.1 million).
- RCO 20 (operational/training): Port State Control inspector training for GCS
  Training of port state inspectors could improve the detection of deficiencies. The allocated costs for such a training measure are relatively small (125 $/year). However, the effect on foundering accidents (mainly caused by water ingress) is expected to be significant. The NCAF value is negative.
- RCO 32 (technical): Combine watch alarm with autopilot:
  This RCO leads to relatively small installation costs. Therefore, even if the risk reduction is smaller compared to RCO 20, this RCO is evaluated to be cost-effective. The NCAF value is negative and hence this RCO is evaluated to be beneficial.

For the following RCOs the calculated benefit is higher than the installation costs (negative NCAF)

- RCO 27: see above
- RCO 20: see above
- RCO 32: see above
- RCO 28 (operational/training): Checklist for maintenance procedures. This RCO has relatively low cost and small risk reduction with respect to life. With $ 3.67 million the GCAF value is slightly above the threshold. However, due to the high NCAF value is considered to be beneficial in saving the property.
- RCO 26 (operational/training): ECDIS training of all OOW:
  This RCO leads to an average risk reduction (crew) and because of the relatively small costs for the additional training measures this RCO is evaluated to be cost-effective if the benefit is taken into consideration.
- RCO 23 (operational/training): Simulator training for increasing situational awareness to reduce situation where anchor is dragged: The risk reduction is rather small, however, the costs also and hence it is evaluated as beneficial.

- RCO 8 (operational/training): Improve preparation and handling of ship for manoeuvring in restricted waters (crew & pilot preparation): again a small impact on the risk. Due to low costs it is evaluated as beneficial.

From the perspective of NCAF the following risk control options are cost-effective with a value below $ 3 million

- RCO 17 (technical/operational/training): Improvement of cargo stowage especially bulk (other than grain) and heavy items: NCAF is about 1/3 of the threshold.
- RCO 19 (operational/training) Extended survey on GCS: NCAF is about 1/2 of the threshold.
- RCO 2 (technical): ECDIS with AIS and RADAR (only for new ships): the NCAF value is less than 1/10 of the threshold.

Table 3-6: Results of CBA ranked with respect to GCAF. Summarised are the costs of an RCO, the risk reduction with respect to safety and property and GCAIl as well as NCAF.

RCO	Costs		Risk Reduction		GCAF	NCAF
	Total operating	total	ΔPLL	ΔPLP (Benefit)		
	$/ship year	$	fat/ship year	$/ship year	$/fat	$/fat
RCO 27	0.00E+00	0.00E+00	5.41E-05	6.63E+02	0.00E+00	-1.23E+07
RCO 20	1.25E+02	3.13E+03	1.10E-03	2.43E+03	1.14E+05	-2.09E+06
RCO 32	4.00E+01	1.00E+03	6.94E-05	5.76E+02	5.76E+05	-7.72E+06
RCO 17	3.00E+03	7.50E+04	9.76E-04	1.96E+03	3.07E+06	1.07E+06
RCO 19	4.00E+03	1.00E+05	1.10E-03	2.43E+03	3.63E+06	1.43E+06
RCO 28	5.95E+02	1.49E+04	1.62E-04	5.26E+03	3.67E+06	-2.88E+07
RCO 26	1.25E+03	3.13E+04	2.72E-04	1.89E+03	4.59E+06	-2.36E+06
RCO 23	1.82E+02	4.56E+03	3.01E-05	3.69E+02	6.07E+06	-6.20E+06
RCO 2	3.03E+03	7.57E+04	3.75E-04	2.96E+03	8.06E+06	1.79E+05
RCO 16	3.60E+03	9.00E+04	4,63E-04	1,35E+03	7,77E+06	4,85E+06
RCO 3 a	9.52E+02	2.38E+04	8.69E-05	5.18E+02	1.10E+07	5.01E+06
RCO 3 b	1.10E+03	2.75E+04	8.69E-05	5.18E+02	1.27E+07	6.71E+06
RCO 8	3.48E+02	8.70E+03	2.50E-05	3.83E+02	1.39E+07	-1.41E+06

RCO	Costs		Risk Reduction		GCAF	NCAF
	Total operating	total	ΔPLL	ΔPLP (Benefit)		
	$/ship year	$	fat/ship year	$/ship year	$/fat	$/fat
RCO 18	8.92E+03	2.23E+05	4.70E-04	1.04E+03	1.90E+07	1.68E+07
RCO 13 a	1.72E+04	4.29E+05	7.74E-04	2.94E+03	2.22E+07	1.84E+07
RCO 9	6.88E+02	1.72E+04	2.41E-05	3.71E+02	2.85E+07	1.31E+07
RCO 21	2.64E+03	6.60E+04	9.14E-05	2.03E+02	2.89E+07	2.67E+07
RCO 12	9.64E+02	2.41E+04	3.30E-05	2.45E+02	2.92E+07	2.18E+07
RCO 13 b	3.08E+04	7.71E+05	7.74E-04	2.94E+03	3.98E+07	3.60E+07
RCO 31	2.13E+03	5.31E+04	4.63E-05	9.91E+02	4.59E+07	2.45E+07
RCO 5 a	4.73E+04	1.18E+06	2.30E-04	2.12E+03	2.05E+08	1.96E+08
RCO 5 b	5.01E+04	1.25E+06	2.22E-04	2.12E+03	2.26E+08	2.16E+08
RCO 6 a	4.33E+03	1.08E+05	1.82E-05	2.42E+02	2.38E+08	2.25E+08

4 Sensitivity Analysis

All data used in the CBA are uncertain. For instance the costs for the ship repair are estimations covering a variety of possible accident consequences. The determination of all cost parameters is explained in section 3.1.3 In Annex A.4 the distributions specified on basis of the available data is explained in detail. Also the probabilities for the different accident categories (ref. to MSC 87/INF.3) are afflicted by uncertainties.

In order to provide additional information with respect to the validity of the cost-effectiveness evaluation (section 3.2) a sensitivity analysis was performed taking into consideration:

- The GCAF threshold. The threshold of $ 3 million was specified in the FSA guidelines (MSC/Circ. 1023) of 2002, based on a submission in 2000, and since then never updated. Since 2002, the US-Dollar has lost one third of its value against other currencies. In the sensitivity analysis a GCAF threshold of $ 6 million is considered, as this would result from an update using the Life Quality Index method (Skjong, 2009).
- The variation of the loss of property (loss of ship, repair of ship). In the analysis a lower limit equivalent to the 5 % percentile and an upper limit equivalent to the 95 % percentile are considered (Table 3-4);

- The variation with respect to the costs of the RCOs using the minimum and maximum values given in Table 2-2 and Table 2-2. These values are estimations made in consideration of the uncertainty of the available information;
- The probability of the accident

Table 4-1: Lower and upper bound values of accident frequency used in sensitivity analysis

Accident category	Frequency per ship year		
	Mean	**Min**	**Max**
CN	5.5 E-03	4.8 E-03	6.3 E-03
CT	2.3 E-03	1.9 E-03	2.8 E-03
FD	1.5 E-03	1.1 E-03	1.9 E-03
FX	2.7 E-03	2.2 E-03	3.2 E-03
HD	2.0 E-03	1.6 E-03	2.5 E-03
MD	1.2 E-02	1.1 E-02	1.3 E-02
WS	7.5 E-03	6.7 E-03	8.4 E-03

- The minimum and maximum values of the effectiveness of the RCOs

First of all the effect of the increased GCAF threshold is discussed. As shown by the results summarised in Table 3-6 (p. 46) the increased threshold leads to a positive evaluation of the following RCOs

- RCO 17: Improving the cargo stowage has relatively low cost and small risk reduction with respect to life. The GCAF value is $ 3.07 million.
- RCO 19: Augmenting extended surveys with unified requirements has relatively low cost and small risk reduction with respect to life. The GCAF value is $ 3.63 million.
- RCO 28: Checklist for maintenance procedures. This RCO has relatively low cost and small risk reduction with respect to life. The GCAF value is $ 3.67 million.
- RCO 26: ECDIS training of all OOW: The GCAF value is $ 4.59 million.

In the sensitivity analysis the extreme values were superimposed, which means that in one case all minimum values were used to perform the CBA and in the other case all maximum values.

The results of the minimum values is summarised in Table 4-2. In this case three RCOs are below the threshold values of $ 3 million:

- RCO 27: Anchoring watch alarm integrated in ECDIS
- RCO 20: Port State Control inspector training for GCS
- RCO 32: Combine watch alarm with autopilot:

These RCOs are already in the group of cost-effective RCOs for the evaluation based on average values. So, no new RCO is evaluated to be cost-effective.

Taking into consideration a possible higher GCAF threshold of 6 million $ the RCOs 17 and 28 are evaluated to be cost-effective. This was also the case for the evaluation based on the average values. However, RCOs 19 and 26 are not cost-effective, even for the increased threshold. With the minimum values and increased GCAF threshold, RCO 16 is evaluated as effective, but it will be investigated if it continues to be effective with the maximum values.

The evaluation with respect to NCAF shows that like for the average values, the RCOs 27, 20, 32 and 28 have negative NCAF. RCO 23 is still below the threshold, but the benefit is now smaller than the costs. For RCO 17 again a positive NCAF is determined. RCO 8, previously evaluated with a negative NCAF has now an NCAF above the threshold.

Table 4-2: Results of CBA using minimum values ranked with respect to GCAF. Summarised are the costs of an RCO, the risk reduction with respect to safety and property and GCAF as well as NCAF.

RCO	Costs		Risk Reduction		GCAF	NCAF
	Total operating	total	ΔPLL	ΔPLP(Benefit)		
	$/ship year	$	fat/ship year	$/ship year	$/fat	$/fat
RCO 27	0.00E+00	0.00E+00	2.68E-05	2.09E+02	0.00E+00	-7.78E+06
RCO 20	6.30E+01	1.58E+03	4.26E-04	3.07E+02	1.48E+05	-5.72E+05
RCO 32	2.00E+01	5.00E+02	3.06E-05	1.57E+02	6.54E+05	-4.50E+06
RCO 17	1.68E+03	4.20E+04	5.06E-04	3.01E+02	3.32E+06	2.72E+06
RCO 16	1.28E+03	3.20E+04	3,08E-04	4,13E+02	4,16E+06	2,81E+06
RCO 28	4.46E+02	1.11E+04	9.72E-05	3.99E+00	4.57E+06	-3.65E+07
RCO 19	3.00E+03	7.50E+04	4.26E-04	3.07E+02	7.05E+06	6.33E+06
RCO 26	9.40E+02	2.35E+04	9.53E-05	3.40E+02	9.87E+06	6.30E+06
RCO 23	1.37E+02	3.42E+03	1.34E-05	1.04E+02	1.02E+07	2.41E+06
RCO 2	2.12E+03	5.29E+04	1.93E-04	8.35E+02	1.09E+07	6.62E+06
RCO 21	6.00E+02	1.50E+04	4.02E-05	2.93E+01	1.49E+07	1.42E+07
RCO 8	1.77E+02	4.43E+03	1.09E-05	1.13E+02	1.62E+07	5.88E+06
RCO 3 a	7.34E+02	1.83E+04	4.21E-05	1.50E+02	1.74E+07	1.39E+07
RCO 3 b	8.25E+02	2.06E+04	4.21E-05	1.50E+02	1.96E+07	1.60E+07

RCO	Costs		Risk Reduction		GCAF	NCAF
	Total operating	total	ΔPLL	ΔPLP(Benefit)		
	$/ship year	$	fat/ship year	$/ship year	$/fat	$/fat
RCO 9	3.44E+02	8.60E+03	1.09E-05	1.13E+02	3.15E+07	2.12E+07
RCO 13 a	1.29E+04	3.22E+05	3.72E-04	7.17E+02	3.47E+07	3.27E+07
RCO 12	5.72E+02	1.43E+04	1.45E-05	6.61E+01	3.95E+07	3.50E+07
RCO 31	1.52E+03	3.80E+04	2.78E-05	7.53E+02	5.47E+07	2.76E+07
RCO 13 b	2.06E+04	5.16E+05	3.72E-04	7.17E+02	5.55E+07	5.35E+07
RCO 18	6.82E+03	1.70E+05	9.57E-05	6.97E+01	7.12E+07	7.05E+07
RCO 6 a	3.25E+03	8.11E+04	9.59E-06	8.74E+01	3.39E+08	3.29E+08
RCO 6 b	6.85E+03	1.71E+05	9.59E-06	8.74E+01	7.14E+08	7.05E+08
RCO 5 a	4.44E+04	1.11E+06	4.18E-05	2.51E+02	1.06E+09	1.05E+09
RCO 5 b	4.64E+04	1.16E+06	4.18E-05	2.51E+02	1.11E+09	1.10E+09

The results of the maximum values are summarised in Table 4-3. In this case five RCOs are below the threshold values of 3 million USD:

- RCO 27: Anchoring watch alarm integrated in ECDIS
- RCO 20: Port State Control inspector training for GCS
- RCO 32: Combine watch alarm with autopilot
- RCO 19: Augmenting extended surveys with unified requirements
- RCO 26: ECDIS training of all OOW

The first three RCOs are already in the group of cost-effective RCOs for the evaluation based on average values. RCOs 19 and 26 are new.

Taking into consideration a possible higher GCAF threshold of 6 million $ the RCOs 17, 23 and 8 are evaluated to be cost-effective. It is pointed out that RCO 16 is not cost-effective, justifying the evaluation from the average values.

With respect to the NCAF evaluation, the maximum values yield 14 RCOs with a negative NCAF, but one with a positive NCAF below the threshold. Of these RCOs, the RCOs 27, 20, 32 and 28 have already a negative NCAF in the evaluation based on average and minimum values. The RCOs 19, 26, 17, 3 (a+b), 2, 11 and 31 are new in the group of RCOs with a negative NCAF.

Table 4-3: Results of CBA using maximum values ranked with respect to GCAF. Summarised are the costs of an RCO, the risk reduction with respect to safety and property and GCAF as well as NCAF.

RCO	Costs		Risk Reduction		GCAF	NCAF
	Total operating	total	ΔPLL	ΔPLP (Benefit)		
	$/ship year	$	fat/ship year	$/ship year	$/fat	$/fat
RCO 27	0.00E+00	0.00E+00	1.01E-04	1.84E+03	0.00E+00	-1.82E+07
RCO 20	1.88E+02	4.70E+03	2.05E-03	1.02E+04	9.15E+04	-4.86E+06
RCO 32	6.00E+01	1.50E+03	1.18E-04	1.50E+03	5.07E+05	-1.21E+07
RCO 19	5.00E+03	1.25E+05	2.05E-03	1.02E+04	2.43E+06	-2.52E+06
RCO 26	1.60E+03	4.00E+04	5.35E-04	6.46E+03	2.99E+06	-9.07E+06
RCO 17	4.76E+03	1.19E+05	1.40E-03	6.50E+03	3.40E+06	-1.24E+06
RCO 23	2.28E+02	5.70E+03	5.05E-05	9.18E+02	4.51E+06	-1.37E+07
RCO 8	2.28E+02	5.69E+03	4.28E-05	9.26E+02	5.32E+06	-1.63E+07
RCO 3 a	1.19E+03	2.97E+04	1.66E-04	1.56E+03	7.17E+06	-2.26E+06
RCO 2	3.49E+03	8.72E+04	4.61E-04	5.05E+03	7.56E+06	-3.38E+06
RCO 28	7.43E+02	1.86E+04	2.27E-04	1.58E+04	7.65E+06	-1.55E+08
RCO 3 b	1.38E+03	3.44E+04	1.66E-04	1.56E+03	8.29E+06	-1.14E+06
RCO 18	1.12E+04	2.79E+05	1.32E-03	6.57E+03	8.45E+06	3.48E+06
RCO 16	7.56E+03	1.89E+05	6,48E-04	3,72E+03	1,17E+07	5,92E+06
RCO 13 a	2.15E+04	5.36E+05	1.40E-03	9.97E+03	1.53E+07	8.22E+06
RCO 12	1.22E+03	3.05E+04	5.63E-05	6.45E+02	2.17E+07	1.02E+07
RCO 13 b	3.91E+04	9.77E+05	1.40E-03	9.97E+03	2.79E+07	2.08E+07
RCO 9	1.37E+03	3.42E+04	4.28E-05	9.26E+02	3.19E+07	1.03E+07
RCO 21	6.84E+03	1.71E+05	1.62E-04	8.04E+02	4.22E+07	3.72E+07
RCO 31	2.56E+03	6.39E+04	6.48E-05	2.97E+03	9.19E+07	-1.50E+07

RCO	Costs		Risk Reduction		GCAF	NCAF
	Total operating	total	ΔPLL	ΔPLP (Benefit)		
	$/ship year	$	fat/ship year	$/ship year	$/fat	$/fat
RCO 5 a	5.02E+04	1.26E+06	4.61E-04	6.63E+03	1.09E+08	9.45E+07
RCO 5 b	5.38E+04	1.34E+06	4.61E-04	6.63E+03	1.17E+08	1.02E+08
RCO 6 a	5.41E+03	1.35E+05	2.42E-05	4.68E+02	2.23E+08	2.04E+08
RCO 6 b	1.14E+04	2.85E+05	2.42E-05	4.68E+02	4.71E+08	4.51E+08

5 Discussion

5.1 Points related to the RCOs

In this section, remaining issues concerning the identified RCOs are mentioned. Some of the issues have been pointed out at Section 2.3 and Table 2-2.

RCO 16/17/21. Within the context of the current study, calculations were only performed for one GCS with L_S = 100 m. A separate project needs to be established in order to evaluate design modifications to other GCS sizes as well as damage stability requirements for GCS.

From Figure 4-1 (Norway and UK 2003) and the calculations for the GCS provided on Appendix A.3, the design modifications of versions B (R-Index = 0.55) or D (R-Index = 0.61) assure increased safety level as compared to the original version. They also provide better safety level than the HARDER proposal. The combination of versions B and D (R-Index = 0.61) does not seem to contribute in comparison to version D.

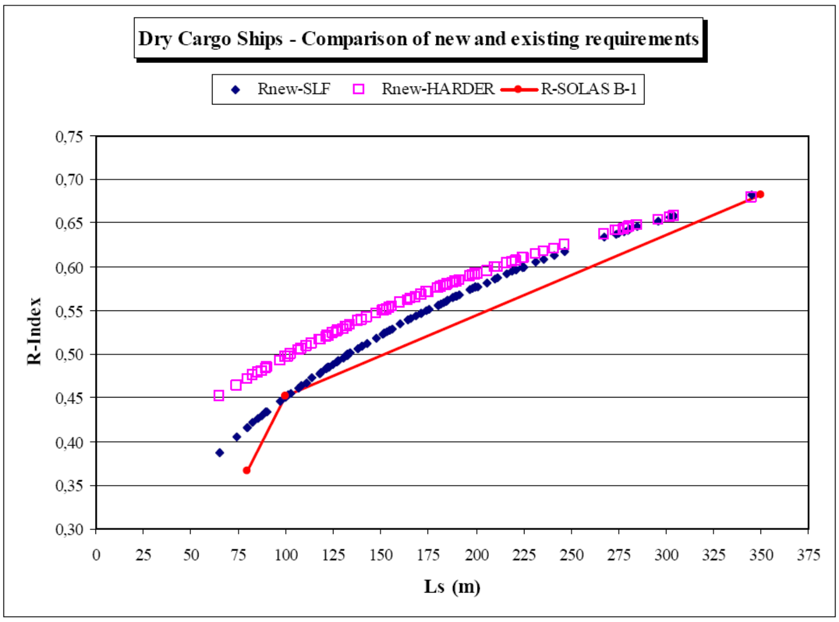

Figure 4-1: Required Indices based on SLF and HARDER proposal as well as the SOLAS Part B-1 Reg.25-1 standard (Norway and UK 2003)

RCO 29. For engine room fires (Figure 4-2), it is shown that after 2003, fire incidents were suppressed in the majority of cases by onboard means, probably due to the regulations introduced on 2002 (i.e. SOLAS Reg.II-2/10.5.6)

RCO 30. In the case of accommodation fires (Figure 4-3), these were mainly extinguished with external assistance. However, another study is needed for performing evacuation/consequence analyses.

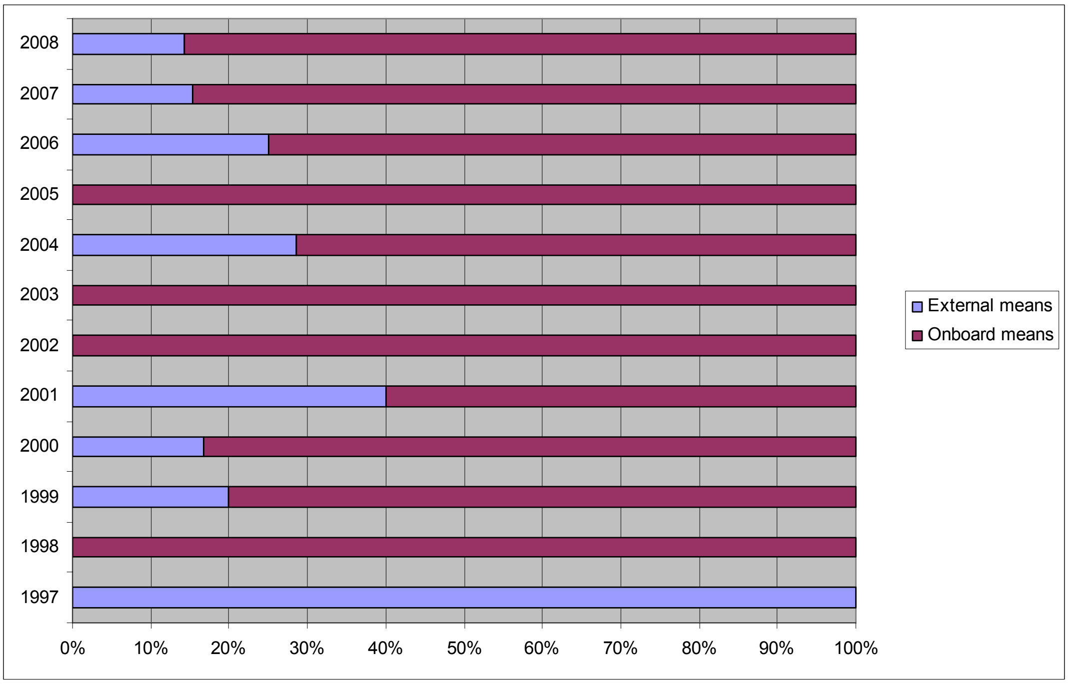

Figure 4-2: Percentage suppression of fire/explosion incidents on engine rooms

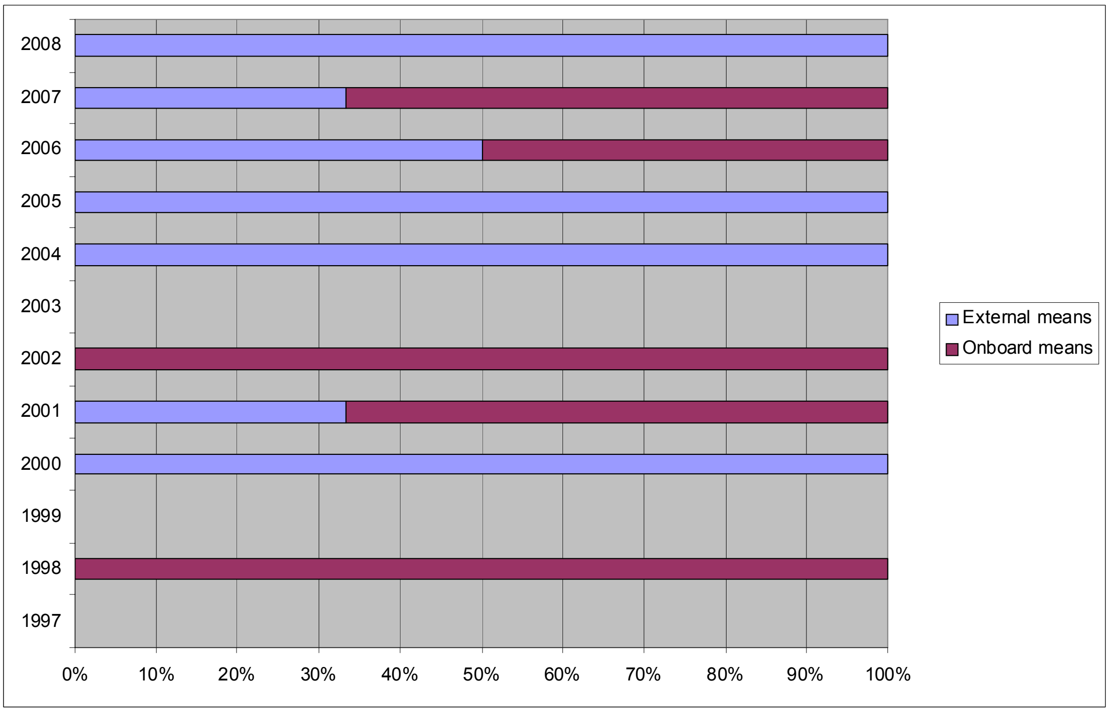

Figure 4-3: Percentage suppression of fire/explosion incidents on accommodation areas

5.2 Other points

During the expert session, RCOs for fires and explosions in the cargo hold area were not discussed. As stated in MSC87/INF.4, cargo hold fires can be considered similar to bulk or break bulk carrier fires, whilst when fire or explosions occurred to containerised cargoes (liquid, dry, bulk) the provisions of the FSA on containerships (MSC 83/INF.8, MSC 87/INF.2 both submitted by Denmark) apply. However, it should be noted that this is a high level generic FSA and a separate project needs to be established for dealing with fires/explosions related to cargoes and cargo stowage/securing practices onboard GCSs.

6 Summary

The safety of general cargo ships was brought to the attention of IMO by a submission by Russia in 2006. To bring forward the discussion of general cargo ship safety IACS started an FSA project in 2007. The intermediate results of this IACS activity were submitted to IMO:

- MSC 85/19/1, MSC 86/INF.4 and MSC 87/INF.3 focused on step 1 of the FSA process and dealing with the investigation of historical data in order to identify the major hazards of general cargo ships. The submissions to MSC 85 and MSC 86 were superseded by the later submissions.
- MSC 87/INF.4 focused on the development of the high level generic risk models for general cargo ships (step 2 of the FSA process) for the respective accident categories.

This report contains the results of the subsequent FSA steps 3 and 4, i.e. the identification of risk control options and their cost-effectiveness evaluation.

The whole FSA for general cargo ships is performed for

- Ships "due or delivered" after 1981-12-31 and before 2009-01-01 (corresponding to a maximum ship age of 27 at the end of the investigation period);
- Ships with a gross tonnage greater than 499;
- Ships classed by IACS society (based on the assignment in LRF 2009);
- Casualty reports for IACS classed ships and classified as "severe" accident.

Deviating from other FSAs submitted to IMO, in step 1, the hazards were determined by a comprehensive analysis and evaluation of historical data instead of brainstorming sessions. This proceeding is regarded to be adequate due to the huge amount of accident records available. Additionally, detailed information especially with respect to accident causes were identified by the analysis of accident investigation reports in IMO GISIS database.

In detail this report summarises the determination of the property losses related to the consequences of an accident and, therefore completes the high level generic risk models. Property losses were determined for all accident categories as well as for all consequence classes specified in step 2 of the FSA (small[10], severe, loss). These losses consider the repair costs (steel work, machinery), the docking time (if required for repair), the loss of charter, the payment of crew during the time without charter. Conservatively with respect to the cost-effectiveness evaluation damage to cargo is considered only for the loss of ship. The costs for a loss of ship were estimated for a general cargo ship of average size and on basis of estimation for the new building price and the scrapping price. All prices are in US dollar and where it is deemed necessary transferred to 2010 US dollars.

The costs for the accident consequences categories small and severe (ship damaged) were estimated using the information provided by the detailed accident investigation reports and the expertise of a shipping company (Peter Döhle Schiffahrts-KG, Hamburg) as well as a surveyor of an insurer (Association of Hanseatic Marine Underwriters, Hamburg).

For the identification of risk control options detailed information of Flag State investigation reports were used (access provided by Germany and Norway). The risk control options were

[10] These definitions are related to the consequences and not to the accident classification by LRF database of GISIS database.

identified by means of an expert brain storming session. The experts received a detailed introduction into the previous results of the IACS FSA for general cargo ships. In total 32 RCOs were proposed by the experts. The main effects of the RCOs (effect on accident categories) as well as their effectiveness were determined after this session by an email discussion of the expert group.

After the brainstorming session, further information with respect to technical or operational details, rules and regulations already in place, common practice etc. was collected for the RCOs. During this process, the number of RCOs considered in the subsequent steps of the FSA was reduced to 20.

In order to evaluate the cost-effectiveness of the RCOs, their costs were determined. Variants were specified in cases where different realisations with different costs are feasible. The costs include also maintenance, annual fees etc. Depreciation of 5 % is considered when appropriate, i.e. for all crew costs no depreciation is considered.

In order to investigate the robustness of the result of the cost-effectiveness assessment a sensitivity analysis was performed. In the sensitivity analysis the effect of the extreme values (minimum, maximum) on the cost-effectiveness was investigated. For this sensitivity analysis a cost model for the property losses was developed considering the estimated uncertainty for the different cost parameters. The 5 % and 95 % percentiles were calculated by a Monte Carlo simulation. The uncertainty in the accident frequency was determined on basis of the accident statistics. For the costs of the RCOs, minimum and maximum costs were estimated on basis of the supplier information. Finally, the uncertainty with respect to the effectiveness was determined on the expert judgments and it was taken into consideration.

The cost-effectiveness assessment shows that the following RCOs have a GCAF value below the threshold value of $ 3 million that was specified in the FSA Guidelines

- RCO 27 (technical): Anchoring watch alarm integrated in ECDIS (no additional costs if ECDIS is already integrated into Bridge),
- RCO 20 (operational/training): Port State Control inspector training for general cargo ships,
- RCO 32 (technical): Combine watch alarm with autopilot,

. As shown by the sensitivity analysis these RCOs are cost-effective also for the extreme values. RCO 27 and RCO 32 are relatively simple technical modifications that improve the efficiency of technical equipment already in place. Hence, the costs for these RCOs are low. However, for instance RCO 32 avoids the de-activation of the watch-alarm and is expected to reduce the number of fatigue related collision and grounding accidents. RCO 20 is focused on an improved exchange of knowledge between port state inspectors with respect to increase the attention to problematic areas of general cargo ships. It is expected that by this RCO the number of water ingress related foundering accidents can be reduced.

As mentioned in the sensitivity analysis (section 4) the GCAF threshold was specified in 2002 and has not been updated since then. An update in 2009, based on the life quality index method gave a $ 6 million threshold (Skjong 2009). The evaluation based on a $ 6 million threshold yields four additional, cost-effective RCOs (GCAF):

- RCO 17 (technical/operational/training): Improvement of cargo stowage especially bulk (other than grain) and heavy items;

- RCO 19 (operational/training): Extended surveys applicable to general cargo ships augmented with unified requirements;
- RCO 28 (operational/training): Checklist for maintenance procedures;
- RCO 26 (operational/training): ECDIS training of all officer of watch.

For these RCOs, the sensitivity analysis performed with the minimum values for accident frequency, costs and efficiency of the RCO shows that RCOs 19 and 26 are above the increased threshold of $ 6 million, whereas for the other two the result is robust (below threshold).

The RCO 17 is a technical as well as operational risk control option focused on the improved stowage of cargo, e.g. for bulk by improved subdivision. By this risk control option the stowage of the cargo as well as the damage stability is improved.

RCO 19 is an operational option that is mainly focused on a reduction of structural deficiencies that may lead to accidents especially in combination with bad weather conditions.

RCO 28 is again an operational option focusing on the quality of maintenance work that should be improved by the introduction of checklists.

RCO 26, again, is a training option focusing on the improved usage of the technical potentials of ECDIS.

All of the seven above mentioned RCOs have an NCAF value below $ 3 million. RCOs 27, 20, 32, 26 and 28 have negative NCAF values meaning that the benefit of these RCOs is higher than the costs for their implementation and that the RCOs are beneficial in saving the vessel. For the RCOs 27, 20, 32, 28 a negative NCAF is observed throughout the sensitivity analysis. RCO 17 has always an NCAF below the threshold.

Following the result of the cost-effectiveness analysis the RCOs 27 and 32 are cost–effective with respect to GCAF and provide a negative NCAF. Hence, it is evident that these RCOs are recommended to be considered in IMO regulations. RCO 20 is not in the IMO responsibility; however, it should be discussed, on how the inspection by port state may be further improved. Due to the robust negative NCAF values for RCO 28 this RCO is also recommended. The RCO 17 is close to the GCAF threshold of $ 3 million and has an NCAF below this threshold. Taking into consideration the sensitivity analysis this RCO should be further discussed.

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8 Glossary

Abbreviation	Explanation
CN	Collision
CT	Contact
FD	Foundering
FSA	Formal Safety Assessment
FX	Fire/Explosion
GCAF	Gross Cost of Averting a Fatality
GCS	General Cargo Ship
GISIS	Global Integrated Shipping Information System
HM	Hull Machinery
NCAF	Net Cost of Averting a Fatality (consideration of benefit)
PLL	Potential Loss of Life
PLO	Potential Loss of Oil
PLP	Potential Loss of Property
RCO	Risk Control Option
WS	Wrecked/Stranded

ANNEX

A.1 *List of experts with area of expertise*

Table 8-1: List of experts with area of expertise

Name	Task	Expertise	Experience
George Psarros	Moderator	Risk analysis FSA	2005-2008, Strathclyde University (SAFEDOR) 2008-present, DNV Research & Innovation Research interests mainly in: • Probabilistic models – Oil outflow performance of tankers – Operational profile of bulk carriers – Fire – Corrosion • Life Cycle Cost Analysis • Risk Assessment (qualitative / quantitative) • Risk management methodologies • FSA • Risk acceptance criteria • Security • Sustainability
Rainer Hamann	Moderator	Risk analysis FSA	1995-present, GL Senior engineer for topics: - finite element analysis, - fracture mechanic - assessment, probabilistic - analysis of pipelines, - development of weld acceptance criteria, - FSA, - Goal based standards - Risk Assessment (qualitative / quantitative) - Alternative Design (SOLAS) - risk related research projects
Rolf Skjong	Moderator	Risk analysis FSA GBS	Chief Scientist, DNV Research FSA and structural reliability specialist with more than 20 years experience within risk and reliability analysis. Project manager and project responsible in a number of international Joint Industry Projects for the maritime, offshore and process industry. Chairman IACS EG/FSA
Peter Zell	Expert	Nautical	Since 2000 GL Lead Senior Approval Engineer / Nautical Expert Previous work experience: August 1981 to September 2000

			employed by Hapag-Lloyd AG, Hamburg, Germany 6 years Nautical- and Technical Officer on Multi-Purpose Cargo- and Container Vessels *1/2 years Nautical- and Safety Officer on Passenger Vessels* 8 months at Kvaerner Masa Yard Helsinki, Owner's Supervisor for safety and security matters 1 year Security- and Chief Officer on Passenger Vessel "Europa"
Uwe Dieckmann	Expert	Stability and damage stability	Naval architect Since 2006 with GL Responsible for stability of container vessels, multi purpose vessels, car carrier, and RoPax vessels Prior to that 14 years stability and related work in design companies as well as on a ship yard
Tore Ronning (only second day, machinery damage)	Expert	Principal surveyor	Since 1985 DNV Approval machinery for repair and conversions of ships Project Manager new buildings ships (bulk carriers, OBO, Container carriers, Multipurpose Bulk / Container vessels, Tanker for oil and Chemicals)
Inger Unn Ramde	Expert	Senior Surveyor	1992-1993 Manning division of NMD 1993-1995 ship consultant, design of offshore vessels 1995-1997 Project engineer Since 1997 DNV Approval surveyor fire safety Plan approval for steel ships and offshore units Fire safety department responsible for rule development and safe return to port

Mathew Seides	Expert	Ship structures Ocean Engineer, MIT, 1989 Bachelor of Science in Naval Architecture and Marine Engineering, University of Michigan, 1981	1982-present, DNV. Title: Senior Principal Engineer 15 years working with newbuilding approval 6 years working with ships in operation Shorter periods in research, offshore structures and surveyor

A.2 *Paragraph Ships*

During the discussion of RCOs, the issue of so-called paragraph ships was raised. These ships can be simply defined as those being built just below a certain gross tonnage or length limit as specified for the application of a regulation.

The investigation with respect to the gross tonnage for IACS classified ships between 500 GT and 10,000 GT is shown in A.2-1 with (50 GT steps). In total 4223 ships belong to this sample (≈ 90 %). Accumulations are observed for the ships just below 1600 GT (108), 2000 (135), 2500 (134), 3000 GT (164), 4000 (100) and 5000 (101). 1951 ships of the sample have a gross tonnage of less than 3000. With respect to the accumulation at 1600 GT this may be related to a previous limit for the navigational equipment. All ships just below 1600 GT were built before 2005, the vast majority before 2000 (≈ 85 %).

The analysis with respect to the length (LBP) is summarised in Figure A.2-2. An accumulation is observed for ships just below 85 m for ships that need no lifeboat.

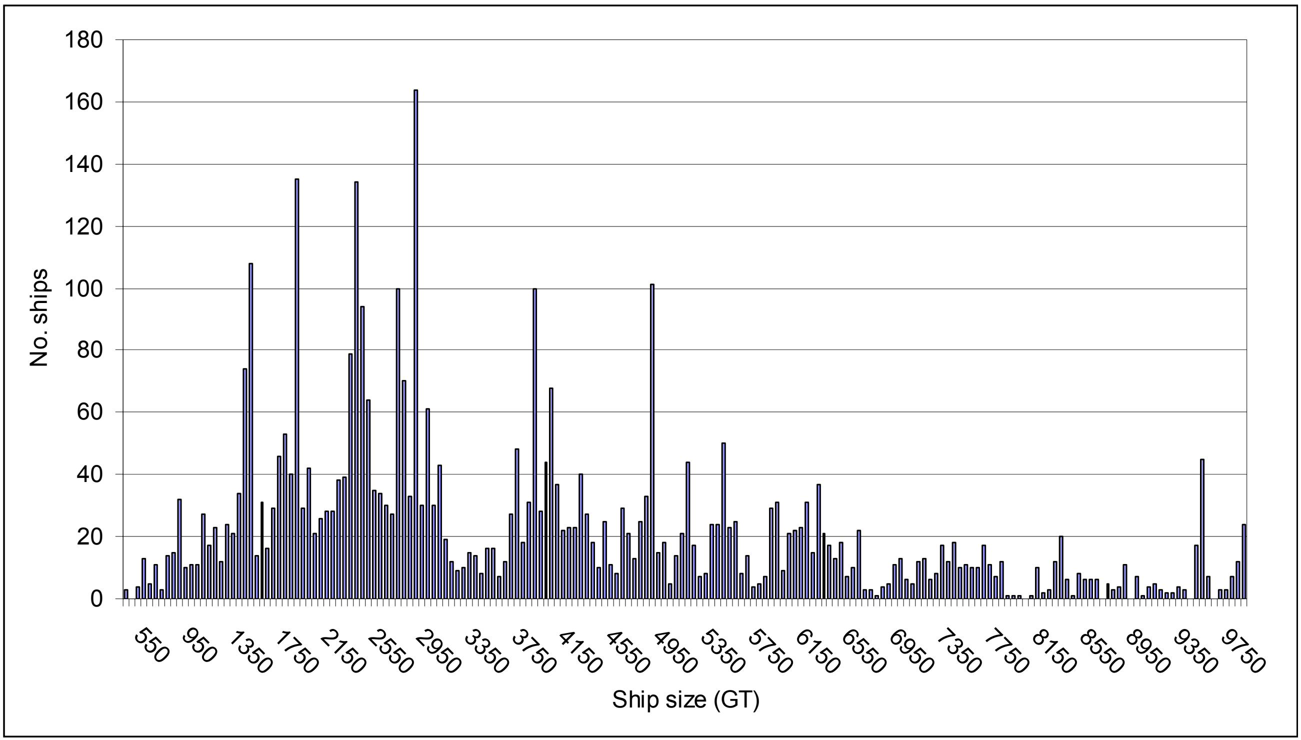

Figure A.2-1: No of ships over size in GT for IACS classified ships with a size of 500 ≤ GT ≤ 10,000.

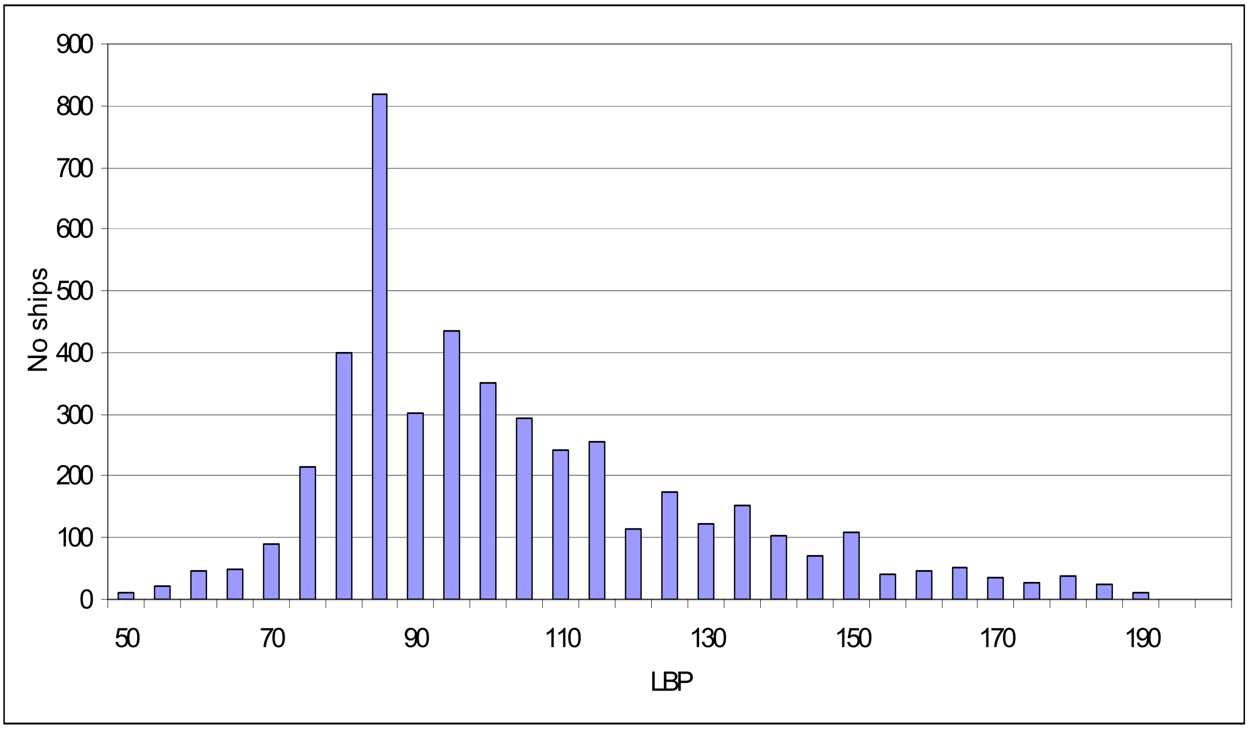

Figure A.2-2: No of ships over LBP for IACS classified ships with a length below 200 m.

During the discussion, the question was raised if an equation exists that gives the relationship between length (LBP) and gross tonnage (GT) for general cargo ships. Therefore, the formula given in Figure A.2-3 can be used as an indication.

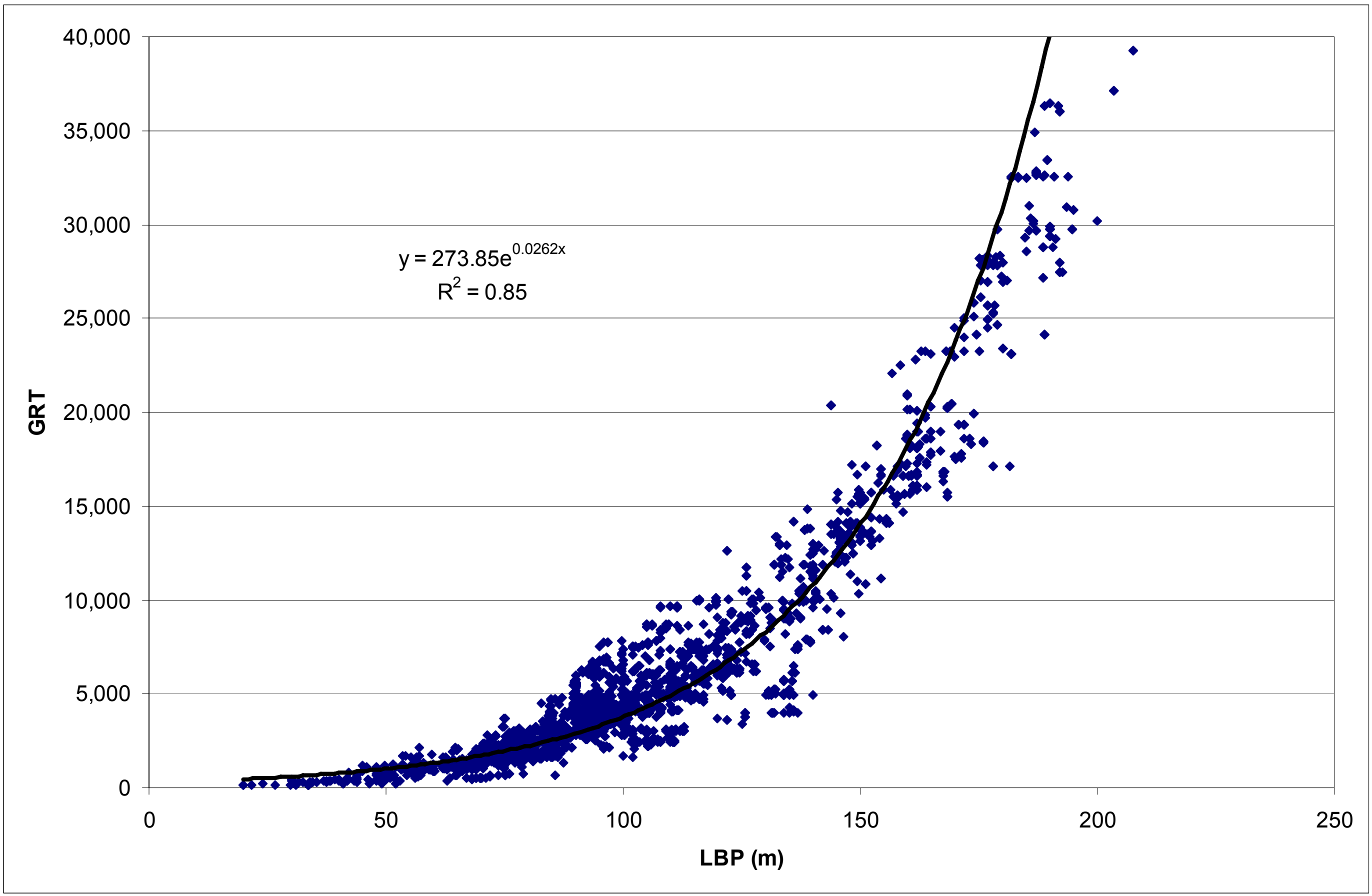

Figure A.2-3: Relationship between length between perpendiculars (LBP) and gross tonnage (GRT) for IACS General Cargo ships fleet

A.3 *Subdivision Index calculations*

Subdivision index calculations were performed for a sample of 20 GCS during the European research project HARDER as shown in figure A.2.1 (Norway and UK 2003). Therefore, it would be interesting to see how much the attained subdivision index could be changed after design modifications with respect to the type of hatch covers, the size of cargo hold area and water ballast tanks as well as inclusion of passageway.

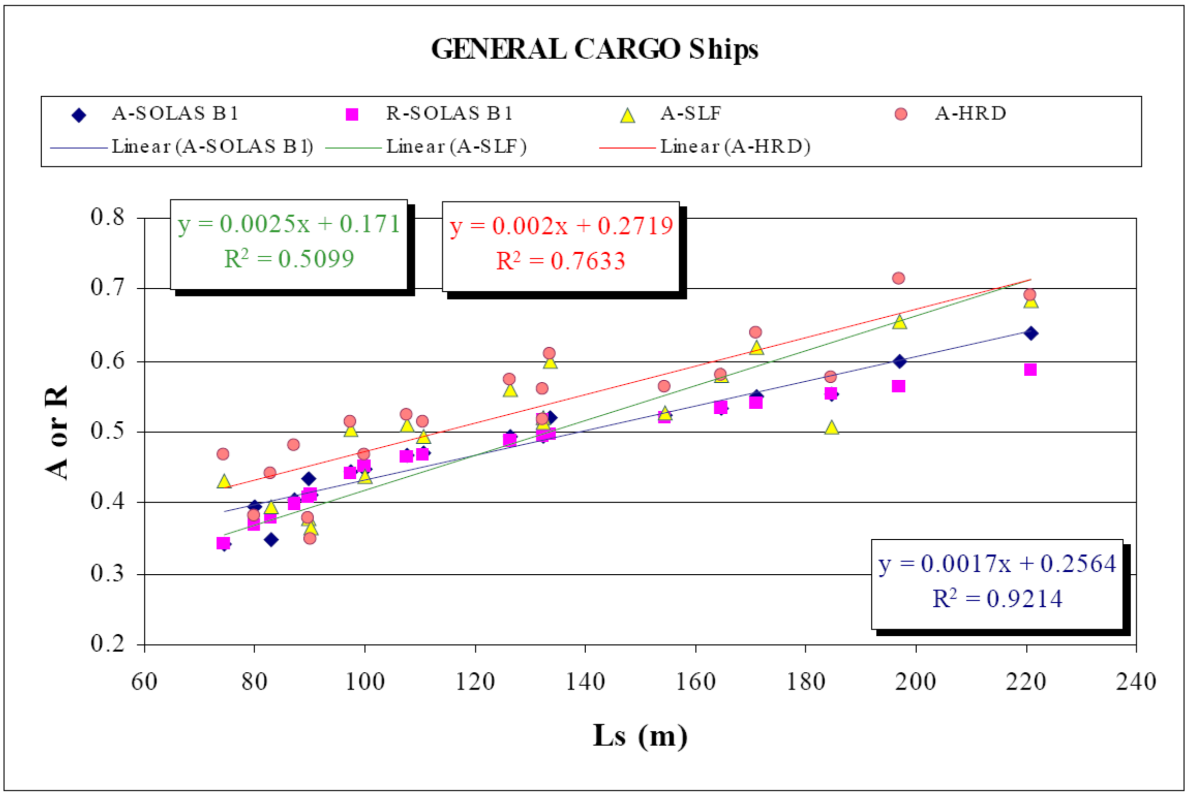

Figure A.2.1. Subdivision index results for the sample of GCS (Norway and UK 2003)

Due to the time limitation, design modifications with respect to RCOs 16, 17 and 21 were performed for a GCS of the following dimensions:

Gross tonnage	3300 GT
Length between perpendiculars	95 m
Length overall	104.5 m
Breadth	20.4 m
Depth	11.9 m

Draught summer	8.21 m
Subdivision length	99.961 m
Required subdivision Index	0.49198

The following modifications were applied to the original design (Version A) with an estimation of the added steel:

A1:	Split WBT3 at frame 76 (2 parts)	Added steel estimation	4 t
A2:	Split WBT3 at frame 88 (2 parts)	Added steel estimation	4 t
A3:	Split WBT3 at frame 76 & 88 (3 parts)	Added steel estimation	8 t
B:	Closed (boxed) hatch covers	Added steel estimation	27 t
C1:	Passageway in full length (undivided)	Added steel estimation	18 t
C2:	Passageway in full length (divided)	Added steel estimation	19 t
D:	Two cargo holds (frame 96)	Added steel estimation	25 t
E:	Increased breadth by 0.5 m	Added steel estimation	34 t
E1:	Split WBT3 at frame 76 (2 parts)	Added steel estimation	38 t
E2:	Split WBT3 at frame 88 (2 parts)	Added steel estimation	38 t
E3:	Split WBT3 at frame 76 & 88 (3 parts)	Added steel estimation	42 t

The results of calculating the subdivision index are given in the following table:

Version	Subdivision Index	Difference (%)
A	0.4635	-
A1	0.46572	0.5%
A2	0.46566	0.5%
A3	0.47262	2.0%
B	0.5478	18.2%
C1	0.54615	17.8%
C2	0.5768	24.4%
D	0.60942	31.5%

E	0.48856	5.4%
E1	0.4973	7.3%
E2	0.48964	5.6%
E3	0.4998	7.8%
B & D	0.60955	31.5%

The effect of the design modifications in the attained subdivision index can be seen from figure A.2.2. Similarly with the values of the previous table, bigger increase is observed for versions B (boxed hatch covers) and D (additional transverse bulkhead in cargo hold area). The combination of boxed shaped hatch covers and the addition of a transverse bulkhead contribute very little in the increase of the subdivision index. Subdividing the ballast tanks has no effect on the attained subdivision index.

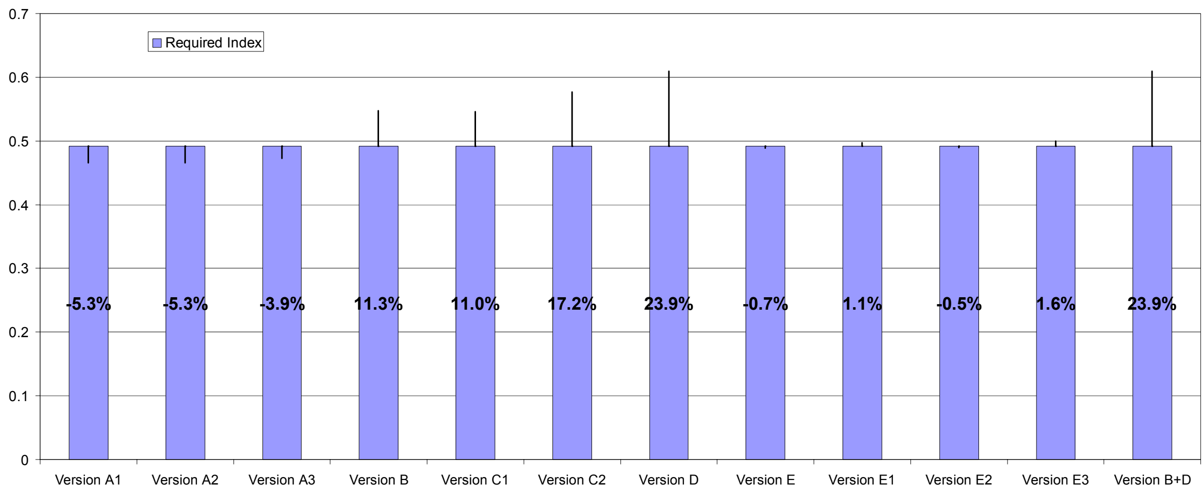

Figure A.2.2. Effect of design modifications on the attained subdivision index (The blue bars indicate the required subdivision index)

A.4 *Distributions of cost Parameters*

The variation of the different cost parameters was considered by distributions. These distributions are explained in the following.

Repair costs
The information available is summarised in section 3.1.3. These data were used to specify a lognormal distribution.

Docking costs
The total docking costs depend on the number of days in dock and the docking costs. For both parameters the variation was taken into consideration. The number of days is approximated by a normal distribution with a truncation providing that the minimum repair time is one day for all accident categories and damage categories. The same type of distribution is used for the dock costs with a truncation at 6,250 $.

Charter costs
Again, two parameters are used to describe this cost factor. The number of days is approximated by a normal distribution with a truncation providing that the minimum repair time is one day for all accident categories and damage categories. The daily charter is approximated by a lognormal distribution. For the determination of the parameter of the distribution it was assumed that the charter is size dependent starting with 12,000 $ for small ships and ending with 18,000 $ for ships of about 36,000 DWT (99 % of all ships). The number of ships in size categories of 500 DWT was determined. Both data was approximated by the lognormal distribution. The offset is 12164 $.

Crew costs
The variation of the crew costs I approximated by three parameter, number of days out of service (lognormal distribution like above), number of crew and costs per day. The number of crew is approximated by a lognormal distribution based on the data summarised in MSC 87/INF.3. The number of crew distribution is truncated at 5 and 25. The costs per day are also approximated by a lognormal distribution with a lower truncation at 60 $.

Ship costs
The ship costs are approximated by a lognormal distribution for the ship size and a lognormal distribution for the distribution in the new building prize as explained in section 3.1.1

Cargo costs
Approximated by a lognormal distribution with a lower bund (truncation) of 100,000 $.

A.5 *Results of the CBA*

In the following table the detailed results of the CBA are summarised. For each RCO this table provides the effectiveness and the percentage of accidents influenced by the RCO, The costs (initial and annual) used in the cost-effectiveness evaluation as well as the risk reduction with respect to potential loss of life, potential loss of oil and potential loss of property (equivalent to benefit). The total operating costs for a risk control option were calculated for the whole ship life of 25 years taking into consideration depreciation where appropriate. The row 'Per ship year' provides the values for costs and risk reduction per ship year (input values for eq. (2) and eq. (3), section 3) The colours used in the columns of GCAF and NCAF indicate

- Green: below the threshold of 3 million USD;
- Apricot: costs are between 3 million USD and 4 million USD;
- Red; above 4 million USD.

RCO	Accident Category	Effectiveness	Percentage of accidents effected	Costs			Risk Reduction			GCAF	NCAF
		Average		Initial	Annual	Total operating	Δ	Δ	Δ (Benefit)		
		%	%	$	$	$	fat/ship year	tonnes/ship year	$/ship year		
RCO 2	CN	30	25	34,800	2,900	40,872	2.61E-04	1.91E-03	1,554		
	WS	30	9				6.05E-05	5.69E-04	742		
	Sum 25 years					75,672					
	Per ship year					3,027	3.75E-04	2.47E-03	2,960	8.1E+06	1.8E+05

RCO	Accident Category	Effectiveness	Percentage of accidents effected	Costs			Risk Reduction			GCAF	NCAF
		Average		Initial	Annual	Total operating	Δ	Δ	Δ (Benefit)		
		%	%	$	$	$	fat/ship year	tonnes/ship year	$/ship year		
RCO 3 a	CN	10	20	15,000	625	8,809	8.69E-05	6.35E-04	518		
	Sum 25 years					23,809					
	Per ship year					952	8.69E-05	6.35E-04	518	1.1E+07	5.0E+06
RCO 3 b	CN	10	20	27,500	625	0	8.69E-05	6.35E-04	518		
	Sum 25 years					27,500					
	Per ship year					1,100	8.69E-05	6.35E-04	518	1.3E+07	6.7E+06
RCO 5 a	CN	5	42	45,000	45,500	1,137,500	1.93E-04	1.93E-03	1,668		
	WS	10	10				3.72E-05	3.50E-04	456		
	Sum 25 years					1,182,500					
	Per ship year					47,300	2.30E-04	2.28E-03	2,124	2.1E+08	2.0E+08
RCO 5 b	CN	5	42	115,000	45,500	1,137,500	1.93E-04	1.93E-03	1,668		
	WS	10	10				2.86E-05	2.69E-04	456		
	Sum 25 years					1,252,500					
	Per ship year					50,100	2.22E-04	2.19E-03	2,124	2.3E+08	2.2E+08
RCO 6 a	CN	30	3	80,000	2,000	28,188	1.06E-05	1.15E-04	160		
	CT	30	1				1.10E-06	1.37E-05	4		

RCO	Accident Category	Effectiveness	Percentage of accidents effected	Costs			Risk Reduction			GCAF	NCAF
		Average		Initial	Annual	Total operating	Δ fat/ship year	Δ tonnes/ship year	Δ (Benefit) $/ship year		
		%	%	$	$	$					
	WS	30	1				6.49E-06	2.04E-05	78		
	Sum 25 years					108,188					
	Per ship year					4,328	1.82E-05	1.49E-04	242	2.4E+08	2.2E+08
RCO 6 b	CN	30	3	200,000	2,000	28,188	1.06E-05	1.15E-04	160		
	CT	30	1				1.66E-05	1.91E-04	4		
	WS	30	1				6.49E-06	2.04E-05	78		
	Sum 25 years					228,188					
	Per ship year					9,128	3.37E-05	3.26E-04	242	2.7E+08	2.6E+08
RCO 8	CN	15	10	100	344	8,600	2.25E-05	2.44E-04	340		
	WS	15	1				2.49E-06	7.81E-06	43		
	Sum 25 years					8,700					
	Per ship year					348	2.50E-05	2.52E-04	383	1.4E+07	-1.4E+06
RCO 9	CN	15	10		688	17,200	2.17E-05	2.36E-04	328		
	WS	15	1				2.40E-06	7.55E-06	43		
	Sum 25 years					17,200					
	Ship year					688	2.41E-05	2.44E-04	371	2.9E+07	1.3E+07

RCO	Accident Category	Effectiveness	Percentage of accidents effected	Costs			Risk Reduction			GCAF	NCAF
		Average		Initial	Annual	Total operating	Δ fat/ship year	Δ tonnes/ship year	Δ (Benefit) $/ship year		
		%	%	$	$	$					
RCO 12	CN	10	5	19,700	600	4,397	2.52E-05	1.84E-04	150		
	WS	10	3				7.73E-06	7.26E-05	95		
	Sum 25 years					24,097					
	Per ship year					964	3.30E-05	2.57E-04	245	2.9E+07	2.2E+07
RCO 13 a	CN	10	27	50,000	300	4,228	1.11E-04	8.14E-04	664		
	FD	5	90		15,000	375,000	4.70E-04	1.42E-02	1,042		
	WS	5	78				1.00E-04	9.44E-04	1,232		
	HD	5	46				9.25E-05				
	Sum 25 years					429,228					
	Per ship year					17,169	7.74E-04	1.59E-02	2,937	2.2E+07	1.8E+07
RCO 13 b	CN	10	27	0	1,500	21,141	1.11E-04	8.14E-04	664		
	FD	5	90		30,000	750,000	4.70E-04	1.42E-02	1,042		
	WS	5	78				1.00E-04	9.44E-04	1,232		
	HD	5	46				9.25E-05				
	Sum 25 years					771,141					
	Per ship year					30,846	7.74E-04	1.59E-02	2,937	4.0E+07	3.6E+07
RCO 16	CN	40	9	90,000			8.73E-05	6.38E-04	520		

RCO	Accident Category	Effectiveness	Percentage of accidents effected	Costs			Risk Reduction			GCAF	NCAF
		Average		Initial	Annual	Total operating	Δ	Δ	Δ (Benefit)		
		%	%	$	$	$	fat/ship year	tonnes/ship year	$/ship year		
	FD	40	18				3,76E-04	1,13E-02	833		
	Sum 25 years					90,000					
	Per ship year					3,600	4,63E-04	1,20E-02	1.354	7.8E+06	4.8E+06
RCO 17	FD	30	36	75,000			8.83E-04	2.67E-02	1,959		
	HD	8	25				9.25E-05				
	Sum 25 years					75,000					
	Per ship year					3,000	9.76E-04	2.67E-02	1,959	3.1E+06	1.1E+06
RCO 18	FD	3	100	170,000		52,925	4.70E-04	1.42E-02	1,042		
	Sum 25 years					222,925					
	Per ship year					8,917	4.70E-04	1.42E-02	1,042	1.9E+07	1.7E+07
RCO 19	FD	11	100		4,000	100,000	1.10E-03	3.31E-02	2,431		
	HD	8	27				4.63E-06				
	Sum 25 years					100,000					
	Per ship year					4,000	1.10E-03	3.31E-02	2,431	3.6E+06	1.4E+06
RCO 20	FD	11	100		125	3,125	1.10E-03	3.31E-02	2,431		
	HD	8	27				4.63E-06				
	Sum 25 years					3,125					

RCO	Accident Category	Effectiveness	Percentage of accidents effected	Costs			Risk Reduction			GCAF	NCAF
		Average		Initial	Annual	Total operating	Δ fat/ship year	Δ tonnes/ship year	Δ (Benefit) $/ship year		
		%	%	$	$	$					
	Per ship year					125	1.10E-03	3.31E-02	2,431	1.1E+05	-2.1E+06
RCO 21	FD	15	7	66,000			9.14E-05	2.76E-03	203		
	Sum 25 years					66,000					
	Per ship year					2,640	9.14E-05	2.76E-03	203	2.9E+07	2.7E+07
RCO 23	WS	5	21	1,400	1,400	3,157	3.01E-05	2.82E-04	369		
	Sum 25 years					4,557					
	Per ship year					182	3.01E-05	2.82E-04	369	6.1E+06	-6.2E+06
RCO 26	CN	10	45		1,250	31,250	2.29E-04	1.68E-03	1,366		
	WS	0	100				4.29E-05	4.04E-04	526		
	Sum 25 years					31,250					
	Per ship year					1,250	2.72E-04	2.08E-03	1,893	4.6E+06	-2.4E+06
RCO 27	WS	10	21	0			5.41E-05	5.08E-04	663		
	Sum 25 years										
	Per ship year					0	5.41E-05	5.08E-04	663	0.0E+00	-1.2E+07
RCO 28	FX	0	40	5,000	700	9,866	6.94E-05				

RCO	Accident Category	Effectiveness	Percentage of accidents effected	Costs			Risk Reduction			GCAF	NCAF
		Average		Initial	Annual	Total operating	Δ	Δ	Δ (Benefit)		
		%	%	$	$	$	fat/ship year	tonnes/ship year	$/ship year		
	MD	10	80				9.25E-05				
	Sum 25 years					14,866					
	Per ship year					595	1.62E-04			3.7E+06	
RCO 31	FX	0	7	32,000	1,500	21,141	4.63E-05				
	Sum 25 years					53,141					
	Per ship year					2,126	4.63E-05				
RCO 32	CN	10	9	1,000			4.37E-05	3.19E-04	260		
	WS	10	26				2.58E-05	2.42E-04	316		
	Sum 25 years					1,000					
	Per ship year					40	6.94E-05	5.61E-04	576	5.8E+05	-7.7E+06

A.6 Summary of RCO Effect Evaluation

In the following table the main estimations and data used to determine the effect of the RCOs are summarised. In order to determine the effectiveness of an RCO the percentage of fleet as well as the percentage of accidents affected were estimated based on the information provided by the casualty reports (ref. section 2.2, p. 5 ff). Finally, the effect of an RCO on this subset of accidents was estimated. The estimations for the effectiveness of an RCO are summarised in section 2.4.

No	RCO	Effect on								Estimated Effect
		CN	**CT**	**FD**	**WS**	**F**	**X**	**H**	**M**	
1	Merged with RCO 2									
2	ECDIS integrated with AIS and RADAR (only for new ships) GT<3,000	X			x					Reduces the number of accidents ECDIS only effective if crew is sufficiently trained In FSA study on ECDIS the efficiency for tanker (example vessels 4,000 DWT and 80,000 DWT) and bulk carrier (75,000 DWT) was determined to 36 % risk reduction for grounding accidents. WS: for 92 of 325 accidents causes known; for the known causes 25 human related (27 %); about 9 % of all accidents (known cause) could be allocated to wrong determination of position which may be avoided by ECDIS. 2 % were related to give way ➔ 9 % of all accidents are caused by wrong determination of position (human related) CN: for 33 of 240 accidents the cause is known; 17 human related accidents of which 9 combined with poor visibility; for 59 of 240 accidents the weather conditions are known; collisions in bad weather condition (poor visibility) may be avoided by better information provided by ECDIS in combination with AIS and RADAR. About 45 % (27) of all collisions took place in fog/mist/poor visibility.

No	RCO	Effect on								Estimated Effect
		CN	CT	FD	WS	F	X	H	M	
										➔ About 45 % of accidents took place in poor visibility; ➔ 50 % of these are human related of which some may be avoided by ECDIS (only for ships without ECDIS)
3	2nd RADAR for ships within 500~3,000 GRT	X			x					CN: for 33 of 240 accidents the cause is known; 17 human related accidents of which 9 combined with poor visibility; for 59 of 240 accidents the weather conditions are known; collisions in bad weather condition (poor visibility) may be avoided by better information provided by ECDIS in combination with AIS and RADAR. About 45 % of all collisions took place in fog/mist/poor visibility. ➔ Second radar avoids 20 % of all poor visibility related CN accidents ➔ assuming that 80 % of all ships < 3000 GT are without second radar
4	At least 1 electronic plotting aid device	X			x					Not considered
5	Increased manning requirements (OOW-master + 2 BWO for ships >500 GRT, STCW 95 Section A-VIII/1 & B-VIII/1 + ILO Conv. No 180 Articles 5 & 7) – survey and control of current requirements that are correctly implemented	X			X					Optimal effect when second watch during operations in coastal waters and on river/canal especially in bad weather conditions (poor visibility) CN: for 33 of 240 accidents the cause and the location are known; 17 human related accidents (~52 %), of these 50 % under poor visibility; none assigned to fatigue or comparable reasons; two accidents night time (mostly no time given) ➔ 8 of 17 human related CNs took place between midnight and 6 in the morning (47 %) ➔ 82 % CNs coastal water, river/canal and harbour CT: It is asserted by a Cardiff University report that 17 % ~ 23 % of collisions are due to fatigue

No	RCO	Effect on								Estimated Effect
		CN	CT	FD	WS	F	X	H	M	
										WS: for 92 of 325 accidents causes known; 25 human related accidents (27 %); about 7 of all accidents (known cause) could be assigned to fatigue (falling asleep) (8 %) NMD study attributes 17% ~ 22% of groundings due to fatigue (fall asleep). By contrast, no grounding was due to fall asleep when there was 3 person watch on the bridge
6	Optimised/reviewed bridge design arrangement and equipment (proper conning position of bridge visibility – change status Circ.982 to requirement)	X	X		X					Should affect mainly CN, CT, WS on river/canal and in harbour CN: for 33 of 240 accidents the cause is known; River/Canal (31 %), Harbour (26 %) of all accidents; 17 (52 %) human related (all locations; sample for river/canal+harbour too small) ➔ assuming that for 10 % of all human related CN were caused by limited visibility CT: for 22 of 94 accidents the cause is known; River/Canal (31 %), Harbour (55 %) of all accidents; 2 (10 %) human related (all locations; sample for river/canal+harbour too small) ➔ assuming that 10 % of all human related CT (10 %) were caused by limited visibility and could be avoided WS: River/Canal (23 %), Harbour (9 %) of all accidents; 25 human related accidents (27 %); ➔ assuming that for 10 % of all human related WS were caused by limited visibility
8	Improve preparation and handling of ship for manoeuvring in restricted waters (crew & pilot preparation)	X	(X)		X					Positive effect for operation on river/canal or harbour only and when pilot is required. Reduces the number of accidents CN: River/Canal (31 %), Harbour (26 %) of all accidents; 17 (52 %) human related CN; however no human related CN in harbour CT: River/Canal (31 %), Harbour (55 %) of all accidents;

No	RCO	Effect on								Estimated Effect
		CN	CT	FD	WS	F	X	H	M	
										WS: River/Canal (23 %), Harbour (9 %) of all accidents; 27 % of all accidents human related; only 18 % of human related accidents on river/canal (probability with pilot) Open issues: - how many ships require a pilot - how many accidents were caused by insufficient preparation of the pilot
9	Pilot simulator training	X	X		X					Positive effect for operation on river/canal or harbour only and when pilot is required. Reduces the number of accidents CN: River/Canal (31 %), Harbour (26 %) of all accidents; 17 (52 %) human related CN; however no human related CN in harbour CT: River/Canal (31 %), Harbour (55 %) of all accidents WS: River/Canal (23 %), Harbour (9 %) of all accidents; for the known causes 25 human related (27 %); Open issues: - how many ships require a pilot - how many accidents were caused by insufficient preparation of the pilot
10	Pilot for smaller ships, what are the requirements for having pilot onboard									River Elbe: Kiel Canal: all ships need a pilot -> negligible effect on all accident categories
11	Information card on the bridge for pilots	X	X		X					Positive effect for operation on river/canal or harbour only and when pilot is required. Reduces the number of accidents CN: River/Canal (31 %), Harbour (26 %) of all accidents; 17 (52 %) human related CN; however no human related CN in harbour CT: River/Canal (31 %), Harbour (55 %) of all accidents WS: River/Canal (23 %), Harbour (9 %) of all accidents; for the known causes 25 human related (27 %) Open issues:

No	RCO	Effect on								Estimated Effect
		CN	CT	FD	WS	F	X	H	M	
										- how many ships require a pilot - how many accidents were caused by insufficient preparation of the pilot CT: no human (pilot) related accidents WS: one accident in harbour with pilot on board (may be avoided by better training/preparation)
12	Voyage Data Recorder for small vessels (500~3,000 GT)	X	X		X					Positive effect on human related accidents in all areas. Reduces the number of accidents CN: for 33 of 240 accidents the cause is known; 17 (52 %) human related CN; CT: WS: for 92 of 325 accidents causes known; for the known causes 25 human related (~27 %);

No	RCO	Effect on								Estimated Effect
		CN	CT	FD	WS	F	X	H	M	
13	Weather routeing				X					Reduce the number of journeys under bad weather conditions (storm) CN: for 33 of 240 accidents the cause is known; for 59 of 240 weather condition are known (~25 %); 16 took place in heavy weather (27 %) FD: for 36 of 64 accidents weather conditions specified (56 %); of these 90 % in bad weather or hurricane. WS: for 59 of 325 accidents weather conditions are known (18 %); of the 37 heavy weather, 9 hurricane (total ~78 %); Hull damage is reduced. Out of the 86 cases, 46% or 9.0E-03 could have been avoided, leading to ΔPLL = 1.44E-04
14	Life boats for smaller vessels (LBP<85 m)	x		X	x					Effect: reduces the consequences for crew CN: for 33 of 240 accidents the cause is known; 22 (~ 9 %) of all accidents are total loss but 85 fatalities (of 99); 10 total losses are with fatalities av. 8.5 fat/acc, of these are 3 with LBP < 85 m with 4 fat; 3 Severe with 9 fatalities; one small with 3 fat.; ➔ reduces the average fatality rate for loss by 1 (7.5 fat/acc) FD: 220 fat in 64 acc.; 25 acc for ships < 85 m with 68 fat WS: 23 of 325 acc end with loss causing 57 fat (of 61); of all ship involved in WS accidents 149 are < 85 m; only one acc of ships < 85 m leads to fat (17)
15	Water ingress alarm for No1 cargo hold	x		X	x					Effect: reduces the number of foundering accidents. CN: for 59 of 240 weather conditions are known (~25 %); 16 accidents in heavy weather

No	RCO	Effect on								Estimated Effect
		CN	CT	FD	WS	F	X	H	M	
										(27 %); Two losses in heavy weather; 22 total losses (~ 9 %); FD: 220 fat in 64 acc. 42 cause known; 15 accidents “took water” (28 %); 1 leaking (2 %); for 5 of 15 location of water ingress further specified, 3 cargo hold (20 % f 15), 2 engine room (13 % of 15) HD: For hull damage accidents, 23 cases or 5.32E-04 would not have been deteriorated. However, only small injuries have been observed, hence ΔPLL = 0.2/43222 = 4.63E-06.
16	Increased R index or stability criteria/requirements	x	x	X						CN: for 59 of 240 weather conditions are known (~25 %); 16 accidents in heavy weather (27 %); FD: 64 accidents 42 cause known; 15 accidents “took water” (28 %); 1 leaking (2 %); for 5 of 15 location of water ingress further specified, 3 cargo hold (20 % of 15), 2 engine room (13 % of 15); 60 % of water ingress in cargo hold
17	Improvement of cargo stowage especially bulk (other than grain) and heavy items			X				x		FD: 64 accidents 42 cause known; of these 12 due to cargo shift (~29 %) and 3 capsize (7 %); except 4 (unknown) all accident in heavy weather
18	Coating requirements for areas of low accessibility			X						FD: 64 accidents 42 cause known; no information with respect to corrosion found in data;
19	Extended surveys on GCS			X				x		Would have effect on documenting and keeping a consistent record of surveys. For foundering accidents, 42% or 6.22E-04 of the cases with water ingress could have been detected, leading to ΔPLL = 9.75E-05 For hull damage accidents, 23 cases or 5.32E-04 would not have been deteriorated. However, only small injuries have been observed, hence ΔPLL = 0.2/43222 = 4.63E-06. FD: 220 fat in 64 acc.; for these in 42 cases the causes were specified; 15 accidents

No	RCO	Effect on								Estimated Effect
		CN	CT	FD	WS	F	X	H	M	
										caused by water ingress (36 %), of these for five the location was known three in cargo hold (3/5) and two in engine room (2/5), rest unknown.
20	PSC inspector training on GCS			x				x		For foundering accidents, 42% or 6.22E-04 of the cases with water ingress could have been detected, leading to ΔPLL = 9.75E-05 For hull damage accidents, 23 cases or 5.32E-04 would not have been deteriorated. However, only small injuries have been observed, hence ΔPLL = 0.2/43222 = 4.63E-06.
21	Reduce BWT size			X						FD: 64 accidents 42 cause known; of these 12 due to cargo shift (~29 %) and 3 capsize (7 %); except 4 (unknown) all accident in heavy weather
22	Merged with RCO19			X						
23	Simulator training for increasing situational awareness (anchor dragging)				X					WS: for 92 of 325 accidents causes known; anchor dragging (19; ~21 %): anchor dragging typically took place in combination with strong wind. → training increase risk awareness
24	Increased design requirements for anchor holding power (inclusion of dynamic effects on Equipment Nr)				X					WS: for 92 of 325 accidents causes known; anchor dragging (19; ~21 %): anchor dragging typically took place in combination with strong wind → improved anchor design should lead to increased anchor force
25	Watch scheme every 4 hrs	X	X		X					CN: for 33 of 240 accidents the cause is known; 17 human related accidents (~52 %), none assigned to fatigue or comparable reasons. → however, it is obvious that the probability increases with fatigue problems (especially in coastal waters (of human related: 7), river/canal (of human related: 3) → 8 of 17 took place between midnight and 6 morning

No	RCO	Effect on								Estimated Effect
		CN	CT	FD	WS	F	X	H	M	
										CT: WS: for 92 of 325 accidents causes known; about 9 % of all accidents (known cause) could be assigned to fatigue (falling asleep) It is asserted by a Cardiff University report that 17% ~ 23% of collisions are due to fatigue NMD study attributes 17% ~ 22% of groundings due to fatigue (fall asleep). By contrast, no grounding was due to fall asleep when there was 3 person watch on the bridge
26	ECDIS training of all OOW	X			X					CN: for 33 of 240 accidents the cause is known; no information how many ships have ECDIS; ECDIS in combination with AIS and radar could reduce number of CNs if used appropriate; 17 human related accidents (~52 %); About 27 (45 %) of all collisions took place in fog/mist/poor visibility ; 9 of 17 human related accidents took place in poor weather conditions ➔ assuming that ECDIS is required for all ships > 500 GT. WS: for 92 of 325 accidents causes known; one accident caused by insufficient training ECDIS (1 %) ➔ assuming that ECDIS is required for all ships > 500 GT.
27	Anchoring watch alarm integrated in ECDIS				X					WS: for 92 of 325 accidents causes known; anchor dragging (19; ~21 %): anchor dragging typically took place in combination with strong wind.
28	Checklist for maintenance procedures					x			X	Reduce the number of associated accidents. The purpose will be to ensure satisfactory and consistent quality of planning, reporting and execution of maintenance procedures with respect to machinery items. From all the cases of machinery damage, 1.16E-03 per ship year (50 accidents) was

No	RCO	Effect on								Estimated Effect
		CN	CT	FD	WS	F	X	H	M	
										associated with lack of maintenance procedures. Assuming that 8 of them (15%) could have been avoided when and if a planned maintenance system was in place, it could lead to a ΔPLL = 9.25E-05 From all fire/explosion accidents, 1.64E-03 per ship year occurred in engine room. Assuming that 1% could have been avoided (1 accident), an estimated ΔPLL = 6.94E-05 could be observed
30	Sprinkler in the accommodation area of cargo ships					X				From all the accidents (3.24E-04 per ship year occurred in accommodation or 14 accidents), it appeared that the portable extinguishers were not capable to suppress the fire and n 57 % of the cases, external assistance was required. However, with 1% being avoided, the effect is considered negligible.
31	Smoke detector					X				From the accidents (3.24E-03 per ship year occurred in accommodation or 14 accidents). Assuming that in 5% of these accidents, the fire could have been detected at an earlier stage, it follows that 1 accident could have been avoided.
32	Combine watch alarm with autopilot	X	x		X					Reduces the number of accidents WS: for 92 of 325 accidents causes known; about 9 % of all accidents (known cause) could be assigned to fatigue (falling asleep) CN: for 33 of 240 accidents the cause is known; 17 human related accidents (~52 %), none assigned to fatigue or comparable reasons ➔ 8 of 17 took place between midnight and 6 morning ➔ watch alarm may avoid sleeping