Objective

*Identify risk control options to be implemented for large passenger ships, relating to safe navigation.*

Scope

This FSA will involve *risk estimates* for the accident scenarios; collision, contact, and powered grounding.

The *function* relates to safe navigation: The reliability of all supporting equipment relating to safe navigation including propulsion and steering failures. No risk control options relating to propulsion and steering will be included, but the risks will be included.

*Risk control options* will relate to the following aspects of safe navigation: Bridge layout, navigational equipment, procedures, manning and training.

The *ship* type will be large non-Ro-Ro passenger ships or cruise ship.

Background FSA

Formal Safety Assessment (FSA) has been developed at the International Maritime Organisation (IMO) based on an initiative in 1993, during the 62nd session of the IMO MSC by the UK Marine and Coastguard Agency (MCA). The proposal was to develop a five steps risk based approach to the development of IMO regulations.

In 1996 the IMO established a working group on FSA, and by 1997 a Circular on Interim Guidelines on the Application of FSA to the IMO Rule-making Process (MSC Circ. 829/MEPC Circ. 335) had been developed, which was adopted by the MSC and MEPC that year. Since then, a number of FSA trial applications have been carried out and presented to the IMO. Whilst not all the formal safety assessments have proved successful, the general methodology has matured and there has been a considerable learning effect in the organisation. Based on the experience gained, the FSA Guidelines were updated at MSC 74 (May-June 2001). It should also be noted
that the Work Group on Bulk Carrier safety (WG/BC) at MSC 74 received FSA studies by Norway, Japan and IACS. These studies were all carried out by similar methods showing that the understanding of FSA has now matured. The FSAs were able to identify a large number of cost-effective risk control options.

A standard presentation of the 5 steps of Formal Safety Assessment as compared to the current process may be found in Table 1.

<table>
<thead>
<tr>
<th>Steps</th>
<th>Layman terminology</th>
<th>Professional terminology</th>
<th>Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>What can go wrong?</td>
<td>Hazard identification</td>
<td>What went wrong?</td>
</tr>
<tr>
<td>Step 2a</td>
<td>How often or how likely?</td>
<td>Frequency and Probability estimation</td>
<td></td>
</tr>
<tr>
<td>Step 2b</td>
<td>How bad?</td>
<td>Consequence estimation</td>
<td></td>
</tr>
<tr>
<td>Step 2c</td>
<td>Can matters be improved?</td>
<td>Risk = Probability x Consequence</td>
<td>How can we fix this?</td>
</tr>
<tr>
<td>Step 3</td>
<td>What would it cost and how much better would it be?</td>
<td>Cost Benefit Assessment</td>
<td></td>
</tr>
<tr>
<td>Step 5</td>
<td>What action should be taken?</td>
<td>Decision</td>
<td>Decision</td>
</tr>
</tbody>
</table>

FSA is a structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property, by using risk and cost/benefit assessments.

FSA can be used as a tool to help in the evaluation of new safety regulations or making a comparison between existing and possibly improved regulations, with a view to achieving a balance between the various technical and operational issues, including the human element, and between safety and costs.

FSA is consistent with the current IMO decision-making process and provides a basis for making decisions in accordance with resolutions A.500(XII) "Objectives of the Organisation in the 1980's", and A.777(18) "Work Methods and Organisation of Work in Committees and their Subsidiary Bodies".

The decision makers at IMO, through FSA, will be able to appreciate the effect of proposed regulatory changes in terms of benefits (e.g. expected reduction of lives lost or of pollution) and related costs incurred for the industry as a whole and for individual parties affected by the decision. FSA should facilitate development of regulatory changes equitable to the various parties, thus aiding the achievement of consensus.

The FSA Guidelines are intended to outline the FSA methodology as a tool, which may be applied in the IMO rule-making process. In order that FSA can be consistently applied by different parties, it is important that the process is clearly documented and formally recorded in a uniform and systematic manner. This will ensure that the FSA process is transparent and can be understood by all parties irrespective of their experience in the application of risk assessment and related techniques.
Background Large Passenger Ship Safety

The Secretary-General of IMO took an initiative to look into the passenger ship safety at MSC 72/21, May 2000. The Secretary-General concluded that the time had come for the Organisation to undertake a global consideration of passenger ships’ safety issues, with particular emphasis on large cruise ships and suggested that, as in the case of bulk carrier safety, the matter might be kept under the Committee’s own auspices, possibly through an Ad Hoc working group. This work group was subsequently established at MSC 73 (December 2000) and reconvened during MSC 74 (May 2001).

The CG (73-74) agreed (MSC 74/4/1) that a three stage risk based approach should be used Identification of Hazards, Risk Assessment and Risk Control Options. It should be noted that this is steps 1 to 3 of an FSA.

Based on work in the CG (74-75) co-ordinated by US (MSC 75/4/X) it may be stated that the HAZID process has been carried out to a considerable extent, and the hazards have been ranked, although this FSA terminology is not used by the CG. All activities are based on expert judgement and subjective ranking. There is no quantification of risks, risk reductions or cost in the CG work, as required in the later stages of an FSA.

It is well known from the risk literature that such subjective ranking of risks may be biased by factors of up to 100 or 1000. This is evident from previously submitted HAZID documents to IMO. By simply converting the risk ranking to risk and comparing the result with historic data it may be realised that a well-qualified expert team may exaggerate the risks.

The risk conversion factors (RCF) that may be involved in the process are listed in Table 2, see Skjong and Wenthworth(2001).

<table>
<thead>
<tr>
<th>Table 2: Risk Characteristics and Risk Conversion Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Volition</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Severity</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Origin</td>
</tr>
<tr>
<td>Effect Manifestation</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Exposure Pattern</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Controllability</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Familiarity</td>
</tr>
<tr>
<td>Benefit</td>
</tr>
<tr>
<td>Necessity</td>
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<tr>
<td></td>
</tr>
</tbody>
</table>

The risk conversion factor in Table 2 represents the bias when two risks are ranked that are identical (in actual numbers) and only being different by one characteristic. For example the same risk would be judged a factor 100 higher if the
exposure was involuntary compared to a voluntary risks, assuming that all other characteristics are the same.

**Why Navigational Safety?**

The statistics gives the following picture of distribution on category of accidents:

- 30% of “all” total losses (LMIS),
- 50% of the claim cost (Swedish Club),
- 50% of the accidents in Canadian waters and
- 70% of accidents in Australian waters

were caused of collision, contact or grounding according to Ramsvik (1999). These are generic data broken down to accident cause and do not specifically relate to passenger ships.

For cruise ships larger than 4000 GT the accident statistics in LMIS is represented by only 73 accidents during the 1990-2000 period. This represented 230 ships in 1990 growing to 250 in 2000. The exposure represents a total of 2662 ship-years, according to DNV Report 2001-0855.

The loss matrix (see MSC 74/WP.19 “FSA Guidelines”) for a 75,000 GT cruise vessel is estimated in Table 3.

<table>
<thead>
<tr>
<th>Accident type</th>
<th>Human costs¹ ($ per ship year)</th>
<th>Environmental costs ($ per ship year)</th>
<th>Property damage costs ($ per ship year)</th>
<th>Total costs ($ per ship year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collision</td>
<td>39,000</td>
<td>180,000</td>
<td>220,000</td>
<td></td>
</tr>
<tr>
<td>Contact</td>
<td></td>
<td>64,000</td>
<td>64,000</td>
<td></td>
</tr>
<tr>
<td>Foundering</td>
<td></td>
<td>73,000</td>
<td>73,000</td>
<td></td>
</tr>
<tr>
<td>Fire/explosion</td>
<td>19,000</td>
<td>600,000</td>
<td>620,000</td>
<td></td>
</tr>
<tr>
<td>Hull/Machinery/Equipment</td>
<td>2,900</td>
<td>240,000</td>
<td>240,000</td>
<td></td>
</tr>
<tr>
<td>War loss/Hostilities</td>
<td></td>
<td>14,000</td>
<td>490,000</td>
<td>500,000</td>
</tr>
<tr>
<td>Wrecked/Stranded</td>
<td></td>
<td></td>
<td></td>
<td>500,000</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
<td></td>
<td></td>
<td>1,100,000</td>
</tr>
<tr>
<td>Occupational accidents</td>
<td>1,100,000</td>
<td>14,000</td>
<td>1,700,000</td>
<td>2,800,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,200,000</td>
<td>14,000</td>
<td>1,700,000</td>
<td>2,800,000</td>
</tr>
</tbody>
</table>

Again, it is seen that collisions and wrecked/stranded account for about 50% of the losses due to ship accidents. Probably, some of these accidents are caused by loss of propulsion or steering (drifting grounding). It should be noted that the data behind these historic risks should be treated as indications of the potential for risk reduction and not as a risk prediction. In reality one single large accident would radically change the historic database.

¹ Number of fatalities x $3 million
Comparison to scope suggested by the report from the correspondence group

The Correspondence Group Report MSC 75/4/X\(^2\) contains a number of strategic goals, objectives and areas for considerations. These goals, objectives and considerations will be covered as far as practical by the suggested FSA, and as limited by the scope in terms of risk estimates, function and Risk Control Options. The FSA will therefore aim to contribute to quantification of the risk reducing effect and cost of all concrete Risk Control Options that may materialise from the ongoing activity or as agreed in the project. The FSA will also serve as an evaluation of the ongoing prioritisation, which is largely reliant on subjective judgement by experts.

The following **Strategic Goals** are relevant (MSC 75/4/X):

1. Improve measures for the prevention of casualties such as collisions, groundings, fires and equipment failures.
2. Improve measures that address the human element in maritime casualties with a focus on design, operations, management and training.
3. Develop a regulatory framework for assessing alternative designs and arrangements so that new concepts and technologies may be permitted which provide a level of safety at least equivalent to that provided by the prescriptive regulations.

The FSA is of particular relevance to strategic goal No.3, which requires that the safety of approved ships be known. Otherwise the “safety equivalency” would be an equivalency to unknown and undocumented safety.

The following **Objectives** are relevant (as limited by the scope):

7. Review human element issues with regard to operations, management and training with a view towards improving safety.
8. Consider measures to ensure ships can safely proceed to port after a fire or flooding casualty.
9. Consider measures to improve prevention of groundings and collisions.

The issues referenced to NAV (MSC 74/WP06) will also be considered, as far as practical RCOs are suggested. These issues are:

**To consider measures to improve prevention of groundings and collisions.**

Tasks to be considered in accomplishing this objective include:

1. Awareness of water depth and squat issues.
2. Review availability of international aids to navigation for vessels operating in remote areas.
3. Review pilot and bridge team interface management issues.
4. Review bridge team resource management measures.
5. Quality and availability of hydrographic information for operation in remote areas.
6. Voyage planning issues.
7. Reliability of equipment issues.
8. Need for requiring modern navigation equipment to avoid collisions and groundings.

Other relevant areas for considerations referred to various sub-committees will also be considered.

Furthermore, the suggested FSA will deal with some of the issues referenced under General discussion in MSC/74/X, relating to:

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\(^2\) This is the report of the intersessional correspondence group to MSC 75, as circulated 2002-02-08
Defining acceptance criteria (see §19). A definition of acceptance criteria or at least a format of common decision parameters will be suggested. The decision parameters in MSC 72/16 will be used as a basis.

Rather than emphasising the improvement of safety measures both the effect and costs will be assessed (see §5.3)

There is no clear need to define large passenger ships. The philosophy should be that the potential risk should be controlled, stricter criteria may therefore apply for the large ships. (see §20)

**Suggested Approach**

The emerging risks relating to large passenger ships relate mainly to two observations

- high consequences (and thereby potentially high risks) are concentrated on fewer ships
- high consequences are less acceptable (the individual risk is not the problem, individuals are likely to be safer on a large passenger ship)

Additionally a number of other observations made in the various MSC documents describing trends are relevant to the FSA study. The trends in terms of probabilities per year and consequences will be assessed by FSA.

As a consequence of the two simple observations:

- the probability of the accident scenarios that could lead to large consequences should be reduced; a proactive approach is necessary

This does not imply that current ships are unsafe, it implies that current rules and regulations applied to larger ships may result in unacceptable or intolerable risks.

How much should the probabilities of the various accident scenarios be reduced? This should be answered by the FSA. Some general observations are of relevance. For example, risks are generally being reduced as a result of technological development. The reduction is to about 50% every 15 years. (It may be assumed that current regulations are on average 15/2 years old and the new rules will apply to ships built in 15/2 years. This result in a demand for a reduction to 50% of the present risk level within 15 years.)

It may further be assumed, however, that currents rules were developed for ships with 1500 passengers, and the next 15 years may have as much as 7500 (or 5 times more).

These two simple observations suggest a demand for a considerable risk reduction. This should be an aim. Only a complete FSA can document how this may be achieved in practice by implementing cost effective preventive and risk mitigating measures. This project aim to focus on the preventive measures.
TASKS

Task 1: Establish current risk level for passenger ships

A review of historic data will be made to present as much information as possible from available historic data. The data will be presented in tabular form by initiating events and by consequence. The format of a loss matrix will be used (see MSC 72/16 or the new FSA Guidelines in MSC 74/WP.19). The data will not be limited to those data relevant for this particular study but cover all recorded losses. The data sources are LMIS, Class data, DAMA, other national statistics and relevant accident reports.

Current risk levels can not be taken to represent the risk for large cruise ships, but a number of individual event and failure probabilities, and other details of a risk model, may be valid in a risk model also for large cruise ships. The historic risk data should also be used to validate parts of the model developed in the detailed FSA study.

For parts of the accident scenarios that are not analysed further in this FSA the historic data will be used to represent the generic large cruise ship. If other flagstates or NGOs carry out other part of the total FSA, these FSA results should be used to update the results from this study.

Deliverable: Report (May be submitted to IMO)

Task 2. Acceptable Risk

The primary concern related to the large cruise ships is the potential for large accidents. The accidents may occur in remote areas where the possibility for SAR assistance is very low or non-existing and the assistance from other ships would take considerable time. To recover a large number of people from the LSA would also be very time consuming.

The large passenger ships only compare to new concepts for e.g. floating cities or airports in their consequence potential. The task will therefore be to discuss and present the various aspects of risk acceptability that have been brought forward in the discussions about risk acceptability of other man made structures and systems with similar consequence potential.

There is a large amount of literature and ideas available. The project will carry out a literature search and produce and extract and recommendations. Some literature of relevance is:

- Bea, RG “Reliability criteria for new and existing platforms, OTC6312 1990
- MSC 72/16 “Decision parameters and Risk acceptance”
- Societal risk criteria presented by national regulatory agencies.

In addition, the literature review is likely to generate a longer list of relevant papers.
Deliverable: Societal risk criteria relevant for large passenger ships.

Task 3: Hazard identification and initial risk control options: FSA Step 1.

Hazard identification will be carried out for safe navigation. The method will be based on the Structured What IF Technique (SWIFT). The SWIFT exercise will also include an initial session on potential Risk Control Options (Step 3 of FSA), linking possible RCOs directly to hazards. An example of how the HAZID is carried out may be found in MSC 73/INF.7.

The HAZID meetings will be carried out both with navigation officers from cruise ship representing current minimum standards and from cruise ships representing state-of-the-art. This will be done to ensure a thorough understanding of all the relevant safety aspects.

A SWIFT meeting will take 3 days and approximately 10 persons will participate. The DNV resources are limited to one SWIFT facilitator and one SWIFT recorder (The SWIFT Report will be written in the meeting), in addition to one surveyor/expert on the topic analysed.

Deliverable: HAZID Report

Task 4: Establish risk model: FSA Step 2

A detailed model of systems and actions involved in avoiding collisions and grounding will be developed. The application of models already developed within DNV will be considered. The modelling will be based on task analysis of bridge operations related to avoidance of collision and powered grounding, and on reliability models of technical components related to drifting grounding. A study will also be carried out with respect to the special operations of large cruise ships, which may expose them to higher grounding risks than many other ship types. Whilst other ships spend much time in open sea, cruise ship operate in narrow waters more frequently (daily) and are often sailing during the nights.

The detailing of the model is based on the need to be able to analyse the effects of the RCOs.

The sources of information are many: Historic accident reports, models for probabilities of collision and grounding, MARCS for drifting grounding, models presented previously to MSC, and various internal DNV reports. The reason for the extensive use of models should be obvious: There are fortunately no recent historic accident data for large losses for the large passenger ships in Western waters, only some data on near misses, reliability data, etc. Due to the difference in operational patterns it is also generally of little value to use event statistics for other ship types in a cruise ship FSA without modelling the risk exposure properly.

Compared to historic risk levels, it is also necessary to quantify the effect of RCOs already implemented or that will be implemented shortly (in particular AIS and ECDIS).

It is repeated here that this project will not cover consequence reduction, which includes such important ship internal aspects as improved damaged stability, effectiveness of escape, improvement of means of evacuation. Neither will ship
external means be considered, e.g. improved SAR, emergency communication means etc. Emphasis will be on preventive measures.

Measures that are relevant to reduce grounding probabilities:

**Ship internal means:**
- Installation of approved Electronic Chart, Display and Information System (ECDIS), in combination with at least two of the following three systems: GPS (eventually DGPS), GLONASS or GALILEO.
- Bridge layout, improved workstation layout, man-machine interfaces, ergonomics, improved overview from the workstation.
- Improved manoeuvrability (e.g. bow and stern thrusters, azimuth thrusters).
- High system availability (Component reliability or redundancy.)
- Training on use of equipment.
- Bridge resource management.
- Two navigating officers on the bridge in narrow waters and in restricted visibility.
- Improved bridge procedures.

**Ship external means:**
- Define safe sailing lanes.
- Vessel Traffic System (VTS) for areas with heavy traffic.
- Extended use of pilots, eventually remote pilotage.

Measures to reduce collision probabilities.

**Ship internal means:**
- Integration of Automatic Identification System (AIS) and Automatic Radar Plotting Aid (ARPA) to provide real-time presentation of traffic pattern (Current ARPA may contain up to 2 minutes delays in updating speed and course of approaching vessels).
- Installation of redundant ARPA.
- Bridge layout, improved workstation layout, man-machine interfaces, ergonomics, improved overview from the workstation.
- Bridge resource management.
- Two navigating officers on the bridge in narrow waters, in restricted visibility and in congested waters.
- Improved training on COLREG, e.g. by use of simulators.
- Integrated system with radar and/or AIS image of other ships exhibited on the ECDIS display.

**Ship external means:**
- Flag state and Port state prosecution of violations (AIS identifies who).
- Define safe sailing lanes.
- Extension of Vessel Traffic System (VTS) for areas with heavy traffic.
- Speed limitation in certain areas.
- Extended use of pilots, eventually remote pilotage.

The risk control options listed under ship internal means are indicative of the risk control option that will be studied and therefore define requirements to the risk model.
(e.g. with respect to level of detail). Actual risk control options to be studied are decided in Task 5/Step 3.

Co-operation with a cruise ship operator is necessary in this task.

Deliverable: Draft Report

Task 5: Identify Risk Control Options. FSA Step 3

The results of the risk analysis will be presented to the team involved in the HAZID, strengthened with people with a design and equipment background, and with navigational experts. Selection of personnel will be based on the findings in Task 4/Step 2. A brainstorming on new Risk Control Options will be carried out.

The risk analysis itself should provide a number of possibilities for identifying RCOs. The tools are minimum cut set representations (common cause) from Fault Trees, causal chains, and numerical risk ranking.

Deliverable: New chapter in the draft report

Task 6: Cost Effectiveness Assessment: FSA Step 4

Cost effectiveness calculations for each Risk Control Option will be carried out. The task consist of:

- Deriving costing model
- Retrieving relevant data from yards, equipment suppliers and ship owners
- Carry out cost calculations
- Reiterate on a number of cases using the risk model in Task 4/Step 2

In principle it is not possible to give a good cost estimate before Task 5 is completed and the RCOs are identified. A reasonable number of RCOs may be assessed by the suggested budget.

Deliverable: New chapter in the draft report

Task 7: Reporting & Recommendations: FSA Step 5

The task is to report in agreement with the FSA standard reporting format and write a summary of recommendations.

A final review meeting will also be arranged.

Deliverable: FRA Report

Schedule
M is May 2002

Reporting to MSC 76 and MSC 77. Note that reporting to NAV may be as relevant.

Steering Committee meetings

**Financing**

As Joint Industry Project. NOK 325,000 per participant

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