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MARITIME SAFETY COMMITTEE
88th session
Agenda item 19

MSC 88/INF.8
20 September 2010
ENGLISH ONLY

GENERAL CARGO SHIP SAFETY

IACS FSA study – summary of results

Submitted by the International Association of Classification Societies (IACS)

SUMMARY

Executive summary:	This document provides at the annex a copy of the summary of results 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; MSC 88/INF.6 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 previous meetings of the Committee. The identification of risk control options and their cost-benefit/effectiveness assessment (steps 3 and 4 of an FSA study) are provided in detail in document MSC 88/INF.6.

2 In conjunction with what is stated in document MSC 88/19/2, the summarized results of the performed FSA study on general cargo ships are set out in the annex to this document.

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

FORMAL SAFETY ASSESSMENT OF GENERAL CARGO SHIPS

1 Summary

A full Formal Safety Assessment (FSA) is performed to estimate the risk level and to identify as well as to evaluate possible risk control options (RCOs) for general cargo ships. Based on a comprehensive investigation of risk characterizing information the focus of this FSA is put on ships classified as general cargo ships by Lloyd's Register Fairplay (LRF) and with a minimum deadweight of 500 gross tonnes. The FSA study shows that both the individual and the societal risk associated with general cargo ships are within the region of tolerable risk. This means that this risk should be made ALARP (As Low As Reasonably Practicable) by verifying if cost-effective risk control options exist and implementing them accordingly. With respect to crew safety three major risk contributors are identified:

.1 Foundering;

.2 Collision; and

.3 Wrecked/Stranded.

Following this FSA, these three accident categories contribute to about 85% of crew fatalities and ship losses. However, the expert discussion to identify potential RCOs considers all accident categories. The identification of risk control options was supported by a comprehensive analysis of casualty reports in order to consider the accident causes during the RCO identification. In total 32 RCOs were proposed by the experts, of which 20 were considered in the cost-benefit assessment. The RCOs are focused on improved navigational equipment, operational aspect (training, manning), technical and structural improvements. The basis for the recommendations given in this study is the following:

.1 with respect to safety an RCO is considered cost-effective if the GCAF (Gross Cost of Averting a Fatality) is less than US$3 million. This is the value used in all decisions made following the FSA studies submitted under agenda item 5, Bulk Carrier Safety, at MSC 76, December 2002 and suggested in document MSC 83/INF.2; and

.2 with respect to safety an RCO is also considered cost-effective if the NCAF (Net Cost of Averting a Fatality) is less than US$3 million.

This FSA study demonstrates that the following RCOs are providing a risk reduction in a cost-effective manner (satisfying the aforementioned monetary criteria) based on the evaluation for the average values as well as for the sensitivity analysis:

.1 RCO 27 (technical): Anchoring watch alarm integrated in ECDIS;

.2 RCO 20 (operational/training): Port State Control inspector training for General Cargo Ships;

.3 RCO 32 (technical): Combine watch alarm with autopilot;

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

.5 RCO 19 (operational/training): Extended survey on General cargo ships; and

.6 RCO 2 (technical): ECDIS with AIS and RADAR (only for new-buildings).

2 Definition of the problem

The issue of general cargo ship safety was noted at IMO in 2006 in the submission by the Russian Federation (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. It was further explained that approximately 73 general cargo ships were lost each year in this period. Additionally, it was stated that in 2004, based on Paris MoU statistics, general cargo ships had the second highest rate of port State control inspections with deficiencies (60% of inspections of general cargo ships compared with an average of 54% for all types of ships) and detentions (8% of inspections of general cargo ships compared with an average of 6% for all types of ships). At MSC 83 several additional documents 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) of 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 to provide the step 1 of an FSA on general cargo ship safety. IACS continued this FSA in the following time and submitted interim results to IMO. The name "general cargo ship" covers ships performing a variety of transport tasks, e.g., bulk, special cargo like windmills or offshore equipment. Following the LRF classification, these subtypes belong to the group of general cargo ships: open hatch cargo ships, general cargo/tanker (container/oil/bulk – COB ship), general cargo/tanker, general cargo ship, general cargo barge (propelled), palletized cargo ship and deck cargo ship. The scope of this FSA is limited to "general cargo ships" disregarding the other subtypes. The minimum ship size is set to 500 GT (application of SOLAS (chapter 1-A, regulation 3)). The analysis is focused on loss of life and environmental impact due to oil spill (bunker oil). The property related risk is considered as far as necessary for the cost-benefit assessment within the ALARP process. Thus, security risks are not considered in this FSA. Occupational accidents are investigated for accidents occurring in Norwegian waters or on ships flying under Norwegian flag. However, due to the lack of data the risk related to occupational accidents is not analysed further in this report. This FSA covers only the operational phase of general cargo ships and, hence, risks associated with vessels at yard or in dock under construction, repair or maintenance, or in the decommissioning and scrapping phase are also excluded from this analysis.

3 Background information

3.1 *Fleet at risk*

The world fleet of general cargo ships, the fleet at risk, is investigated based on the information in the LRF database. In this database about 16,000 general ships are listed. The majority (~80%) of these ships have a gross tonnage between 1,000 GT and 20,000 GT. The investigation showed that for more than 40% of all listed ships no classification society was assigned. This is the case mainly for older ships (Figure 0-1).

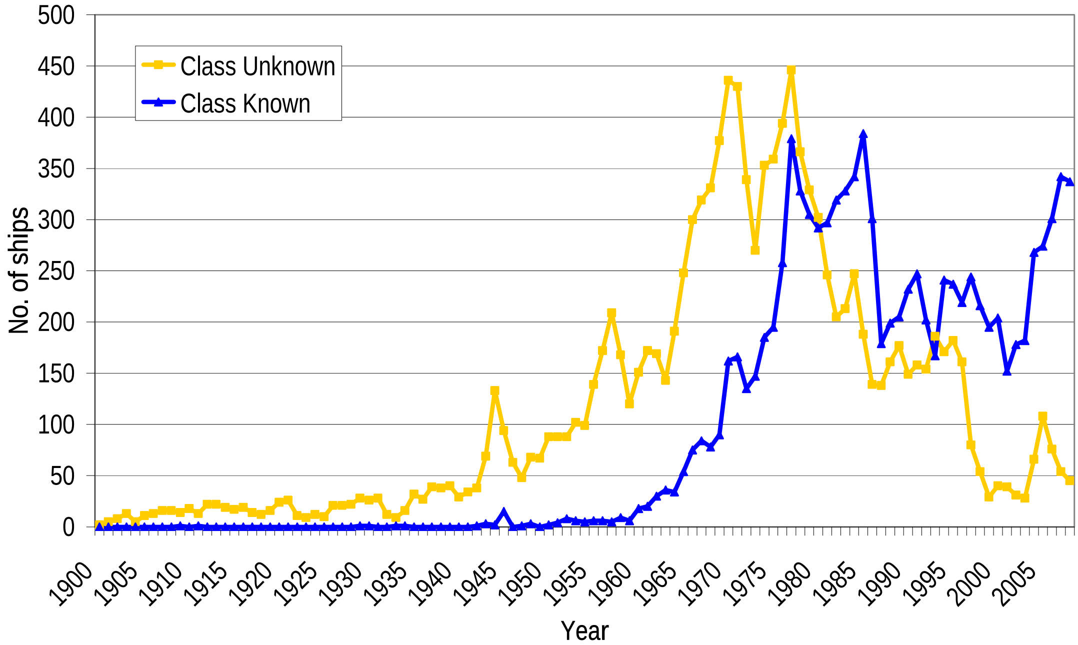

Figure 0-1: Number of ships built per year for the groups "Class Known" and "Class Unknown"

Based on this general investigation of the general cargo fleet the following sample was defined for this FSA:

.1 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): older ships are excluded from the analysis because IMO regulations as well as class rules are subject to continuous improvement, for instance requirement of damage stability calculation for dry cargo vessels entering into force in 1992;

.2 a gross tonnage greater than 499: these ships have to comply with SOLAS regulations;

.3 classed by IACS society (based on the assignment in LRF 2009): due to the limited available information concerning the ships of the group "Class Unknown" with respect to survey and building rules, all ships without class assignment are excluded. Furthermore, the investigations provide strong indications that the present casualty databases are affected by under-reporting, especially for ships operating in national waters and without assignment of a major class society; and

.4 casualty reports for IACS classed ships and classified as "severe" accident: this FSA is focused on crew safety and environmental safety. Accidents related to these risks are normally classified as "severe". Only ship accidents are considered, excluding occupational (personal) accidents.

The final sample considered in this investigation consists of 4,764 ships yielding 43,222 ship years of operation. The number of ship years per given age broken down into three size classes specified for the statistical investigation is shown in Figure 0-2.

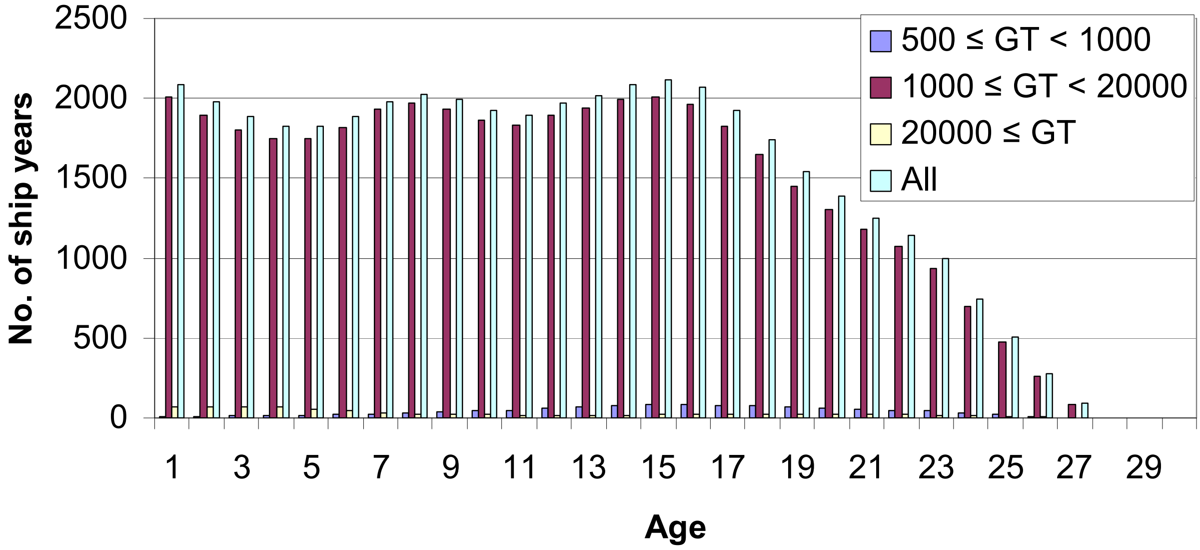

Figure 0-2: Number of ship years observing the given age within the period from 1 January 1997 to 31 December 2008. Ships (A31A2GX) built after 1981 and classed by IACS societies.

3.2 *Casualty statistics*

The number of accidents is determined using the LRF casualty database (version 2009-03-26). This information was amended by the information provided by the IMO database GISIS. In total 1,461 casualty reports were evaluated. The majority of these reports are pertaining to ships between 1,000 GT and 20,000 GT. The LRF casualty database provides a classification into the accident categories collision (CN), contact (CT), foundering (FD), fire and explosion (FX), hull and machinery (HM), missing (MG), miscellaneous (XX), war loss (LT) and wrecked or stranded (WS). The accident categories XX, and LT are not taken into consideration for this FSA. All assignments to the accidents categories were checked during the investigation. The development of the accident numbers broken down into the accident categories is shown in Figure 0-3 regarding only the absolute numbers of accidents. For 2003 to 2008 an increase of the total number of accidents per year is observed. The total number of accidents increases for collision by 430%, wrecked/stranded by 140%, hull/machinery by 130%, contact by 125% and foundering by 100%. However, these numbers allow no conclusions with respect to accident frequencies as the fleet size development is not considered here.

The investigation yields that the:

.1 main accident category is "hull machinery" (41%) followed by "wrecked stranded" (22%) and "collision" (16%);

.2 average relative contribution of "fire explosion" is about 8%; and

.3 average relative contribution of "foundering" is about 4%.

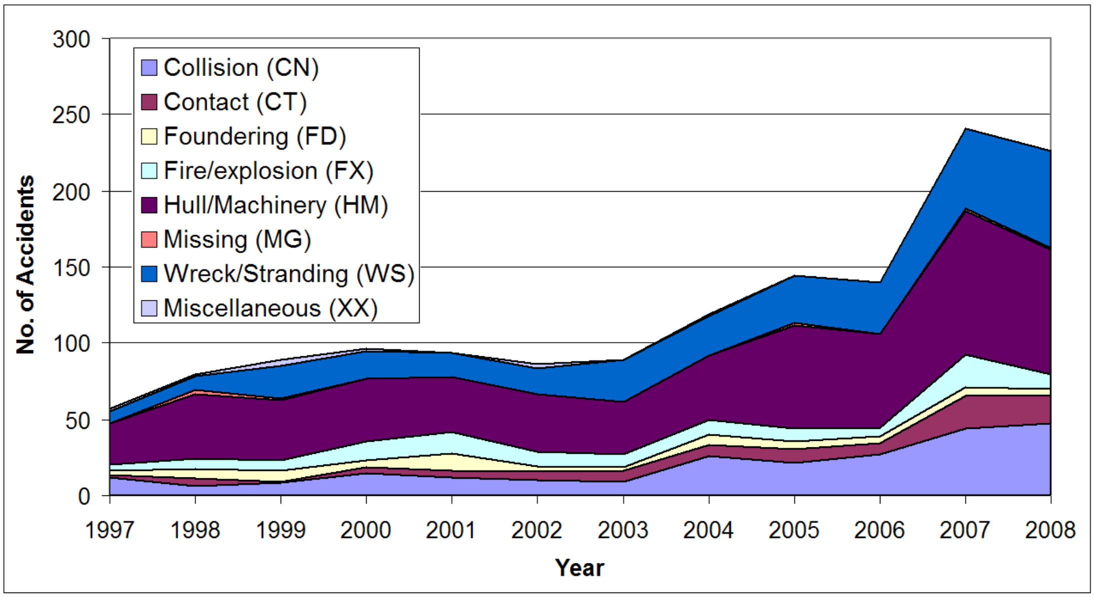

Figure 0-3: Development of annual accident numbers broken down into the accident categories (all size categories, IACS classified ships, period 1997-01-01 to 2008-12-31)

The development of the number of casualty reports over time for the accident outcomes "fatalities" and "total loss" and for ships between 999 GT and 20,000 GT is shown in Figure 0-4. The increase of severe accidents over the whole period is decoupled from the development of "fatalities" and "total loss". Thus, it is concluded, that the increase in the number of casualty reports is most likely a result of improved reporting after 1997, rather than an increase in severe accidents.

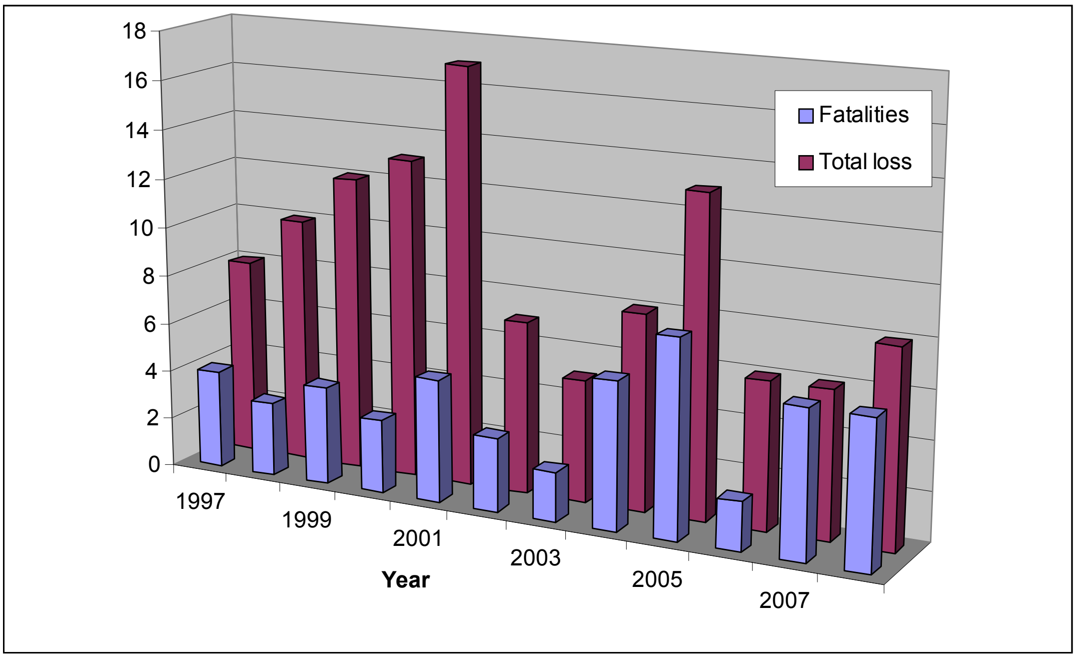

Figure 0-4: Number of casualty reports per year for categories "fatalities" and "total loss" for IACS classed ships together for all size categories

The following characteristics of the accident development are determined:

.1 accident frequency;

.2 frequency of total loss; and

.3 fatality frequency.

The average accident frequency for the IACS classed ships is calculated to $3.4 \cdot 10^{-2}$ showing variations over the observation period with a significant increase in 2007 and 2008 (Figure 0-5).

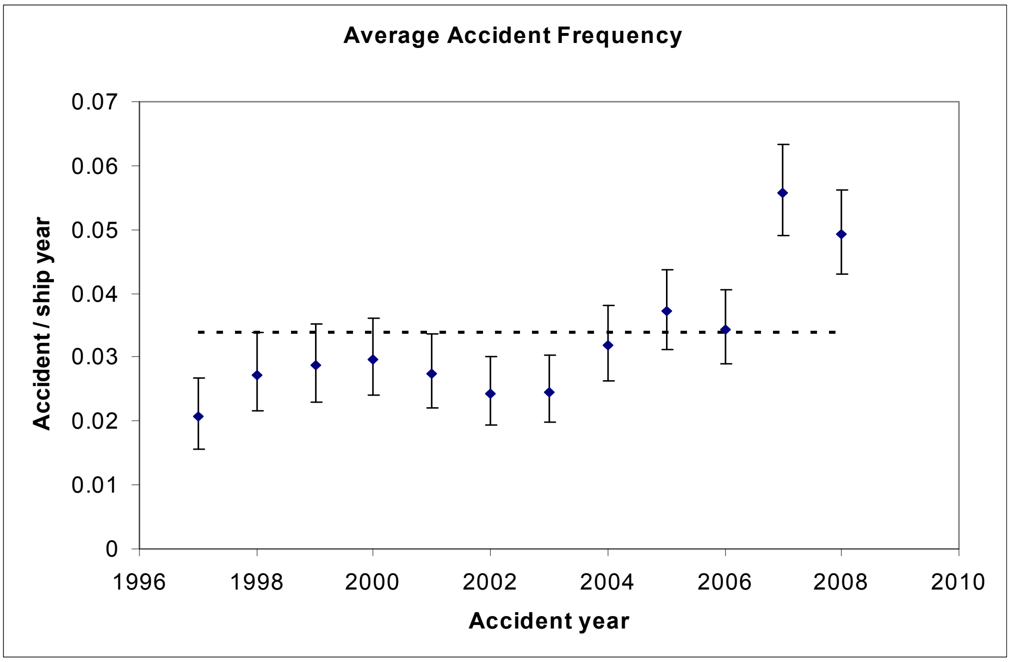

Figure 0-5: Annual frequency of accident for the IACS class ships (average of all size categories) with 95% confidence interval. Additionally the ten year average is plotted.

For total loss a positive trend is observed after 2001 with lower annual frequencies than before (Figure 0-6). The average frequency of total loss is determined to $2.7\ 10^{-3}$.

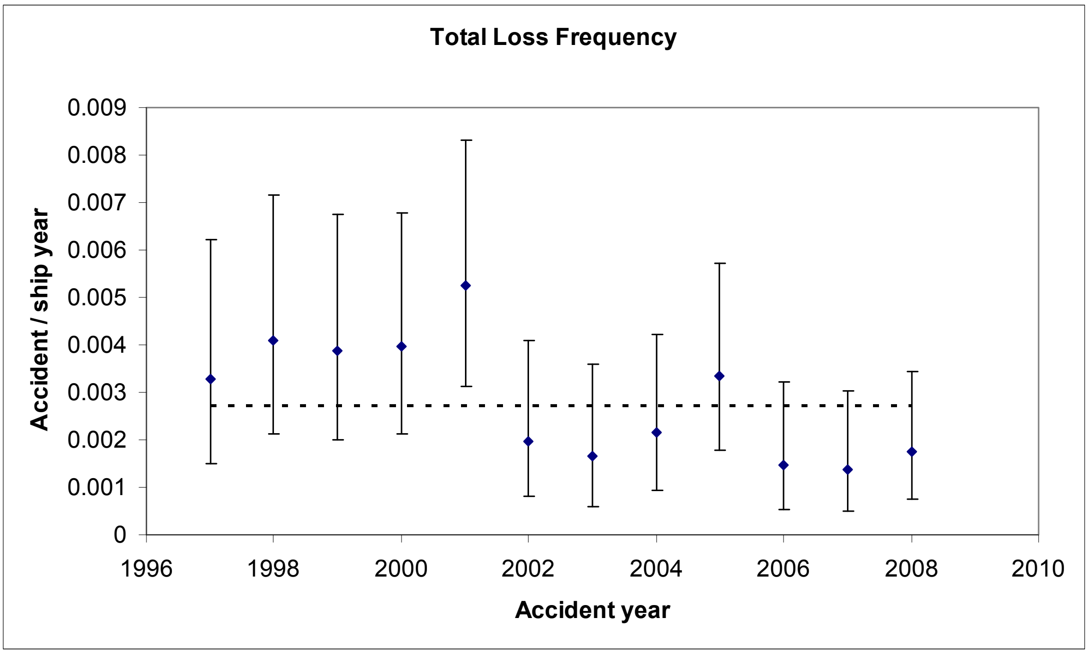

Figure 0-6: Annual frequency of "total loss" for all size categories of IACS class ships and with 95% confidence interval. Additional the ten year average is plotted.

The fatality frequency shows no clear trend in the observation period (Figure 0-7). Bad years with respect to crew safety were 1998, 2004, 2005, 2007 and 2008. In all these years a small number of accidents lead to a high number of fatalities, e.g., in 2008 six accidents with 70 fatalities. The average fatality frequency is determined to about 10^{-2}.

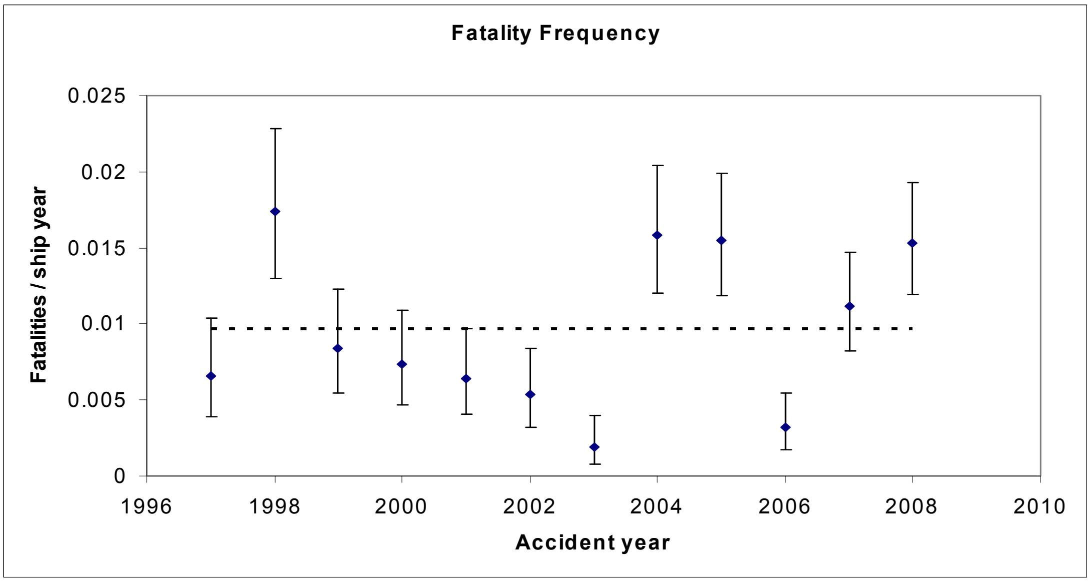

Figure 0-7: Annual frequency of "fatality" for IACS class ships and all size categories with 95% confidence interval. Additionally the twelve year average is plotted.

The F-N diagram for the societal risk for crew members is developed for all size categories together (Figure 0-8). The boundaries for negligible and intolerable risk are determined on the basis of an estimated average turnover of about US$4.5 million per ship and a crew of 20. In document MSC 72/16 (2000) a q-value of one fatality per billion dollar GNP is given. The average annual growth rate of the GNP in the last decade was about 3%. Further, assuming an annual improvement of 2% with respect to safety of worker (decrease of fatalities), a modified q-value of 0.68 is calculated. Thus, general cargo ships are in the upper part of the ALARP "region". However, the boundary to intolerable risk is not touched.

Based on the statistical investigation the potential loss of life (PLL) for crew member yields $9.2 \cdot 10^{-3}$ for ship accidents. This PLL is nearly in the same range as for LNG ($9.32 \cdot 10^{-3}$) and for container ships ($9 \cdot 10^{-3}$).

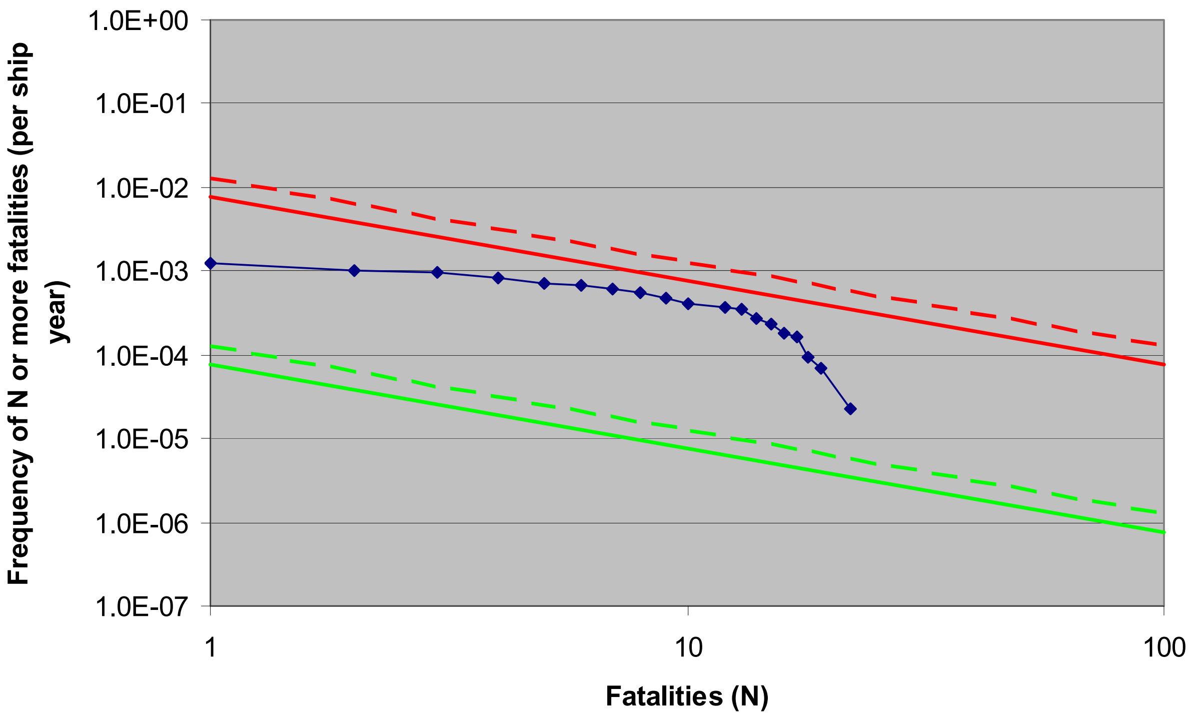

Figure 0-8: FN diagram for IACS class general cargo ship. Boundaries for intolerable and negligible risk calculated on basis of the document MSC 72/16 using updated figures for economic value and two q-values (dashed line: 1 and continuous line: 0.61).

The following table summarizes the results of the casualty statistics with respect to available casualty reports, accident frequency and the consequences.

Table 0-1: Casualty statistics and accident frequencies for general cargo ships (1997-01-01 to 2008-12-31)

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

3.3 *Method of work*

The 5-step FSA methodology outlined in the FSA Guidelines has been used in this study. The FSA application has been carried out as a joint effort between Det Norske Veritas (Norway) and Germanischer Lloyd (Germany) supported by the other IACS members. The coordinator was Det Norske Veritas. The project team was comprised of risk analysts, naval architects and other experts from the partners mentioned above as well as from insurance industry, shipping industry and suppliers. The FSA commenced with a statistical investigation of the general cargo ship fleet and the related casualties. Hazards were identified by this comprehensive investigation that considers also the accident causes, and therefore the normal Hazid meeting including a brainstorming session was not conducted. This analysis was performed in 2008 and submitted to IMO (MSC 85/19/1, MSC 86/INF.4). In order to cover also the latest development in general cargo ship safety the statistical investigation was updated in 2009 and submitted to IMO (MSC 87/INF.3). The risk analysis (step 2 of the FSA) is based on the thorough investigation of accident statistics of step 1 as well as risk modelling utilizing event tree methodologies for the most important accident scenarios. Based on the survey of accident statistics generic accident scenarios were selected for further risk analysis. The risk analysis essentially contains two parts, i.e. a frequency assessment and a consequence assessment. For the frequency assessment, estimating the initiating frequency of generic incidents, accident statistics have been utilized for the selected accident scenarios. The causes of the accidents were investigated in detail. The consequence assessment was performed using event tree methodologies. First, conceptual risk models were developed for each accident scenario and risk contribution trees were constructed combining the potential causes of an accident and the potential consequences.

[1] Number of ship years 43,222. Number of ship years determined in step 1 of the FSA (MSC 87/20/INF.3).

[2] The 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.

The risk contribution trees are high level, generic descriptions of the risk of general cargo ships. The event tree part of the risk contribution trees were subsequently quantified using different techniques for each branch probability according to what was deemed the best approach in each case. The approaches employed include utilizing accident statistics, damage statistics, fleet statistics, simple calculations and modelling as well as elicitation of expert opinions. In order to achieve the highest possible insight of the situation, LRF casualty reports were complemented by IMO GISIS information. The work performed in step 1 and step 2 of this FSA was supported by:

.1 several project team meetings to agree the approach and discuss results; and

.2 three IACS EG/FSA meetings.

Risk control options (step 3 of the FSA) were identified and were prioritized at a technical workshop. Cost-benefit assessments (step 4 of the FSA) were performed on selected risk control options based on the outcome of step 3. The cost-effectiveness for each risk control option was estimated in terms of the Gross Cost of Averting a Fatality (GCAF) and the Net Cost of Averting a Fatality (NCAF). Even if the risk model considers the environmental consequences in terms of bunker oil spilt, the environmental benefit of the RCOs is not taken into consideration. Therefore, the expected costs, economic benefit and risk reduction in terms of averted fatalities only were estimated for all risk control options. The economic benefit and risk reduction ascribed to each risk control option were based on the event trees developed during the risk analysis and on considerations on which accident scenarios would be affected. Estimates on expected downtime and repair costs in case of accidents were based on information by the Association of Hanseatic Marine Underwriters and the ship owner Peter Döhle. The costs of the RCOs were determined based on information by suppliers, training centres, technical experts or previous studies as deemed appropriate. All costs, except labour costs, were depreciated to a Net Present Value (NPV) using a depreciation rate of 5% and assuming an expected lifetime of 25 years for a general cargo ship. The average number of crew is 17. Recommendations for decision-making (step 5 of the FSA) were suggested based on the cost-benefit assessment of risk control options carried out in step 4 and on the evaluation criteria GCAF < US$3 million and NCAF < US$3 million. Considerations on the potential for risk reduction that can be provided by each evaluated risk control option were also taken into account in making recommendations.

4 Description of the results achieved in each step

4.1 *Step 1 – Hazard Identification*

The general cargo ship related hazards were identified by a comprehensive investigation of casualty reports provided by LRF and GISIS databases. The sample regarded to be representative for risk of general cargo ship is characterized as follows:

.1 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);

.2 A gross tonnage greater than 499;

.3 Classed by IACS society (based on the assignment in LRF 2009); and

.4 Casualty reports for IACS classed ships and classified as "severe" accident.

The statistical investigation yields that the risk of general cargo ships is mainly related to foundering, collision and wrecked/stranded accidents that contribute about 85% of all fatalities and about 85% of all ship losses.

In order to identify the accident causes for these major risk contributors GISIS investigation reports submitted by flag States were analysed. Therefore, collisions are mainly caused by the following sources:

.1 human (18 or 55% of all accidents with specified causes);

.2 steering (4 or 12% of all accidents with specified causes);

.3 machinery/Engine (3 or 9% of all accidents with specified causes); and

.4 anchor (4 or 12% of all accidents with specified causes)/Mooring (3 or 9% of all accidents with specified causes).

It might be notable that 27 of 240 (11% of all accidents) collisions 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 summarized below:

.1 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;

.2 negligence to keep a sufficient lookout;

.3 the lookout on the bridge of M/V Y had been sent to carry out cleaning duties elsewhere on the ship; and

.4 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 influence for promoting 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. Foundering accidents are mostly related to:

.1 capsize: 8% corresponding to a frequency $6.9\ 10^{-5}$ per ship year;

.2 loading error: 5% ($4.6\ 10^{-5}$ per ship year);

.3 cargo shift (including listing): 45% ($3.9\ 10^{-4}$ per ship year); and

.4 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 average foundering frequency for ships built between 1981 and 1992 is about five times higher than for the ships built between 1991 and 2009.

For accidents of the category wrecked/stranded the main causes are:

.1 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 aggravated 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, 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 a.m. and 6 a.m. 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 accident causes were mentioned in the reports:

    .1 fatigue (13% of all);

    .2 wrong positioning or missing course change (9% of all);

    .3 wrong usage of ECDIS (2% of all).

.2 Machinery (23 accidents corresponding to ~25% of accidents with known causes) and steering (10; ~11%) failures: machinery or mechanical failures and steering failures cause a loss of manoeuvrability and, hence, easily led 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. In some cases the steering problems were caused by contacts of the rudder.

.3 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 does 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.

4.2 *STEP 2 – Risk Analysis*

Based on step 1 of the FSA high level generic risk models were developed for the accident categories collision, contact, fire and explosion, foundering, hull, machinery, wrecked/ stranded. The initiating frequencies were estimated on the basis of the statistical investigations (Table 0-1). The expected consequences for each of the identified scenarios were identified by the casualty reports. The development of the risk models is based on high level risk contribution model. The models for collision and wrecked stranded are illustrated in Figure 0-1 to Figure 0-3.

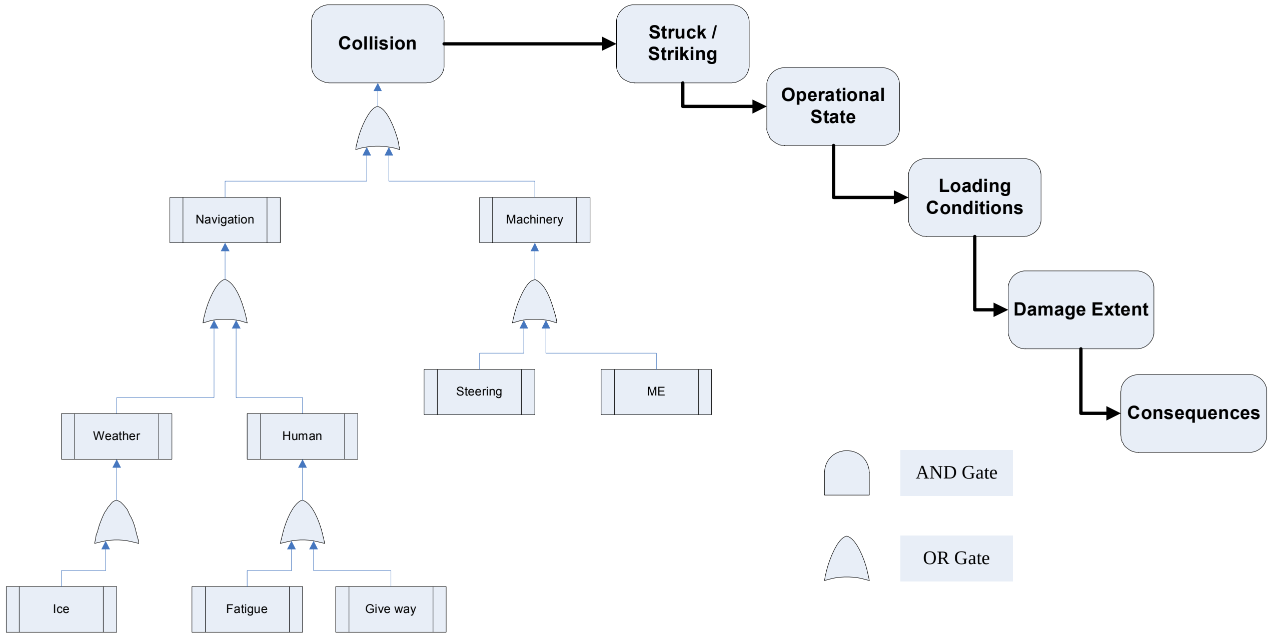

Figure 0-1: High-level generic scenario aspects for *Collision (CN)*

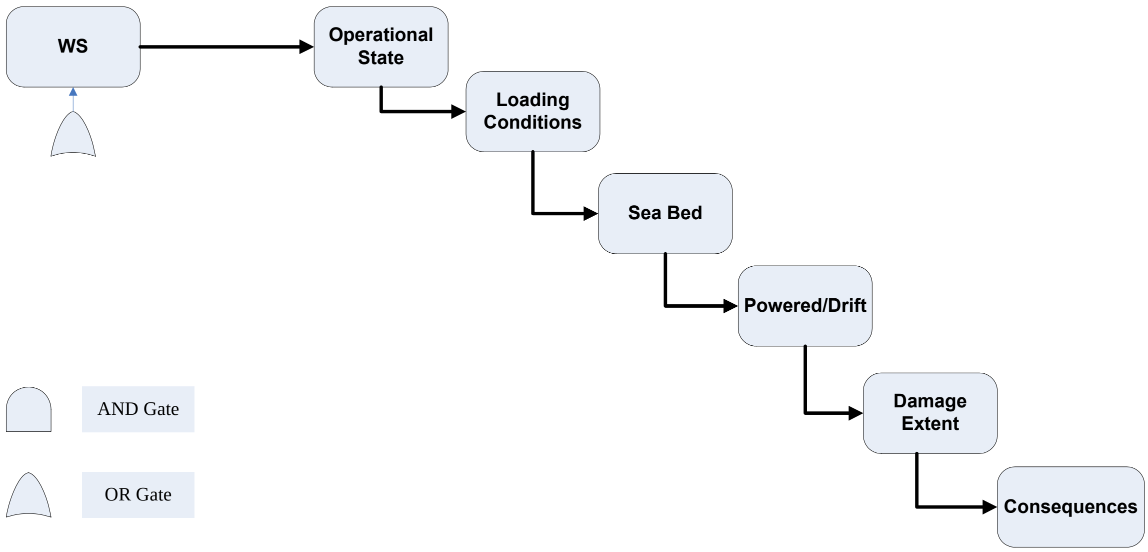

Figure 0-2: High-level generic accident scenario aspects for *Wrecked/Stranded (WS)*

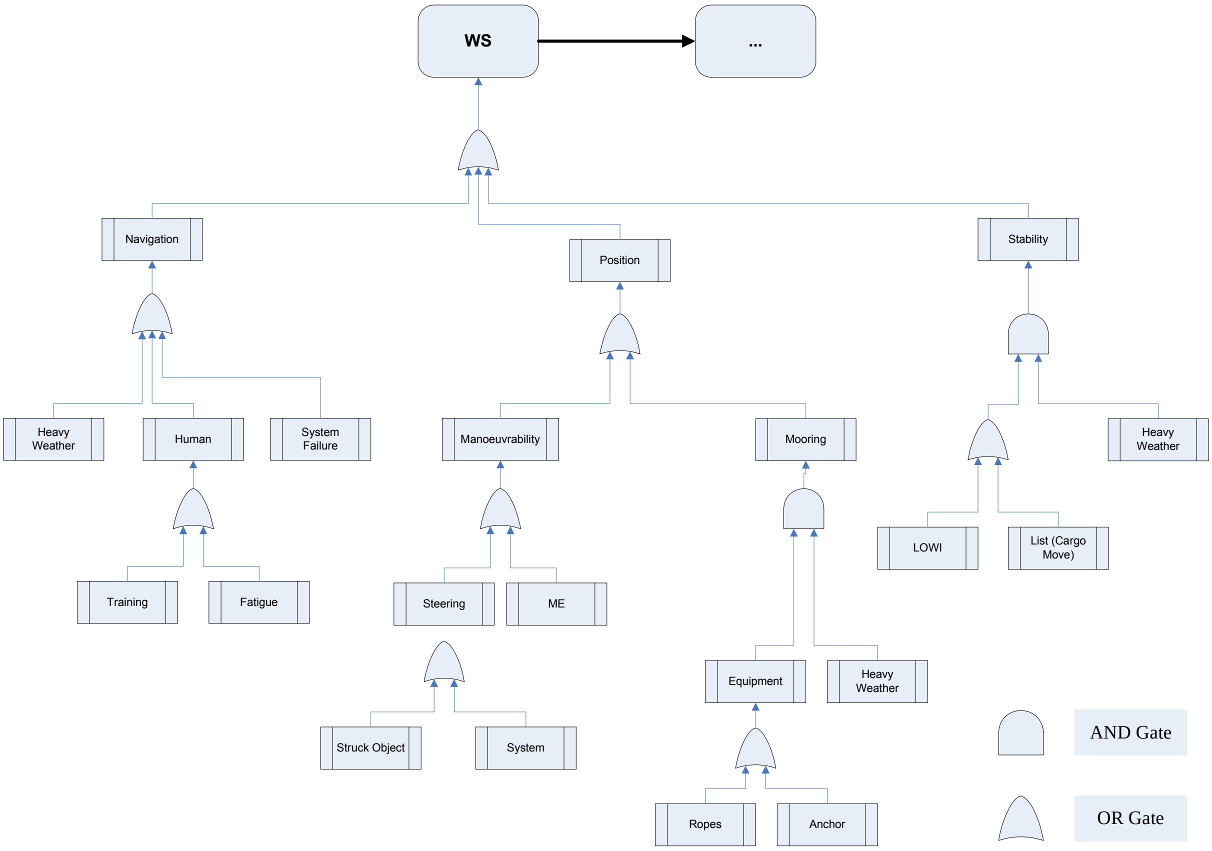

Figure 0-3: High-level generic fault tree for causes of *Wrecked/Stranded (WS)* accidents (updated)

4.3 *STEP 3 – Identification of risk control options*

A two-day brainstorming session was carried out (18 and 19 March 2010) to identify potential risk control options. In this session, the results of steps 1 and 2 as well as the information summarized 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. In total 32 RCOs were proposed by the experts, of which 20 were considered in the following steps of the FSA. These RCOs are:

RCO 2 ECDIS with AIS and Radar for small ships (new building);
RCO 3 2nd RADAR for ships within 500~3,000 GT;
RCO 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 Convention No. 180 Articles 5 and 7. The survey and control of current requirements should be correctly implemented);
RCO 6 Optimized/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);
RCO 8 Improve preparation (including improved information) and handling of ship for manoeuvring in restricted waters (crew and pilot preparation);
RCO 9 Pilot simulator training;
RCO 12 Voyage Data Recorder for small vessels (500~3,000 GT);
RCO 13 Weather routeing;

RCO 16 Increased Required index, R, or stability criteria/requirements;
RCO 17 Improvement of cargo stowage especially bulk (other than grain) and heavy items;
RCO 18 Coating requirements for areas of low accessibility;
RCO 19 ESP implemented on GCS;
RCO 20 Improved PSC inspector training on GCS;
RCO 21 Reduced BWT (Ballast Water Tank) size;
RCO 23 Simulator training for increasing situational awareness (i.e. anchor dragging);
RCO 26 ECDIS training of all OOW;
RCO 27 Anchoring watch alarm integrated in ECDIS;
RCO 28 Checklist for maintenance procedures;
RCO 31 Smoke detector in cabins; and
RCO 32 Combine watch alarm with autopilot.

A detailed description of the RCOs is available in document MSC 88/INF.6.

4.4 *STEP 4 – Cost-benefit assessment*

The objective for the cost-benefit assessment is to evaluate the cost-effectiveness or cost-benefit of implementing the risk control options identified in the previous step. Cost-effectiveness means that the relation between costs of implementation and achievable risk reduction is below a certain threshold. Performing a cost-effectiveness assessment requires an estimation of the risk reduction of an RCO (effectiveness) and the costs of implementation as well as benefits. The thresholds against which the cost-effectiveness is assessed are GCAF and NCAF as specified in the FSA Guidelines (MSC 83/INF.2). The potential of risk reduction was estimated by the experts independently. In the analysis average values were used. Upper and lower bound values were considered in the sensitivity analysis. Cost estimates for the RCOs as well as the property related consequences have been determined based on information from suppliers, service providers, training centres, yards or technical experts where appropriate. The economic benefit and risk reduction ascribed to each risk control options were based on the event trees developed during the risk analysis and on considerations on which accident scenarios would be affected. As a basis for the cost-benefit calculations, the following important assumptions were made:

.1 the typical number of crew: 17;

.2 the average lifetime of a general cargo ship: 25 years; and

.3 depreciation rate: 5%.

All numbers are based on introduction of one risk control option only. Introduction of more than one risk control option will lead to higher NCAF/GCAFs for other risk control options addressing the same accident scenarios as the remaining risk will be less. The costs and risk reductions with respect to life and property (benefit) for each RCO are summarized in the following table.

Table 0-1: Summarized results of CBA

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 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

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

.1 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. Percentiles are based on a Monte Carlo simulation for the different parameters and their respective distributions;

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

.3 the probability of the accident as shown in the following table:

Table 0-2: Lower and upper bound values of accident frequency used in sensitivity analysis			
Accident category	**Frequency per ship year**		
	Mean	**Min**	**Max**
Collision (CN)	5.5 E-03	4.8 E-03	6.3 E-03
Contact (CT)	2.3 E-03	1.9 E-03	2.8 E-03
Foundering (FD)	1.5 E-03	1.1 E-03	1.9 E-03
Fire/explosion (FX)	2.7 E-03	2.2 E-03	3.2 E-03
Hull damage (HD)	2.0 E-03	1.6 E-03	2.5 E-03
Machinery damage (MD)	1.2 E-02	1.1 E-02	1.3 E-02
Wreck/Stranding (WS)	7.5 E-03	6.7 E-03	8.4 E-03

.4 the minimum and maximum values of the effectiveness of the RCOs.

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 sensitivity analysis show that the CBA result for the RCOS 27, 20 and 32 are robust (always below the thresholds). For the CBA with minimum values RCO 28 is also assessed to be cost-effective, whereas RCO 17 is slightly above the threshold of GCAF. For the maximum values RCO 19 and RCO 26 are evaluated to be cost-effective, whereas RCO 17 is slightly above the threshold.

4.5 *STEP 5 – Recommendations*

The results for the RCOs are summarized in Table 0-1 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 US$3 million (MSC 83/INF.2). Hence, all RCOs below this threshold are regarded cost-effective, which are:

.1 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 included in RCO 2 the NCAF value of RCO 2 is further reduced (to -US$1.1 million);

.2 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 (US$125/year). However, the effect on foundering accidents (mainly caused by water ingress) is expected to be significant. The NCAF value is negative.

.3 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.

These RCOs are also recommended by the sensitivity analysis (GCAF always < US$3 million) and the calculated benefit is higher than the installation costs (always negative NCAF).

The following RCOs are recommended based on a negative NCAF value:

.1 RCO 28 (operational/training): Checklist for maintenance procedures. This RCO has relatively low cost and small risk reduction with respect to life. With US$3.67 million, the GCAF value is slightly above the threshold. However, due to the negative NCAF value is considered to be beneficial in saving the property.

.2 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. The GCAF value for this RCO is US$4.6 million.

.3 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 are also small and hence it is evaluated as beneficial.

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

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

.1 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. By this risk control option the stowage of the cargo as well as the damage stability is improved;

.2 RCO 19 (operational/training): Extended survey on GCS. NCAF is about half of the threshold; and

.3 RCO 2 (technical): ECDIS with AIS and RADAR (only for new ships): the NCAF value is less than 1/10 of the threshold.

However, from the sensitivity analysis it is shown that RCO 19, RCO 2, RCO 26 and RCO 8 do not have always an NCAF value below the US$3 million threshold.

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