On formal safety assessment (FSA) procedure

Hermanski, G.; Daley, C.

Publisher's version / Version de l'éditeur:

7th Canadian Marine Hydromechanics and Structures Conference [Proceedings], 2005

On Formal Safety Assessment (FSA) Procedure

Greg Hermanski [1], Dr. Claude Daley [2]

[1] *Institute for Ocean Technology National Research Canada*
St.John's, NL. A1B 3B5, Canada

[2] *Faculty of Engineering and Applied Science, Memorial University of Newfoundland*
St.John's, NL. A1B 3X5, Canada

Email: *greg.hermanski@nrc-cnrc.gc.ca*
cdaley@eng.mun.ca

ABSTRACT

The safety of vessels has been of concern to mariners for centuries. Concepts of vessel stability, the possibility of capsizing, and structural integrity have been recognized by shipbuilders and operators from the beginning of marine shipping industry. The concepts of metacenter and restoring arm as initial stability criteria for small heel angles and practical methodologies for their evaluation were introduced in 18th century.

The first safety regulations referred to sufficient height of the deck above waterline. The oldest traceable ship safety recommendations were found in the Venetian code of maritime law (13th century) requesting marking and inspection of the load line mark. In more modern days, during the second part of 18th century, Lloyd's Register of Shipping issued recommendations for the magnitude of freeboard, 2 to 3 inches per foot of the depth of cargo hold. The development of safety recommendations by the international community was based solely on freeboard criteria and this approach continued until the Titanic disaster. Historically, progress in the development of stability criteria was driven by response to the most publicized marine disasters. After the Titanic tragedy the first International Conference on the Safety of Life at Sea (SOLAS) took place in 1913-1914, but its recommendations on subdivision and damage stability were not adopted until the next SOLAS meeting in 1929.

After the 1987 capsizing of the "Herald of Free Enterprise" the need for more extensive shipping safety research was recognized. The 1992 report on the accident identified and recommended the need for replacement of prescriptive rules with performance based regulations. The UK Marine Safety Agency, in 1993, suggested to the IMO's Marine Safety Committee (MSC) the concept of formal safety assessment with respect to ship design and operations. The proposition was accepted and FSA became a high priority on the MSC agenda.

The Formal Safety Assessment process has been defined by the IMO as: Structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property by using risk analysis and cost benefit assessment. The method is applicable to consider the safety of vessels in a global sense (all systems) or to take into account subsystems or individual aspects of safe operations. It could be applied in situations where risk needs to be reduced but required decisions are not clearly defined and need to be analysed. It can be applied during ship design stages or to analyse single operational aspects of existing vessels. The process can be used to validate existing and/or new regulations developed applying prescriptive or risk based principles.

This paper discusses aspects of FSA procedures and its implementation into deployment and validation of alternative regulations for vessels.

2. INTRODUCTION

Safety generally can be understood as a measure undertaken to either minimize or eliminate hazardous conditions, to prevent accidents from happening and make the consequences of any accident less serious for ship (and those on board), cargo and environment. Historically accidents occur no matter how carefully safety procedures are planned and implemented. It should not, however, prevent engineers from designing and planning for the safest possible structures and their operations.

The safety of vessels has been of concern to mariners for centuries. Concepts of vessel stability, the possibility of capsizing and structural integrity have been recognized by shipbuilders and operators from the beginning of marine shipping industry. Archimedes first defined physical principles of stability for floating systems of simple geometry. The assessment of stability properties of a floating body of an arbitrary shape in its design stage became a general practice in 18th century due to work of Pierre Bouguer and Leonhard Euler. They independently proposed concepts of metacenter and restoring arm as initial stability criteria for small heel angles and developed practical methodologies for evaluating those criteria. Guillame Clairin-Deslauriers conducted first known recorded inclining test on the newly built naval ship. The test established the ship's GM at 1.8m [1].

From the regulatory point of view, the first safety rules referred to sufficient height of the deck above the waterline. The oldest traceable ship safety recommendations were found in the Venetian code of maritime law (13th century) requesting the marking and inspection of the load line symbol. In more modern days, during the second part of 18th century, Lloyd's Register of Shipping issued recommendations for the magnitude of freeboard, 2 to 3 inches per foot of the depth of cargo hold [2]. The development of safety recommendations based solely on freeboard criteria continued until the Titanic disaster.

Historically, international and national regulations are, for the most part, developed as a reaction to the most publicized publicly sensitive marine disasters as lessons learned. This approach tends to quickly fix a problem at hand to meet media/public-defined goals, but may not address the issue of safety in a global engineering sense.

Only after the capsizing of the naval ship CAPTAIN in 1870, and the loss of six fishing vessels in Germany in 1894 was it realized that the metacentric height was not a sufficient measure of stability. Recommendations for the minimum value and range of the righting arm were developed and issued [2].

The 1878 sinking of the excursion steamer Princess Alice after collision with the cargo ship Bywell Castle and the resulting loss of 640 passengers brought attention to need for watertight bulkheads [3].

After the Titanic tragedy (1912) the first International Conference on the Safety of Life at Sea took place in 1913-1914. It set standards for safe navigation, construction of ships, fitting of radio, life-saving equipment and protection from fire. There have been four more SOLAS conventions expanding the safety rules in many areas. Recommendations on subdivision and damage stability were adopted at the next SOLAS meeting in 1929. The 1960 SOLAS recommended to the Intergovernmental Maritime Consulting Organization (IMCO, IMO from 1982) development of intact stability standards for passenger, cargo ships and fishing vessels. Until then the SOLAS Convention did not directly referred to the intact stability, except that they included the provision that the stability information must be provided to the master.

The response to disasters like that of the Morro Castle (1934) has been to built ships in which fire is less likely to break out and spread and to ensure that, if it does, it is detected early. Fireproof doors and bulkheads are part of ship structure, smoke alarms and heat detectors are placed at key locations and sprinkle systems have been installed since [3].

Pollution from Torrey Canyon tanker disaster (1964) inspired construction of double hull tankers hoping that double skin would prevent the cargo spill and devastation of the environment [3].

In 1992 Lord Carver's House of Lords committee published a report on the Safety Aspects of Ship Design and Technology in the wake of the British car ferry Herald of Free Enterprises accident (1987) where within 90 seconds the vessels had settled on her side on the bottom of the sea and a total of 193 lives were lost as a result of leaving the bow door to the car deck open after the ship left port. The report concluded that modern science and technology were not adequately used to improve safety within the shipping industry. The committee recommended, for all commercial vessels, the application of goal-based safety founded on quantitatively assessed risks and cost benefit analysis. The final conclusions referenced safety practises implemented by other industries, especially the nuclear, chemical and offshore business [3].

The UK government follow up on those recommendations. They understood the international aspect of the notion and prepared a submission to 62nd session of IMO's Maritime Safety Committee (MSC

62) as a concept of Formal Safety Assessment (FSA) in 1993. The concept was presented as applicable for safety analysis of individual ships but also as a tool in decision-making process, in formulating new and amended rules for shipping in general. The original Formal Safety Assessment concept was, at least partially, developed after the Piper Alpha catastrophe in 1988 [4] in which an offshore platform exploded in the North Sea and 167 people lost their lives. In their proposal the UK delegation used the experience of the offshore industry.

2. IMO'S APPROACH TO NOTION OF FORMAL SAFETY ASSESSMENT

The UK government submission to MSC was successful and was supported by the majority of member organizations. The method was described as a rational and systematic process for assessing any risks related to shipping activities and for evaluating costs and benefits of different options for identified risks reduction.

The process of FSA implementation into IMO MSC activities was as follow:

- MSC 62 (1993) UK submission of FSA concept.
- MSC 68 (1997), the committee approves draft Interim Guidelines (MSC/Circ.829-MEPC/Circ.335) for application of FSA to IMO's rule making process and trials for assessing FSA usefulness.
- MSC 70 (1998), the MSC agreed to carry out FSA study of bulk carriers by IMO Member States in collaboration with observer organizations.
- MSC 74 (2001), the committee approves MSC/Circ.1023-MEPC/Circ.392 guidelines for formal safety assessment in IMO's decision-making process [5].
- MSC 75 (2002), based on completed bulk carriers FSA studies the MSC approves list of 25 recommendations for decision-making concerning hull envelope, closing appliances, evacuation and operations.
- MSC 80 (2005), the MSC agrees to establish an FSA Group of Experts for the purpose of reviewing of a FSA study if the committee plans to use the study for making decision on a particular issue.

The FSA subject is still a high priority item on IMO MSC agenda. The MSC 80 established the FSA correspondence group's term of reference containing discussion of amendments to present FSA guidelines and including details of the FSA review process, risk acceptance criteria, issues related to environment protection in connection to outcome of MEPC 53, as well as possible links between FSA and Goal Based Standards (GBS).

3. FORMAL SAFETY ASSESSMENT PROCESS

The purpose of FSA is to create a tool that could be used by IMO or other international and national regulatory authorities and class societies to create new or evaluate existing regulations based on hazard probabilities and consequences, risks and cost effectiveness, all with the aim of comparing alternatives. It aims at improving marine safety including protection of life, environment and property. The method is applicable to validate existing and/or new regulations developed applying prescriptive or risk based principles. It could be also applied in situations where risk needs to be reduced but required decisions are not clearly defined and needs to be analysed. The FSA can be used as a proactive tool that could be applied to evaluate safety of ship systems in a generic and/or holistic sense in their design stages or for existing ships. The process is applicable to consider safety of a ship's subsystem or individual aspects of shipping operations. The FSA will quantify safety based on a hazard's probabilities and society's acceptable risk levels. The process is envisioned as being objective and transparent with all assumptions and uncertainties clearly identified and defined up front for their validation and acceptance or rejection.

The formal FSA process should comprise five following steps:

- Hazards identification
- Assessment of risks associated with those hazards
- Consideration of risk control options
- Cost benefit assessment of risk control options
- Decision on implementation of risk control option.

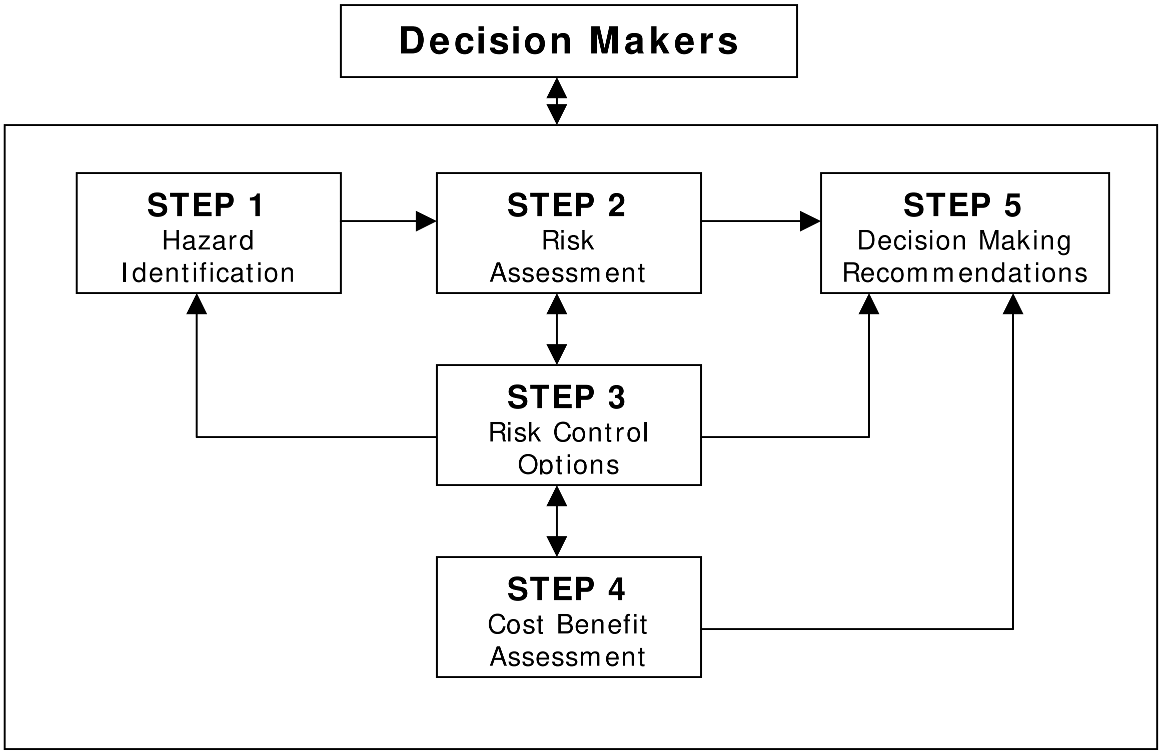

Figure 1. Flow chart of the FSA process [5].

In general, any FSA process should be initiated by defining the purpose and objective of the study. The scope of the analysis should refer to ship type and size, operational specification, type of hazards, risk acceptance criteria and available historical data, so, that all aspects of the problem are included and uncertainties can be considered. The type of risk information refers to individual or societal risks and hazard refers to personal, marine environmental and/or property. The historical data refers to accidents database, near miss situations and operational failures. In cases when appropriate historical data is not available, expert opinion, physical or numerical modeling and/or analytical models can be used to obtain the required information.

3.1 FSA Step 1 – Hazard(s) Identification

In a common formal safety assessment a hazard is defined as "a physical situation with potential for human injury, damage to property, damage to environment or some combination". With respect to ship formal safety assessment an accident can be defined as " status of the vessel, at the stage where it become a reportable incident which has the potential to progress to loss of life, major environmental damage and/or loss of the vessel" [4].

The goal of step 1 is to identify and prioritize, by risk level, causes of accidents and their associated scenarios relevant to the problem under review. The approach should assure that the process is proactive and not limited to past experience only. Information to achieve this goal can be obtained by analysis of historical accident data, near miss data and experts' consultation sessions. Experts in both FSA analysis and the relevant domain should carry out the task and qualitative and quantitative should be considered.

Several techniques are available to carry on and document the process [6]: Hazard and Operability Studies (HAZOP), Failure Mode and Effect Analysis (FMEA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA). The hazards should be categorized and prioritized. The prioritization of identified hazards can be achieved using a generic risk matrix with defined hazard probabilities (frequency) and consequences.

An example of a risk matrix is shown in Figure 2. It can be used as tool for prioritizing risks. Qualitative

FREQUENCY

	Minor	Significant	Severe	Catastrophic
Frequent	A	M	U	HIGH RISK (U)
Reasonably Probable	A	M	U	U
Remote	A	A	M	U
Extremely Remote	LOW RISK (A)	A	A	M

CONSEQUENCES

Figure 2. Example of Risk Matrix

or quantitative indexes can be used to define frequency and consequences and resultant risks can be defined as acceptable (A), marginal (M) and unacceptable (U) in a qualitative method.

The prioritized list of hazards and possible accident scenarios provides the input to Risk Analysis.

3.2 FSA Step 2 - Risk Assessment:

The purpose of this phase is to identify the distribution of risks, and conduct causes and consequences analysis for the most important scenarios identified in step 1. This allows focusing on areas of the highest risk and factors affecting the risk the most. Risk is a product of accident probability and its consequences.

With respect to human life, the risk must be considered in terms of individual risk and societal risk. When a large number of people are exposed to or affected by a possible accident, societal risk acceptance criteria should be considered. In the shipping industry this could be a passenger on a cruise ship, crewmember, port employees or society at large. Societal risks can be expressed in terms of frequency versus number of fatalities and usually are presented in format of FN diagram or risk matrix.

When an individual or a group of individuals are exposed to hazards imposed by the system, criteria based on individual risks could be more suitable. Individual risks could be related to occupational risk due to work related hazards and include risks of death, injury or ill health. This would comprise a crewmember or passenger on board the ship or other parties affected by an accident. Individual risks can be presented in the form of probabilities per unit of time (year). The level of risk acceptable for an individual will depend on if the risk is taken voluntarily or involuntarily. Passengers on a ship have little control over risks and they are involuntarily exposed. A crewmember has chosen his work place and has been trained and educated to have some control over the working environment.

In certain situations for a large number of people involved in public activities risk of an accident can be described in terms of societal risk, however, some individuals can in addition be exposed to other hazards best described by individual risks. In order to assess acceptable level of safety, all risks, societal and individual, must be considered.

Establishing of explicit and qualitative risk criteria for the decision-making process in the shipping industry is a necessity and one of the most imperative items on IMO's agenda.

Individual risk criteria are very often established based on acceptable risk levels adopted by other industries. The societal acceptable risk criteria can be developed based on various principles. Absolute probabilistic risk criteria do not consider costs associated with them and they are formulated as a maximum level or risk that cannot be exceeded. For example frequency of death, due to a hazardous situation, should not be higher than 10^{-6} per person-year. Another method for establishing (determining) acceptable criteria is the ALARP (as low as reasonably practical) approach. It assumes that risks should be as low as reasonably practicable and both risks and costs of risk mitigation are considered.

From the pragmatic point of view, three levels of risk are presently broadly recognized:

- Intolerable (unacceptable risk that cannot be justified except for extraordinary circumstances)
- Tolerable (all risks should be in ALARP region)
- Negligible (broadly acceptable, so small that no action is necessary)

When determining intolerable, tolerable and negligible risk levels for specific circumstances, all individual and societal risks should be taken into account.

The following example individual risk criteria were proposed by Norway and submitted to IMO in 2000 [8]:

1. Boundary between broadly acceptable and tolerable risk, 10^{-6} per year
2. Maximum tolerable risk for workers (crew member), 10^{-3} per year
3. Maximum tolerable risk for public (passenger), 10^{-4} per year

The proposal matches well other available statistical data. In Great Britain an annual fatality rate was 7.9×10^{-6} for all industries in 2002/03. An average fatality rate for EU states for year 2000 was 2.8×10^{-5}, and for Norway 2.1×10^{-5}. All the above individual risk statistics are within proposed ALARP boundary limits. Individual risks were also presented for shipping. Most of them were within ALARP region, however, only ship accidents were accounted for and no data from fishing and passenger ships was included (Figure 3).

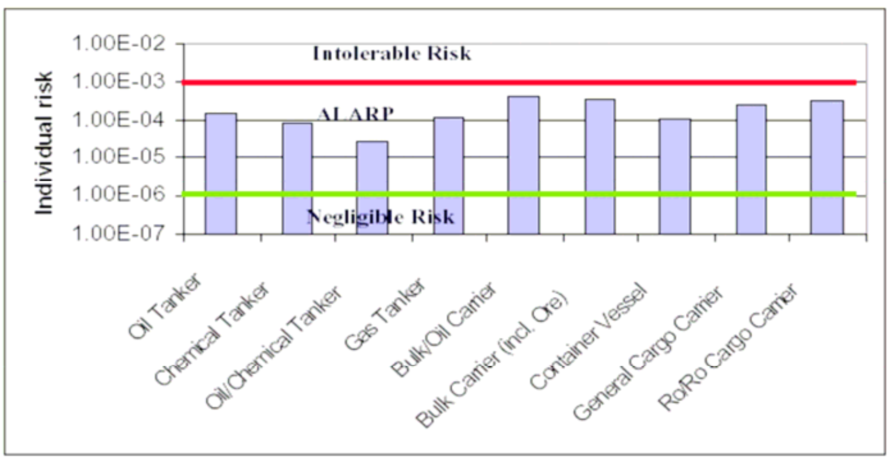

Figure 3. Individual fatality risk (annual) for crew of different ship types, shown with the proposed individual risk acceptance criteria [8].

Development of societal risk criteria is more complicated than the individual risk criteria and must consider the frequency of accidents and the severity of their consequences. One of the methods adopted for that purpose is the use of criterion lines in conjunction with FN curves (Figure 4). FN curves represent the number of fatalities N and the probability of accident with N or more fatalities. Criterion lines (broken limit lines) are defined by anchor points and the slope. Based on studies conducted in Norway [8] anchor points for different type of ships were proposed as follow:

	N	Frequency
Tankers:		
Boundary between negligible and tolerable (ALARP) risk	10,	2×10^{-5}
Boundary between tolerable and intolerable risk	10,	2×10^{-3}
Bulk and ore carriers:		
Boundary between negligible and tolerable (ALARP) risk	10,	10^{-5}
Boundary between tolerable and intolerable risk	10,	10^{-3}
Passenger ro-ro ships:		
Boundary between negligible and tolerable (ALARP) risk	10,	10^{-4}
Boundary between tolerable and intolerable risk	10,	2×10^{-2}

The slope of the FN criterion lines is usually between –1 and –2 on a log-log diagram. Referring again to the study [8] a slope equal to –1 is recommended. It tends to represents scenarios of more frequent accidents with fewer fatalities which potentially are as intolerable as fewer accidents with more fatalities. Output of step 2 includes identified high-risk area(s) that needs to be addressed to bring risks to levels acceptable to society.

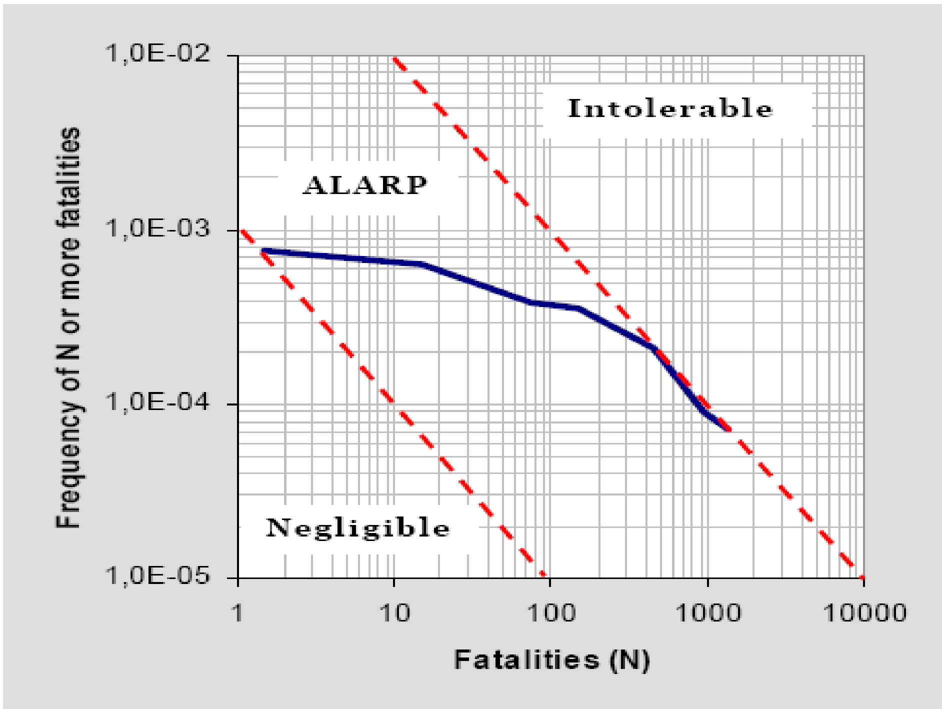

Figure 4. FN curve (example) with two probabilistic values for negligible and intolerable risks with ALAPR area in between.

3.3 FSA Step 3 – Risk Control Options (RCOs)

The aim of step 3 is to identify the range of options to control risks. Risk control measure (RCMs) can control single element of risk, reduce the likelihood of an accident or mitigate the possible consequences. The risk control option is an appropriate combination

of risk control measures. The selected RCOs should address historical risks and new risks recognized in

foreseen accident scenarios. The effort should focus on areas needing control. They should be selected based on:

- Risk levels (accidents with unacceptable risk levels are of high priority),
- Probability of occurrence (high frequency should be controlled irrespectively of severity),
- Severity (high severity should be controlled irrespectively of probability)
- Uncertainty (high uncertainty in frequency and consequences)

New RCMs should be identified for risks that are not satisfactorily controlled by current measures. RCMs in general should aim at reducing frequency of failure and mitigate their consequences. They should be grouped into practical RCOs with goals to control the likelihood of initiation of an accident and/or escalation of accidents.

The outcome of step 3 is a range of RCOs that are assessed for their effectiveness in reducing risk and a list of hazards affected by those RCOs.

3.4 FSA Step 4 – Cost Benefit Assessment

The purpose of step 4 is to estimate and compare benefits and costs associated with implementation of RCOs identified in step 3. Costs of risk reduction and willingness to pay such costs could become the criteria for defining the reasonable risk (ALARP) area.

Costs with regard to individual and societal risks could be expressed in terms of the cost of averting fatality, cost per-life-saved, value of life and should include initial, operating, training, inspection, certification, decommissioning and other elements. Benefits may include reduction in fatalities, injuries, environmental damage, liabilities, and increase in the average life of the ship.

The IMO recommended indices for presentation of RCOs cost effectiveness in relation to safety of life are Gross Cost of Averting a Fatality (GCAF) and Net Cost of Averting a Fatality (NCAF). They are defined as:

$$\mathrm{GrossCAF} = \frac{\Delta C}{\Delta R}$$

and

$$\mathrm{NetCAF} = \frac{\Delta C - \Delta B}{\Delta R}$$

Where,

ΔC is the cost per RCO

ΔB is the economic benefit per ship from the implementation of RCO (this might include pollution prevention)

ΔR is the risk reduction per ship, in term of fatalities averted, implied by RCO.

The study [8] suggests CAF cost for use as acceptance criteria at US$ 3 million. For risks that are almost not tolerable the cost can jump up to US$ 8 million. Those costs were recommended to IMO but might not be globally acceptable. The most appropriate values will depend on geographic location, local economy, and type of activity and public tolerance of risk.

Conducted and published FSA studies [8] on bulk carriers indicate various GCAF and NCAF costs. For example FSA of double skin in all cargo hold for new construction and existing 10 years old bulk carriers show GCAF costs of US$ 0.8-1.1 million and 4.3-8.2 million respectively. The NCAF costs for the same study are reported to be US$ 0.1-0.4 million and 3.6-7.6 million correspondingly.

Both GCAF and NCAF criteria can be effectively used as the Cost Benefit Assessment tools. It is however recommended that GCAF be considered before NCAF. NCAF takes into consideration economic benefits of relevant RCOs. In some cases this approach could be biased due to overestimating of economic benefits of considered RCOs. NCAF could be applied when GCAF is within the accepted CAF range. In some studies, RCOs presented were associated with NCAF, which were very high and negative. This could mean that expected benefits were higher than the costs of RCO implementation (in monetary units) and/or that risk reduction potential ΔR was very low. Proposed RCOs with negative NCAF should always be considered from cost benefits and risk reduction potential point of views.

The purpose of RCA estimate is to provide data for decision making about RCOs. The output included costs and benefits for each considered RCO. The value judgment is left for the decision-makers on RCO implementation.

3.5 FSA Step 5 – Decisions

The purpose of this step is to provide recommendations on relevant safety subjects to decision makers. The recommendations should be based on comparison and ranking of hazards identified in step 1, risk analysis conducted in step 2, comparison of RCOs selected in step 3, and cost benefit analysis conducted in step 4. The rationale for recommendation should be based on the assumption of risk reduction to ALARP levels and cost effectiveness.

The output of the step 5 should be an unbiased and transparent comparison of RCOs based on cost effectiveness and reduction of risks to improve safety.

4. FSA APPLICATIONS

Since IMO published its interim guidelines on FSA (MSC/Circ.829-MEPC/Circ.335) in 1997 many FSA studies were conducted. Member governments, non-governmental observer organizations, International Association of Classification Societies (IACS) and individual class societies carried out variety of FSA studies. The purpose of those studies was to support international and national regulatory requirements for most concerned safety cases. The studies were carried out for various types of ships at holistic and generic level and for specific ship systems [7]. These studies resulted in development of innovative risk control options and many of them were used to develop or amend new regulations.

Examples (not a summary) of FSA studies and resultant RCOs influencing IMO regulations:

- RCOs regarding fore-end watertight integrity of bulk carriers submitted by IACS to MSC 74/5/4 (2001) :

  - Water ingress alarm in all cargo holds and forepeak

- Double side skin for all cargo holds, new and existing ships, and for cargo holds 1 and 2 only

- RCOs regarding life saving appliances for bulk carriers submitted by Norway and ICFTU to MSC 74/5/5/ (2001):
- Immersion suits for all personnel
- Free-fall lifeboats
- Redundant trained personnel

- RCOs regarding bulk carrier safety submitted by Japan to MSC 75/5/2/ (2002):
- Corrosion control of hold frame
- Double skin for ships less than 150 m in length

- RCOs regarding hatch covers of bulk carriers submitted by UK at MSC 76/5/3 (2002):
- Hatch cover strength increased by 30% above IACS requirements.

- RCOs regarding bulk carrier safety, international collaborative study, submitted by UK at MSC 76/5/5/ and described in MSC 76/INF.8 (2002):
- Increase hatch cover strength
- Improve coating system for greater protection against corrosion
- Improve crew training
- Enhance survey and inspection
- Port security inspections
- Weather routing
- Introduce double hull

- RCOs regarding navigational safety of large passenger ships submitted by Norway at NAV 50/11/1 (2004):
- Improvement to bridge design
- Electronic Chart Display and Information System
- Automatic Identification System

5. FSA SUMMARY

The FSA process has a potential to become a very functional tool supporting the decision-making process at IMO and national regulatory levels as well it could be applied as a proactive tool at the design stages to optimize risk and safety (costs at affordable levels) for new ship designs. FSA can be employed for generic and holistic ship analysis and to study individual ship systems or operations. However, this useful tool could be rather complicated, particularly when applied at generic or holistic levels.

The FSA is facing a few challenges. Critics of the process are using the following arguments based on observed limitations of the process [9]:

- Lack of IMO recommended acceptable risk criteria.
- FSA is time consuming and slows down decision process. Most studies conducted to date required at least one year to be completed. Assuming that most studies are still conducted as a response to an existing hazard(s) or an accident, public pressure for fast solution could make it a very stressful process.
- FSA could be a manipulative tool. It should be an independent and transparent study and all risk and cost assumptions, including uncertainties, should be clearly stated.
- Cost effective data is sensitive to time and geographic location. Analysis should present current costs and conservative cost estimates based on a predicted long-term approach.
- Lack or incompleteness of historical accident records and information on near-miss situations forces a need to rely on FSA experts' assessment to estimate acceptable risk levels, hazard probabilities and cost effectiveness. The obtained information could be unintentionally biased and relevant uncertainties must be estimated based on confidence in experts conducting the analysis.
- Costs of conducting FSA study are high. They, however, can be compensated by completeness and comprehensiveness of the approach.

ACKNOWLEDGEMENTS

The work was made possible with the support of funding from Transport Canada. In particular we acknowledge the input and support from Mr. Victor Santos-Pedro (TC).

REFERENCES

1. Nowacki, H., Ferreiro, L.D., "Historical Roots of the Theory of Hydrostatic Stability of Ships", 8th International Conference on the Stability of Ships and Ocean Vehicles (STAB 2003), Madrid, Spain, September 2003.
2. Kobylinski, L.K., Kastner, S., "Stability and Safety of Ships, Volume I: Regulation and Operation", Elsevier Ocean Engineering Book Series, Volume 9, 2003.
3. http://www.plimsoll.org/WrecksAndAccidents/ImprovingSafety/Accidents/default.asp#2
4. http://www.imo.org/HOME.html
5. IMO, "Guidelines for Formal Safety Assessment (FSA), for use in the IMO Rule-making Process", MSC/Crc.1023, MEPC/Circ.392, April 2002. http://www.imo.org/includes/blastDataOnly.asp/data_id%3D5111/1023-MEPC392.pdf
6. Wang, J., Sii, H.S., Pillay, A., Lee, J.A., "Formal Safety Assessment and Novel Supporting

Techniques – Maritime Applications”, The Royal Institute of Naval Architects, 2002.
7. Dasgupta. J., “Quality Management of Formal Safety Assessment (FSA) Process”, SNAME Transactions, Vol.111, pp. 331-352.
8. Skjong, R., Vanem, E., “Review of existing risk evaluation criteria”, Det Norske Veritas report T03-01-2004-09-15-REP-DNV-V2, 2004-10-15.
9. International Association of Classification Societies, “Formal Safety Assessment, Overview and IACS Experience”, Presentation at MSC 75, May16, 2002