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FSA for Cruise Ships – Subproject 4.1

Task 4.1.1 – Hazid identification

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Title: *FSA for Cruise Ships – Subproject 4.1. Task 4.1.1 – Hazid identification*

Executive summary:

Project objective

This subproject 4.1 is part of the larger Safedor Integrated Project in which the overall goal is to propose a new, or improved, regulatory framework which will permit the approval of innovative ships that challenge today's prescriptive regime of rules and regulations. This document only relates to HAZID identification, Task 4.1.1.

This document reviews existing risk evaluation criteria to help establish an indication of the acceptable / tolerable risk level for cruise vessels, and it looks at historical risk levels for cruise vessels, taking into account recorded accidents, public perception and information from the cruise industry.

Finally, this document provides results and discussions from two HAZID sessions which were conducted to identify various hazards relating to design and operation of cruise vessels which could lead to a large scale event.

Task 4.1.2 (risk analysis) and 4.1.3 (cost benefit analysis, recommendations) of this subproject will continue this project by using the results from this Task 4.1.1.

Risk acceptance criteria, CAF

According to established IMO criterion, a RCO (Risk Control Option) is considered cost-effective (and consequently suitable for recommendation) when the overall CAF is below $3 mill. The project team accept the generally accepted $3 mill impact from one fatality.

HAZID results (Task 4.1.1)

A HAZID has been preformed in order to establish the main risks related to cruise vessels operation and design. The historical risk levels for cruise vessels, taking into account recorded accidents, public perception and information from the cruise industry is used to form a picture of the risk exposure in the industry. The existing risk evaluation criterion is used to establish an indication of the acceptable / tolerable risk level for cruise vessels.

Two workshops were preformed by gathering a panel of different experts from the cruise industry to assess the risk exposure on cruise ships. One workshop dealt with the operation of the cruise vessel, and one looked at the design of the vessels.

A total of 118 hazards related to operation and design were identified, of which 12 hazards were prioritized based on their consequences and the possibility for finding cost effective risk reducing measures. This project focused on hazards with high consequences and low frequency rather than low consequences and high frequency.

The three major *operational* hazards identified are as following:

1. Tender boat failure – structural failure
2. Tender boat operations, in particular related to launching/heaving
3. Tender boat davit failure

The five major *collision* hazards identified:

1. Officer on duty not watch-keeping
2. Failure of critical navigational aids (in fog)

3. Severe loss of functionality (e.g. loss of rudder/steering at full speed, failure of shaft bearings)
4. Lack of knowledge of navigating procedures
5. Misinterpretation of bridge information

The five major *fire/explosion* hazards identified:

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

These hazards will be subject for further analysis later in this subproject 4.1.

Other issues from the subproject 4.1.1:

1. The highest level of industry experts has provided input to the hazid(s).
2. "High consequence hazards" have been identified that are relevant for design and operation of cruise vessels. That is, identified hazards cover potential high-consequence incidents, rather than low-consequence slips & fall hazards.
3. Hazards have been identified which are beyond the obvious, and which are not openly "evident" for most industry people.

Work carried out by	**Approved by**
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Contents

Abbreviations

ALARP	As Low As Reasonably Practicable
CAF	Cost of Averting one Fatality
CBA	Cost Benefit Analysis
DNV	Det Norske Veritas (www.dnv.com)
FSA	Formal Safety Assessment
HAZID	Hazard Identification
IMO	International Maritime Organization (www.imo.org)
LRFP	Lloyds Register Fairplay Database
NCAF	Net Cost of Averting a Fatality
SWIFT	Structured What-If Technique
VOAF	Value of Averting a Fatality

1 Introduction

1.1 *Project objective*

This subproject 4.1, FSA on cruise ships has many objectives, however this document only relates to HAZID identification, Task 4.1.1.

This document reviews existing risk evaluation criteria to help establish an indication of the acceptable / tolerable risk level for cruise vessels

This document looks at historical risk levels for cruise vessels, taking into account recorded accidents, public perception and information from the cruise industry.

Finally, this document provides results and discussions from two HAZID sessions which were conducted to identify various hazards relating to design and operation of cruise vessels which could lead to a large scale event.

The objective of this FSA (Formal Safety Assessment) project is to document the acceptable risk level for cruise vessels, including all major incident scenarios. Furthermore, this assessment looks to identify cost effective risk control options (RCO) for cruise ships, related to design and operation. These will be documented in deliverable D4.1.3.

1.2 *Background*

For cruise ships as well as for other types of ships, the likelihood of accident scenarios that could lead to large consequences should be reduced. This FSA project will therefore investigate preventive measures to reduce these likelihoods. Both preventive and mitigating measures related to design and operation of cruise ships will be analyzed.

This subproject 4.1 is part of the larger Safedor Integrated Project in which the overall goal is to propose a new, or improved, regulatory framework which will permit the approval of innovative ships that challenge today's prescriptive regime of rules and regulations. The aim is to improve the safety of maritime transportation and to increase European shipbuilding competitiveness through the integration of risk criteria within ship design and approval frameworks on a rational and cost-effective basis.

The general background and history of FSA methodology, possible applications, and so on, are not included in detail in this report (see IMO MSC/Circ 1023), yet a brief summary is included below.

The partners for this project are DNV and Carnival plc.

1.3 *Short explanation of FSA*

FSA is a structured and systematic risk based methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property by using risk and cost/benefit assessments. In 1997, IMO agreed on guidelines for use of risk assessment as a basis for developing maritime safety and environmental protection regulations.

FSA comprises the following main steps:

1. Identification of hazards
2. Risk assessment
3. Risk control options
4. Cost benefit assessment
5. Recommendations for decision making

The decision parameters including risk acceptance criteria are required in steps 4 and 5, when the FSA team present the result of cost benefit assessment and when the recommendations are formulated.

1.4 *Related SAFEDOR Tasks*

This SAFEDOR project (4.1) is divided into the following manageable work tasks:

Task 1 (4.1.1): Risk acceptance criteria

Historical risk level for cruise vessels

Hazid process – risk evaluation

Task 2 (4.1.2): Risk analysis (quantification of risk)

Task 3 (4.1.3): Risk control options

Cost benefit analysis

Reporting of the Tasks 4.1.1 comprise the remainder of this report. The Tasks 2 and 3 will be submitted in separate reports.

2 Risk Acceptance Criteria

This section reviews existing risk evaluation criteria to help establish an indication of the acceptable/tolerable risk level for cruise vessels based on history, public perception and the cruise industry's incidence records.

Furthermore the document looks at acceptable/tolerable risk levels for people onboard the vessel and acceptance for large accidents with a large number of fatalities.

The review is not limited to the maritime industry, as risk methods have a wide scope of application.

2.1 Introduction

Nearly all activities in life involve risk in some way or the other, and there is no universally agreed criteria for what levels of risk are acceptable. Nevertheless, identified and unidentified risks are always sought to be controlled, i.e. minimized. The most commonly used strategy for managing risk in the public interest is through legislation and regulation, although everyone is constantly voluntarily accepting risk in daily life on an individual level, both consciously as well as unconsciously.

However, risk reduction will generally come at a price and it will be necessary to trade-off between the level of risk one accepts to be exposed to and the cost one is willing to pay to mitigate the risk. For decision-makers responsible for the safety of the public, at the expense of the wealth of the public, this trade-off needs to be considered carefully and thoroughly. The overall objective is always to best allocate the society's limited resources for risk reduction, by supporting the implementation of efficient risk reduction measures and to avoid wasting efforts on inefficient ones i.e. resources should be targeted towards measures that make the largest risk reduction.

The subject of acceptable risk or risk acceptance criteria in relation to maritime safety and pollution prevention is a topic where little authoritative literature exists. Historically few accidents have occurred with cruise vessels. However, this does not necessarily mean that a certain event can not happen. Therefore studies often use statistics to coarsely calibrate results using modelling techniques. Although this is considered not to be the correct answer, it is a best estimate on what the actual risk levels may be.

It is important to make the distinction between risk tolerability and risk acceptability.

The general public accept risk when they undertake an activity by choice even when the activity is hazardous (including driving cars), but will only tolerate risk that they perceive to be imposed on them (e.g. when travelling by train). By contrast companies have to accept a level of risk attendant on their activities.

It is concluded from the above that this document should be dealing with risk tolerability levels as opposed to risk acceptability levels as this reflects the fact that the risks inherent in cruise ship operation are imposed on individuals rather than accepted by them.

An important principle in the following discussion is that formal risk criteria for which a business or operator could be expected to demonstrate compliance would be specified by a regulator. Risk targets, the numerical risk values to which a company aspires, would be set by the company taking due account of relevant criteria. This is important as it establishes the distinction between regulation (defined in the Concise Oxford Dictionary as 'a prescribed rule; an authoritative direction') and the process of risk management which current best practice believes should be understood and owned by those who own the risks (in this case the company or operator).

2.2 Available Literature

IMO

Within the maritime industry, decisions regarding matters that involve risk and safety are primarily made by the International Maritime Organisation (IMO). Within IMO the term 'risk evaluation criteria' is used rather than 'risk acceptance criteria'. This is because IMO decided to use this terminology in the revision of the IMO Formal Safety Assessment (FSA) guidelines after considerable debate. The terminology used reflects the observation that risks are not *accepted*; it is *decisions* involving risks that are accepted because their benefits outweigh the risks.

The FSA guidelines only contain a few sentences relating to risk acceptance. As no decision can ever be made based on a risk assessment without disclosing the risk criteria, IMO invited member countries to submit proposals for such criteria.

To date, although submissions have been made, IMO has not yet reached firm conclusions on this subject. Further debates will be required before making a decision on which parameters and acceptance criteria to include in the revised FSA Guidelines.

Two FSA's relating to large passenger ships has been submitted to IMO by Norway / ICCL:

- FSA on Helicopter Landing Area (HLA) for Passenger Vessels by Norway and ICCL, Report no 97-2053
- FSA on navigation for Passenger Vessels by Norway.

The full FSA report with all annexes and appendices can be downloaded from

http://www.dnv.com/research/transport_systems/safer_transport/rskjong.asp

In these studies a risk control option (RCO) is considered cost effective if the GrossCAF (Cost of Averting a Fatality) is less than **$3M**. According to the studies, 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 MSC 72/16.

HSE

Britain's Health and Safety Commission (HSC) and the Health and Safety Executive (HSE) are responsible for the regulation of almost all the risks to health and safety arising from work activity in Britain.

The principle source of health and safety legislation in the UK is the Heath and Safety at Work Act 1974. This act requires that employers (or duty holders) ensure so far as is reasonably practicable the health, safety and welfare of employees and others. This act has supported regulatory requirements that require a suitable and sufficient assessment of risk to be performed.

2.3 Tolerability of Risk

A framework known as the tolerability of risk is used for reaching decisions on whether risks from an activity or process are unacceptable, tolerable or broadly acceptable and its application in practice.

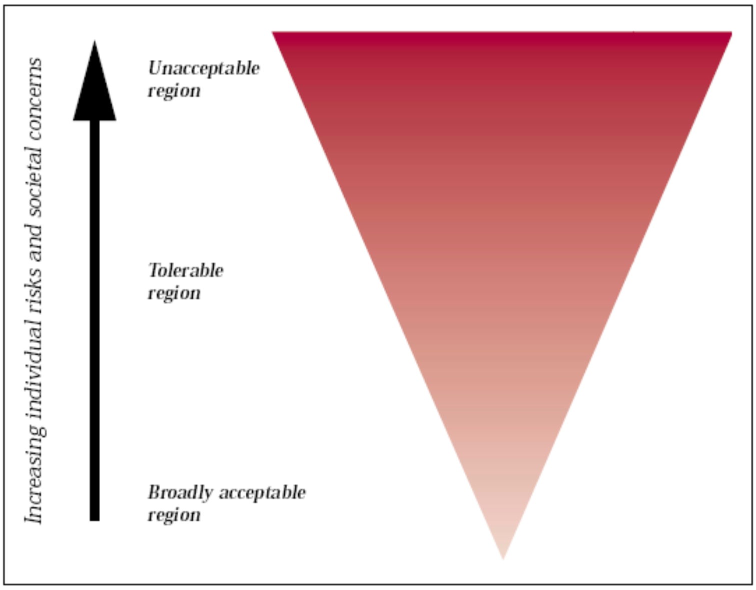


Figure 1: Framework for the tolerability of risk

The framework is illustrated in Figure 1. The triangle represents increasing level of ‘risk’ for a particular hazardous activity (measured by the individual risk and societal concerns it engenders) as we move from the bottom of the triangle towards the top. The dark zone at the top represents an **unacceptable region**. For practical purposes, a particular risk falling into that region is regarded as unacceptable whatever the level of benefits associated with the activity. Any activity or practice giving rise to risks falling in that region would, as a matter of principle, be ruled out unless the activity or practice can be modified to reduce the degree of risk so that it falls in one of the regions below, or there are exceptional reasons for the activity or practice to be retained.

The light zone at the bottom of the triangle, on the other hand, represents a **broadly acceptable region**. Risks falling into this region are generally regarded as insignificant and adequately controlled. Regulators would not usually require further action to reduce risks unless reasonably practicable measures are available. The levels of risk characterising this region are comparable to those that people regard as insignificant or trivial in their daily lives. They are typical of the risk from activities that are inherently not very hazardous or from hazardous activities that can be, and are, readily controlled to produce very low risks. Nonetheless, regulators would take into account that duty holders must reduce risks wherever it is reasonably practicable to do so, or where the law so requires it.

The zone between the unacceptable and broadly acceptable regions is the **tolerable region**. Risks in that region are typical of the risks from activities that people are prepared to tolerate in order to secure benefits, in the expectation that:

- The nature and level of the risks are properly assessed and the results used properly to determine control measures. The assessment of the risks needs to be based on the best available scientific evidence and, where evidence is lacking, on the best available scientific advice;
- The residual risks are not unduly high and kept As Low As is Reasonably Practicable (the ALARP principle); and
- The risks are periodically reviewed to ensure that they still meet the ALARP criteria, for example, by ascertaining whether further or new control measures need to be introduced to take into account changes over time, such as new knowledge about the risk or the availability of new techniques for reducing or eliminating risks.

It must be stressed that Figure 1 is a conceptual model. Moreover, the factors and processes that ultimately decide whether a risk is unacceptable, tolerable or broadly acceptable are dynamic in nature and are sometimes governed by the particular circumstances, time and environment in which the activity giving rise to the risk takes place. For example, standards change, public expectations change with time, what is unacceptable in one society may be tolerable in another, and what is tolerable may differ in peace or war.

Nevertheless, the protocols, procedures and criteria described in this document should ensure that in practice, risks are controlled to such a degree that the residual risk is driven down the tolerable range so that it falls either in the broadly acceptable region or is near the bottom of the tolerable region, in keeping with the duty to ensure health, safety and welfare so far as is reasonable practicable.

Boundary between the 'broadly acceptable' and 'tolerable' regions for risk entailing fatalities

HSE, as regulator, believes that an individual risk of death of one in a million per annum (10^{-6}) for both workers and the public corresponds to a very low level of risk and should be used as a guideline for the boundary between the broadly acceptable and tolerable regions.

We live in an environment of appreciable risks of various kinds, which contribute to a background level of risk – typically a risk of death of one in a hundred per year averaged over a lifetime. A residual risk of one in a million per year is extremely small when compared to this background level of risk. Indeed many activities which people are prepared to accept in their daily lives for the benefits they bring, for example air travelling, entail or exceed such levels of residual risk.

Boundary between the 'tolerable' and 'unacceptable' regions for risk entailing fatalities

HSE suggest that an individual risk of death of one in a thousand per annum should on its own represent the dividing line between what could be just tolerable for any substantial category of workers for any large part of a working life, and what is unacceptable for any but fairly exceptional groups. For members of the public who have a risk imposed on them 'in the wider interest of society' this limit is judged to be an order of magnitude lower – at 1 in 10 000 per annum.

Summary of HSE (2001) Boundaries

In HSE (2001), the following boundaries between unacceptable risk, tolerable risk and broadly acceptable (negligible) risk are suggested based on tolerability of risk in nuclear power stations, but also applicable in other areas, e.g. offshore installations (HSE, 2002c, IMO MSC 72/16):

Boundary between broadly acceptable and tolerable risk	10^{-6} per year
Maximum tolerable risk for workers (e.g. crew members)	10^{-3} per year
Maximum tolerable risk for public (e.g. passengers)	10^{-4} per year

2.4 The ALARP Principle

Another widely used principle for determining criteria for acceptable risks is the ALARP principle. The ALARP principle dictates that risks should be managed to be 'As Low As is Reasonably Practicable'. Both risk levels and the cost associated with mitigating the risk are considered, and all risk reduction measures should be implemented as long as the cost of implementing them is within the reasonably practicable area/region according to cost effectiveness considerations.

Before this principle can be used in establishing risk acceptance criteria there is thus a need for some standard measures of practicality to which the risk levels can be compared. Again, there are several principles for defining such standards of practicality for comparison.

2.5 Costs of Averting a Fatality (CAF)

The issue of cost of life is included in this report, but will be further applied in a broader context in Task 2 and 3 of this subproject 4.1, cost benefit assessment and recommendations.

The formulation of an appropriate gross/net cost of averting a fatality (Gross/Net CAF, or CAF) is necessary to construct a reasoned argument that the risk identified has been reduced to a level that is as low as is reasonably practicable (ALARP), i.e. the duty holder has so far as reasonably practicable ensured the health, safety and welfare of employees and others. A risk reduction measure is considered reasonably practicable if the cost of the measure is not disproportionate to the value of risk averted (i.e.

benefit over cost ratio greater than 1). For a risk to be considered as managed to a level that is ALARP, the risk reduction measure or measures that reduce the risk to its lowest level whilst retaining a benefit over cost ratio of 1 or greater must be implemented.

HSE guidance "Reducing Risks, Protecting People – HSE's decision making process" ("R2P2") sets the CAF at £1 million and by implication the level at which mitigation costs are disproportionate to the benefits gained. Other industries use alternative values for example, the Railway Group CAF for 2003-4 is set at £1.3 million (single fatalities) and is calculated using the Department of Transport formula for the cost of a road accident fatality to society. See Table 1 for further examples (reviewed in SAFEDOR D.4.5.2).

Organisation	***CAF***
HSE R2P2	£ 1 mill
Railway Group (RSSB) (Based DfT)	£ 1,3 mill
London Underground Limited (LUL)	£ 1,4 mill
US Department for Transport	$ 3,0 mill (£ 2,0 mill)
IMO	**$ 3,0 mill**

Table 1: Examples of CAF's in use

Source: HSE, DNV/Carnival

According to established IMO criterion, a RCO (Risk Control Option) is considered cost-effective (and consequently suitable for recommendation) when the overall CAF is below $3 mill.

However, in practice case law indicates that justifications of ALARP should not be constructed using the disproportionate method but that the costs should be grossly disproportionate to the benefit to justify that a measure is not reasonably practicable. Therefore, in constructing justifications of ALARP it is not unusual for a CAF in *excess* of those in Table 1 to be used. The extent to which the level at which a measure is deemed grossly disproportionate is largely dependent on the level of *risk* one is attempting to avert, and is usually a multiple of the disproportionate value.

There are a number of factors to take into account when deciding on a **gross disproportion factor** but generally high levels of individual risk (close to the level of intolerability) tend to have higher levels of cost that can be borne without being judged grossly disproportionate. Some of the factors listed by the HSE to consider in determining this value are:

- Potential for multiple fatalities in a single event.
- Societal concerns.
- Uncertainties.
- Significant risk trade-offs or transfer.

In the table below, there are some examples of factors used in gross disproportion justifications. For cruise ship industry, no particular factors have so far been proposed.

Organisation	***CAF***	***Factor***	***Gross Disproportion***
Railway Group (RSSB) (Multi fatalities)	£1,300,000	2.8	£3,640,000
London Underground Limited (LUL)	£1,400,000	3	£4,200,000
HSE Offshore Division (min accepted in Offshore cost benefit analysis)	£1,000,000	6	£6,000,000
Railway Group (RSSB) (Train Protection System)	£1,300,000	7.7	£10,000,000

Table 2: Examples of Gross Disproportion in use

Source: HSE

The conclusion of this note is there is no definitive value assigned beyond which the cost of a risk reduction measure is deemed to be grossly disproportionate. The value chosen to represent the level at which a measure becomes grossly disproportionate must be set by the duty holder to reflect the factors mentioned above Table 2. The higher the proportion factor is set the more conservative the risk management strategy becomes. In general the level at which the CAF is set is at or slightly above the HSE R2P2 guidance with gross disproportion set at some multiple of this value that is not necessarily fixed.

It should be noted that the status of risk evaluation criteria is different in the different regulatory regimes that exist through out the world.

Furthermore, although some industries publicly declare a value of life, there is still reluctance amongst the maritime industry and in particular amongst individual operating companies to use CAF/ALARP methods. The main reason for this is public perception. It is assumed that using these methods implies that a value has been assigned to human life, and this has further implications in any possible legal action after an incident. The other raised concern is the effect on public perception when potential safety improvements are not implemented because of cost issues.

2.6 Proposed Risk Criterion for Cruise Industry

A. Individual risk

The purpose of individual risk acceptance is to limit the risks to people onboard the ship or to individuals who may be affected by a ship incident. As previously mentioned in this document there are general three specified levels of tolerability. These are:

- A level of intolerability (specified separately for employees and the general public on the basis of most exposed individual) above which controls must be implemented to reduce risk below the tolerable level or the operation stopped.
- A region where individual risk should be reduced based on the cost/benefit balance of possible control measures.
- A level below which the level of individual risk could be argued to be ‘broadly acceptable’ and no further action will be justified.

Taking account of the discussion on individual risk criteria in earlier sections of this document and whilst reviewing available literature, the following individual risk criteria may be proposed for **existing ships**:

Maximum tolerable risk for crew members	10^{-3} per year
Maximum tolerable risk for passengers	10^{-4} per year
Maximum tolerable risk for public ashore	10^{-4} per year
Negligible risk	10^{-6} per year

Above criteria refers to risk of the most exposed individual.

Risks below the tolerable risk but above the negligible level should be made ALARP by adopting cost effective measures.

Furthermore, it has thought that when a comprehensive FSA is carried out for **new ships**, it may be appropriate to have a more demanding target. In these cases, perhaps the following criteria should be followed (IMO MSC 72/16):

Target individual risk for crew members	10-4 per year
Target individual risk for passengers	10-5 per year
Target individual risk for public ashore	10-5 per year

An important principle in interpretation of these criteria would be that they should be applied in the context of individual ‘slots’ on the ship rather than to particular individuals. This means that the crew member exposure would be evaluated on the basis of a particular post (e.g. Cabin Steward, Staff Captain, Assistant Purser etc) and public exposure on the basis of a particular passenger profile. This removes the opportunity to reduce the calculated individual risk exposure through a policy of risk sharing (i.e. frequent personnel changes in particular posts).

Overall it is recommended that, while outline guidance could be provided to assist operators in development of risk control measure valuation, statement of definitive values would be unwise and would act against best practice in risk management (that the risk owners should understand and manage the risks).

B. Societal risk

The purpose of societal risk acceptance criteria is to limit the risks from ships to society as a whole, and to local communities (such as ports) which may be affected by ship activities. In particular, societal risk acceptance criteria are used to limit the risks of catastrophes affecting many people at the same time, since society is particularly concerned about such events.

There is a difficulty in translating the above individual risk levels into risk tolerability levels for multiple fatality events for the following reasons:

- Individual risk levels are based on an evaluation of the most exposed individual where as, in multiple fatality events, each individual must be assumed to be equally exposed.
- The tolerable frequency of multiple fatality incidents in any particular ship will vary depending on the population exposed.

Hence multiple fatality events must be considered within their individual environment if the targets are to be meaningful.

A traditional approach to multi fatality incidents is that of **FN curves**. Here the frequency of an incident resulting in N or more fatalities (F) is plotted against the number of fatalities (N). FN curves traditionally are plotted using historic data, but require some “translation work” and careful interpretation. Also, FN curves are not necessarily suitable for multi fatality events, that is, events with (very) low frequency and high consequences. Application of FN curves on cruise vessels must therefore be done with due care.

The issues associated with multi fatality risk targets are complex. Current thinking from ship operators is that these values must be influenced to a large degree by risk owners. This leads to a position where, to reflect best practice, the output from the project would present a method through which operators can determine appropriate multi fatality risk targets that are compliant with the basic individual risk criteria but allow (and require) operators to take account of the nature of their operations.

A suggested method would be:

Step 1: Preparation and verification of a marine sector FN curve as the basis of current performance.

Step 2: Derivation of a multi fatality incident frequency consequence line showing the event frequencies that represent the upper limit of tolerability set by individual risk criteria.

Step 3: Setting of multi fatality consequence bands into groups of events with broadly similar consequences.

Step 4: Setting of frequency tolerability values at the upper bound of each consequence band.

It should be noted that the nature of operations across the cruise sector is such that any generic targets would require a large degree of compromise. The danger here is that depending on the degree of compromise, the targets may not be effective for all sectors of the business.

2.7 Frequency and consequence indexes used in this project

The frequency (FI) – consequence/severity index (SI) used in this project is as in below table. The standard format applied by other Task 4 participants was hence slightly deviated for the following reasons:

- Too many frequency categories (7) in the standard format
- The below risk matrix was tailor-made for the cruise industry, and one in which, for example, the cruise building/designers felt comfortable with.

Monetary terms were not used as the participants felt this could not be established for cruise ships. For example, monetary losses for a delay to a cruise vessel is likely to cost (much) more to business than a delay to a long haul container ship. That said, however, the project team accept the generally accepted $3 mill impact from one fatality.

		Severity				
		1	2	3	4	5
	Likelly to occur...:	Minor injury: first aid, medical check	Sick leave and hospitalised	One or two lives lost	Maxium 10 lives lost	More than 10 lives lost
5	Once every ship year					
4	Once every 10 ship year					
3	Once every 100 ship year					
2	Once every 10 years for a fleet of 100 ships					
1	Once every 100 years for a fleet of 100 ships					

Figure 2: Framework for the tolerability of risk

Usually, this kind of matrix is coloured (green/yellow/red). For this project, however, the colours and hence the tolerability levels (for all hazards) were not agreed and this will be a subject to discussion in the next tasks of this report, Task 4, Risk Analysis.

Assuming a world fleet of some 300 cruise vessels (i.e., pure passenger vessels above 4000 GT), an alternative – and maybe more understandable – way of describing the frequencies would then be is as following:

"Likely to occur…:	*…corresponds to:*
Once every ship year	300 incidents for the (world cruise) fleet per year
Once every 10 ship year	30 incidents for the fleet per year
Once every 100 ship year	3 incidents for the fleet per year
Once every 10 years for a fleet of 100 ships	1 incident every 3 years
Once every 100 years for a fleet of 100 ships	1 incident every 30 years

This hazard matrix was used in the hazards sessions; see Section 3 of this report.

3 Historical Risk Level For Cruise Vessels

Below follows an overview of the incident profile for cruise vessel industry (not ro-pax). Only pure cruise vessels are included; total fleet size abt 300 vessels. First, however, some general comments to accident groups used in this report.

Cruise ships accident groups

Through the Lloyds Register Fairplay Database (LRFP) accident registry systematic, every single accident is categorised into one out of eight possible accident groups. The accident groups represent the first level of a typical accident categorisation used in shipping risk management.

A brief description of the eight categories is provided below to get a better understanding of the course of events of the generic accidents. Definitions are reproduced from LMIS (Lloyd's Maritime Intelligence Services) Ship Editorial Casualty System Guide, 1995 revised:

1. Collision

Striking or being struck by another ship, regardless of whether under way, anchored or moored. This category does not include striking under water wrecks.

2. Contact

Striking or being struck by an external substance but not a ship or the sea bottom. This category includes striking drilling rigs/platforms, regardless of whether in fixed position or in tow.

3. Foundering

Includes ships which sank as a result of heavy weather, vessel springing leaks, breaking in two, and not as a result of the other seven categories.

5. Fire/explosion

Where the fire and/or explosion is the first event reported (except where first event is hull/machinery failure leading to fire/explosion)

6. Hull/machinery/equipment

Includes ships lost or damaged as a result of hull/machinery damage or failure which is not attributable to any of the other seven categories.

7. War loss/hostilities

This category is intended to encompass damage or other incidents occasioned to ships by hostile acts.

8. Wrecked/stranded (Includes grounding)

Includes ships reported hard and fast for an appreciable period of time and cases reported touching sea bottom. This category includes entanglement on under water wrecks.

Miscellaneous

Includes ships which have been lost or damaged which, for want of sufficient information, or for other reasons, cannot be classified.

Industry overview

Fleet size
In 2004 the cruise fleet consisted of 264 ships over 4,000 GT. "Cruise vessels are defined as:

- Passenger ship/ferry (incl. tender) - LMIS Code 19004, 19100, 19104
- Passenger light craft - LMIS Code 40004, 60004
- Miscellaneous passenger ships/ferry - LMIS Code 15100, 19106, 19116,

The average vessel size for these vessels was 38.000 GT. An illustration of the vessel size distribution is found in Figure 2.1.

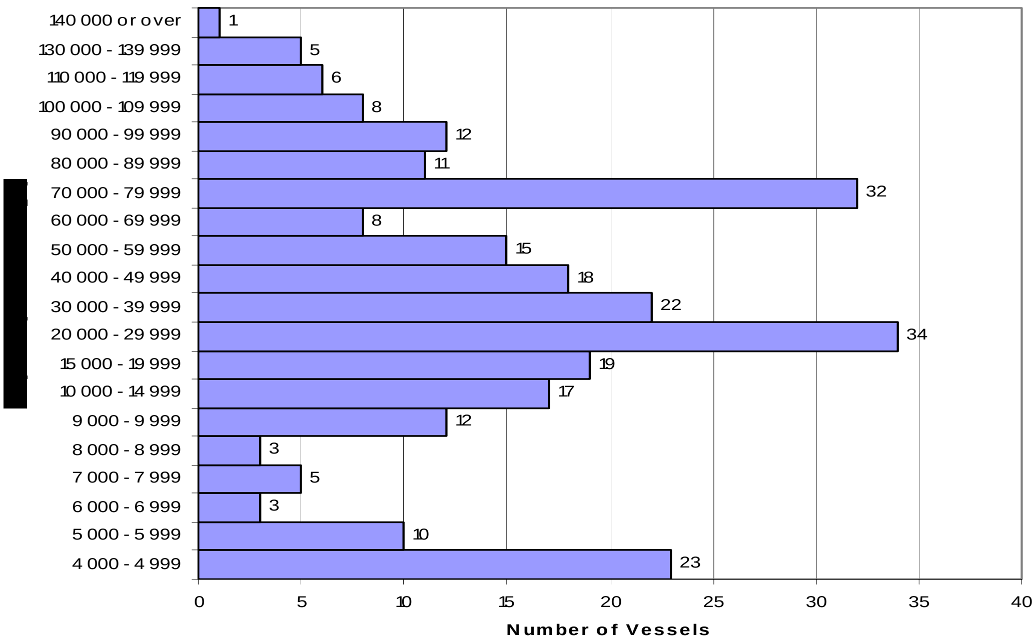


Figure 2.1 Cruise fleet size distribution 2004

Source: World Fleet Statistics, Lloyd's Register Fairplay 2004

The size distribution shows two typical "generations" of vessels, one between 20.000-30.000 GT and one between 70.000-80.000 GT. It is assumed that future new buildings are likely to enter the larger size categories while some of the older vessels are rather small, so that an increase in average vessel size can be expected over the next years.

Fleet age

A brief look at the age distribution of the cruise vessel fleet has been done to disclose that several vessels are rather old and soon will be ready to leave the trade. An illustration of the age profile of current cruise vessels is found in Figure 2.2. Note that only vessels larger than 4,000 GT are included. As will be seen later in this section, the average of vessels with total loss (between 1990 and 2004) was almost 40 years - this kind of phenomena is virtually non-existent among other vessel types (e.g., you hardly find any tankers or chemical tankers older than 30 years).

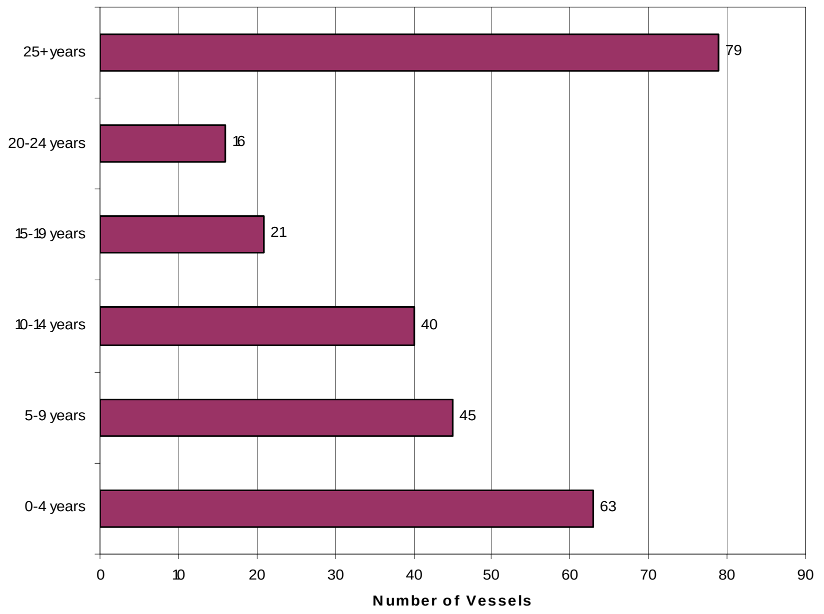


Figure 2.2 Cruise fleet age distribution, 2004

(Source: World Fleet Statistics, Lloyd's Register Fairplay 2004)

Fleet flag of registry

An overview of the cruise fleet major flags in the world is provided in Figure 2.3. Bahamas is the dominant flag used by cruise vessel operators, followed by Panama and the UK flag. The relation between flag and the quality of the fleet is relatively clear for other vessel types, however, the dominating flags for the cruise industry – Bahamas, Panama, UK – are by large perceived as quality flags.

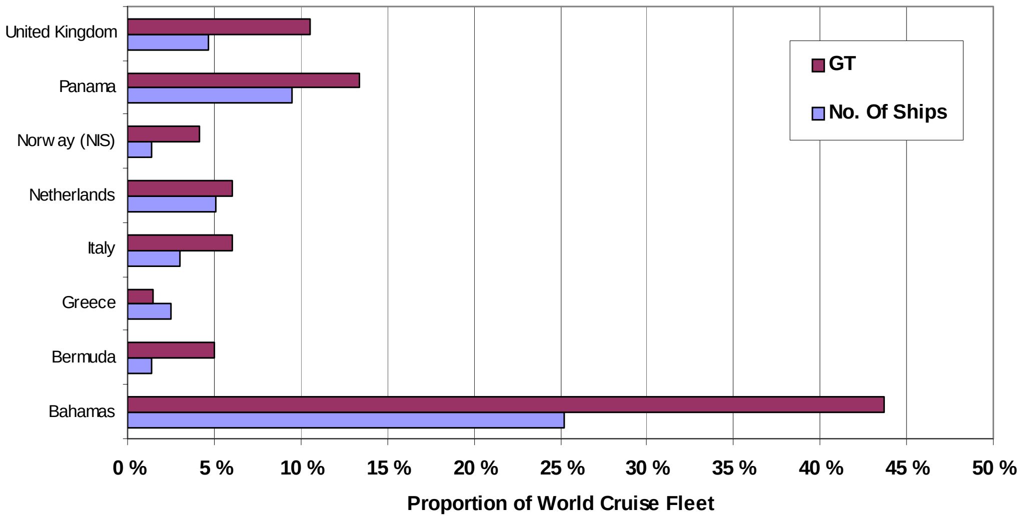


Figure 2.3 Cruise fleet major flags

Source: World Fleet Statistics, Lloyd's Register Fairplay 2004

Accident history

The following accident history information has been obtained from the following DNV reports: *"FSA Generic Vessel Risk, Result summary – all generic ship types"* report no 2003-1190 rev.02 and "*"FSA Generic Vessel Risk, Cruise Vessel"* report no 2003-1078 rev.02. Both reports have been based on accident information for the period 1990-2003, with 2004 updates, provided by LRFP (Lloyds Register Fairplay) accident database.

Cruise ships compared to other ship types

This section aims to show how the historical risk level for cruise vessels compared to other generic ship types. The consequences have been split in two sub-categories:

- Property/ship damage, and,
- Fatalities.

For ship damage further two categories (serious accident and total loss) have been created to get a better understanding of the risks. Similarly, further two categories have been made for loss of lives as the two different ways to present fatality risks can give very different results. An illustration of the structure on how the risk level is presented is illustrated in Figure 2.4.

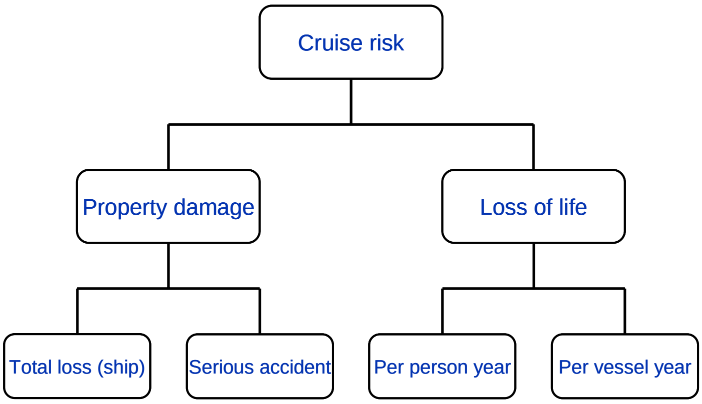


Figure 2.4 Risk parameter structure

Source: DNV internal

Property damage

Property damage – serious accident

Figure 2.5 shows the number of vessel years between each serious accident. The definition of a serious accident by LRFP is:

> *A breakdown resulting in the ship being towed or requiring assistance from ashore; flooding of any compartment; or structural, mechanical or electrical damage requiring repairs before the ship can continue trading. In this context, serious casualty does not include total loss.*

A vessel year is defined as one vessel trading for one year. I.e. one vessel trading for ten years is equal to ten vessels trading for one year as both scenarios have been exposed to ten vessel years.

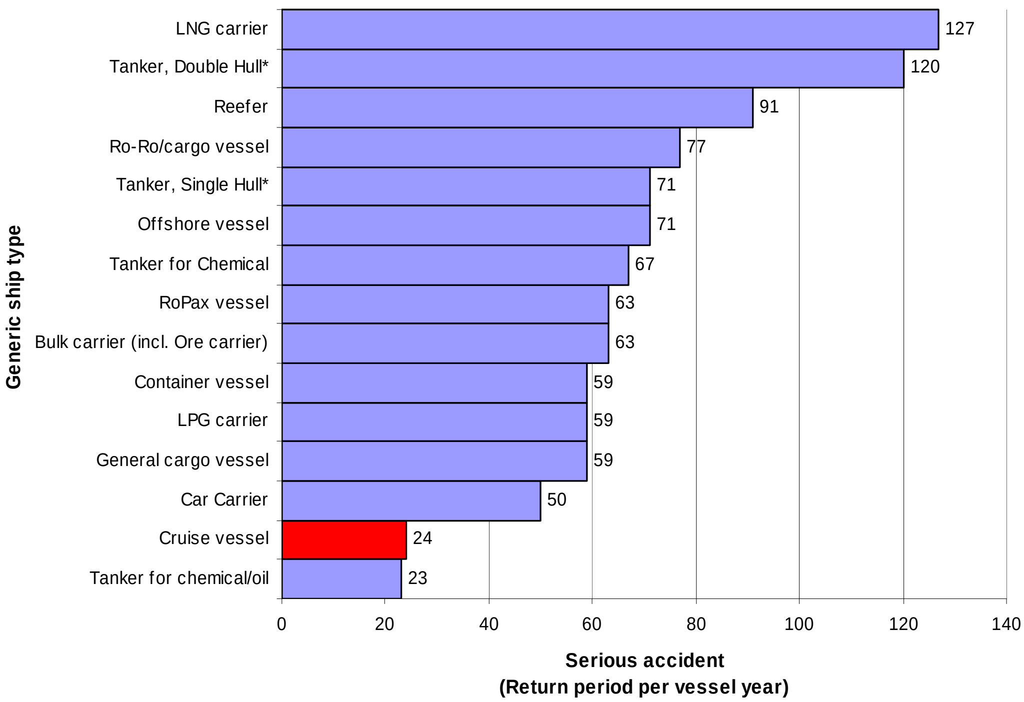


Figure 2.5 Serious accident return periods for generic ship types

Source: DNV FSA Generic Vessel Risk, Result summary – all generic ship types" report no 2003-1190 rev.02

The results show that cruise vessels historically have a high risk of serious accidents per vessel year compared to other ship types. Please note that the figure shows *return period* – estimated number of years between each incident – not absolute number of serious incidents.

Recalling that the cruise fleet exists of some 270 vessels one could expect around 10 serious accidents (not total loss, however) per year for the total cruise fleet.

Property damage – ship total loss rate

Figure 2.6 expresses frequency for having a total loss. LRFP's definition of a total loss is: *A total loss is where the ship ceases to exist after a casualty, either due to it being irrecoverable (actual total loss) or due to it being subsequently broken up (constructive total loss). The latter occurs when the cost of repair would exceed the insured value of the ship.*

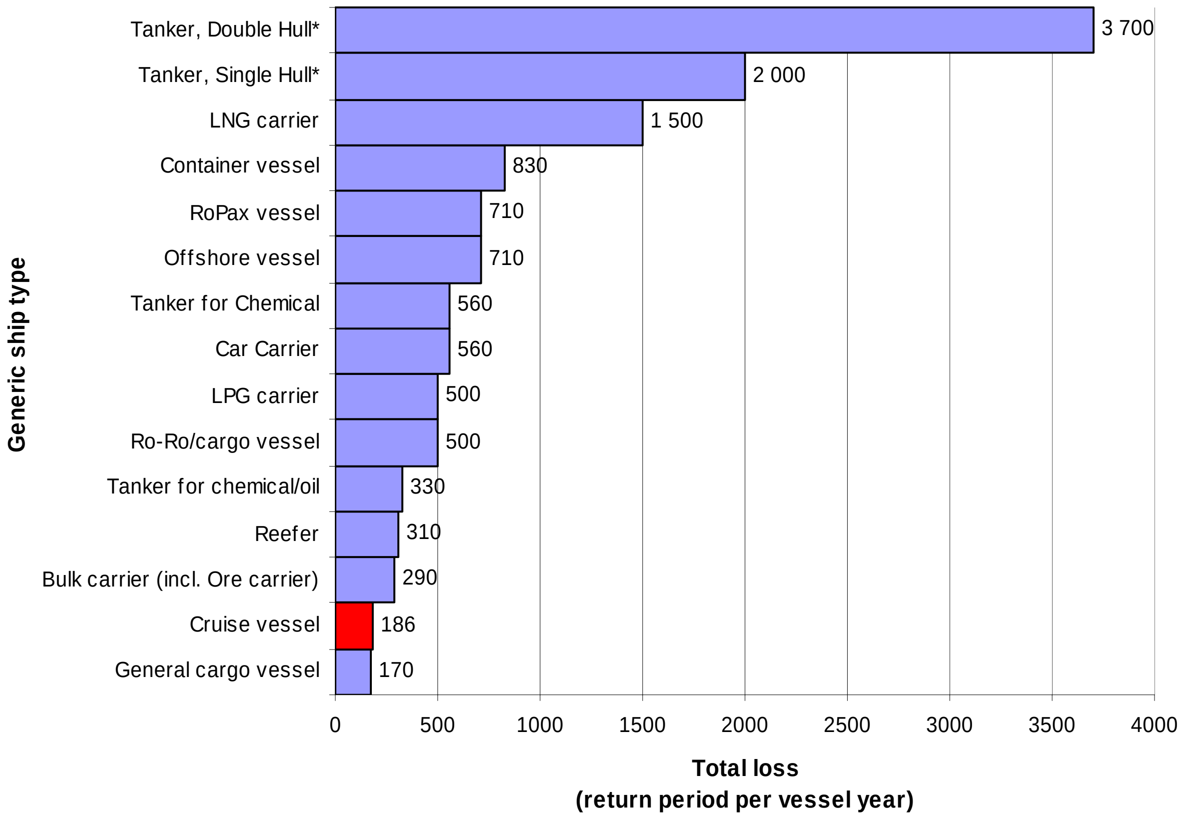


Figure 2.6 Total loss return periods for generic ship types

(Source: DNV FSA Generic Vessel Risk, Result summary – all generic ship types" report no 2003-1190 rev.02)

Please note again that the figure is showing return periods. The total loss rate for cruise vessels ranks second for all the generic vessels types studied. With the cruise fleet consisting of some 270 vessels, approximately 2.5 - 3 total losses can be expected every second year (or 1.5 total losses every year: 300 vessels / 186). This is supported by the fact that there are 19 recorded total loss's (ref LMIS) during a period of 14 years.

Loss of life

Loss of life – individual risk per person year*

*Note: Thjs is valid for ship accidents only. Occupational accidents and ill health etc are excluded.

A person-year is one person (crew or passenger) onboard a vessel for one year. The results show that cruise ships have experienced a very low risk for loss of life when taking into account all the person years which have been exposed over last 15 years (1990-2004). For every person who perished on board a cruise vessel, 80.000 persons have been at sea for one year.

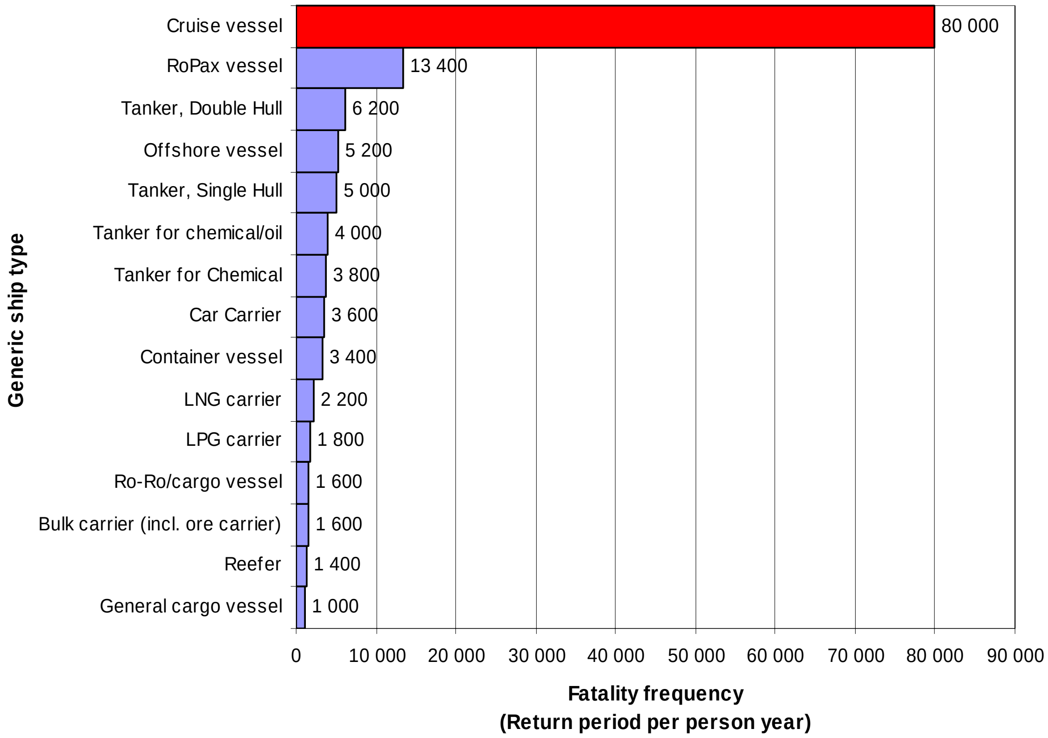


Figure 2.7 Fatality return periods per person year

(Source: DNV internal)

The low numbers for passenger ships can be explained with the high exposure (many people on board) for these vessels compared to merchant cargo vessels.

Historically, the most unsafe ship to be for an individual has been general cargo vessel where one out of 1,000 people have perished each year. (ship accidents)

It may seem a paradox that with a high rate of serious incidents, the fatality rate is so low, yet this can be explained by the large number of people onboard the cruise vessels. A key point is that the cruise industry is high profile, and for this reason it could be said that the regulations are more strictly enforced with more inspections etc. In addition, the protection of passengers is related to the business. Safe passengers results in more repeat bookings and less litigation. Therefore there are already a number of RCOs effectively implemented to enhance the safety of passengers, and also crew members.

Loss of life – per vessel year

A somewhat different way of expressing the risk of loss of life is provided in Figure 2.8. The return period per vessel year measures the number of vessel years between each fatality. Again, note that only fatalities due to ship accidents are included. Occupational accidents and ill health are excluded.

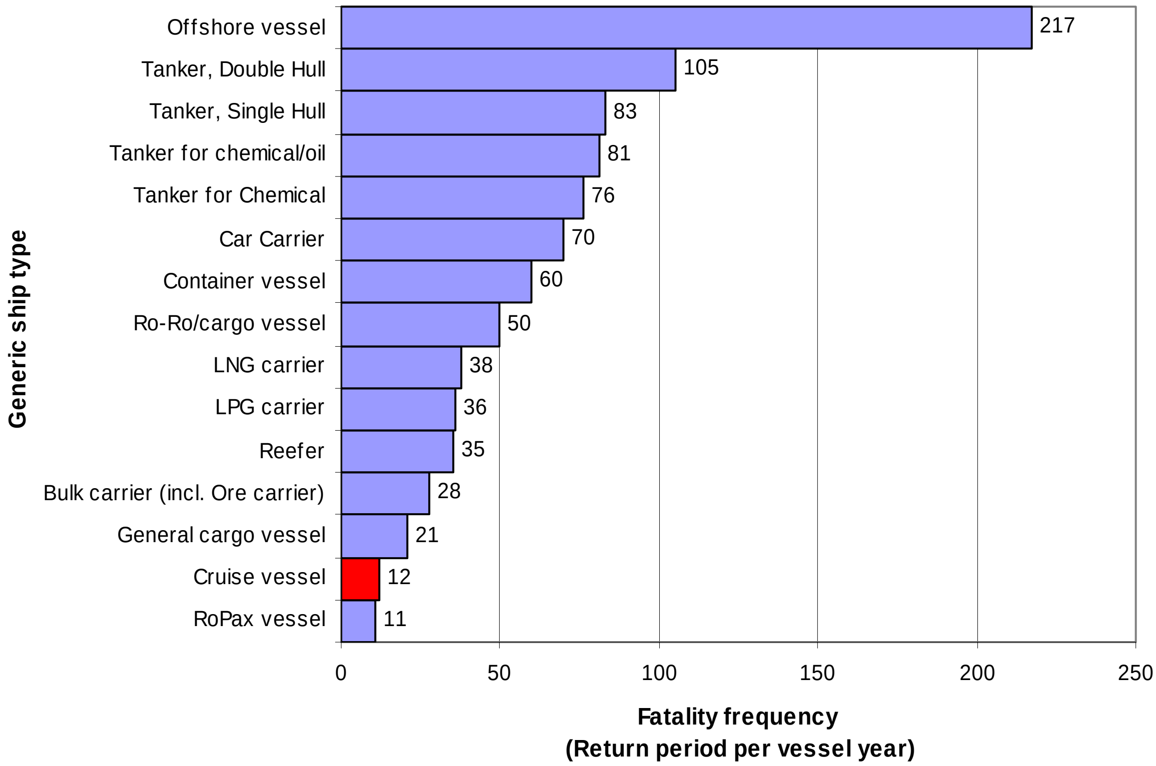


Figure 2.8 Fatality return periods per vessel year

(Source: DNV internal)

Cruise vessels have experienced a fatality in average every 12 vessel years. The reason for the person risk for loss of life is low (every 80.000 person years) is because the large number of people on board a cruise ship compared to cargo vessels.

Property damage

Property damage - serious accidents distribution

A distribution of the accident frequency (return period of 1 serious accident every 24 vessel year) on the eight generic accident types is illustrated in Figure 9. Hull and machinery failures together with grounding (wrecked/stranded) amount to more than half of all serious accidents on cruise vessels.

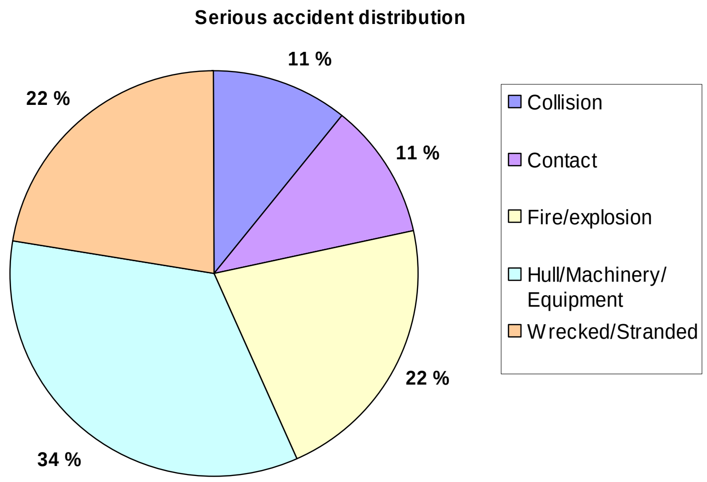


Figure 2.9 "Serious" accident distribution

(Source: DNV internal)

Property damage – total loss distribution

Similarly to "serious accidents" the recorded total losses for the period 1990-2004 are categorised on the eight generic groups of accidents. Fire/explosion accounts for almost half of all total losses.

It should be noted however, that the statistical foundation is rather weak due to the fact that only 19 total losses were recorded for the period (1990-2004).

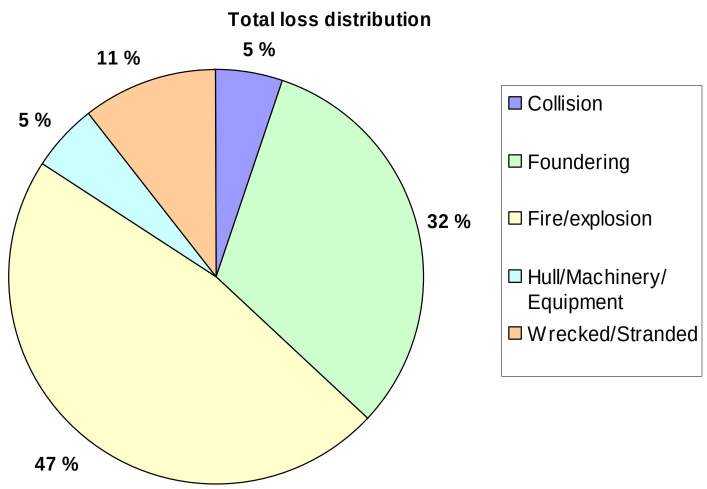


Figure 2.10 "Total loss" accident distribution

(Source: DNV internal)

Loss of life accident distribution

The percentage distribution of loss of lives is similar regardless of how the rate is measured (per person year or per vessel year). Figure 2.11 shows that more than 95% of all lives lost on cruise vessels the past decade and a half has been related to collisions or fire/explosion accidents. Again it should be noted that the statistical foundation is rather weak as only 22 fatalities were recorded for the period (1990-2004).

Appendix 1 provides an overview of cruise vessel incidents (1990-2004) resulting in total loss, while Appendix 2 shows an overview of cruise incidents resulting in fatalities.

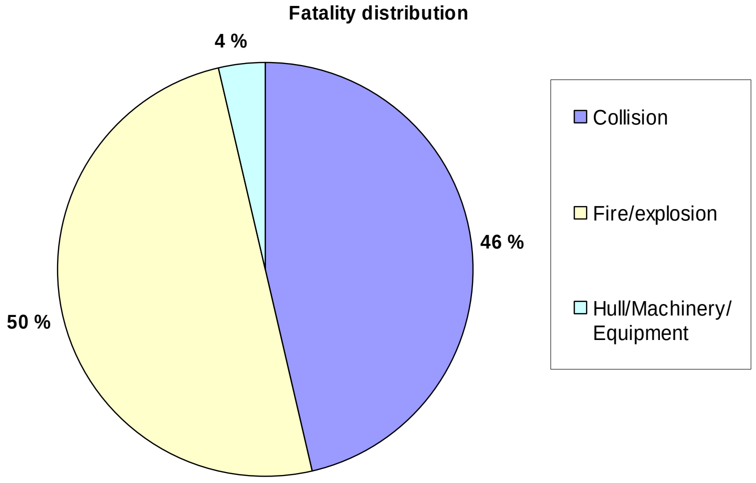


Figure 2.11 Loss of life accident distribution

(Source: DNV internal)

Additional information on fire incidents

From other studies (ref: company confidential) we also know there are certain trends concerning the origin of fires. For example, some internal studies done by DNV show the following distribution of where the fire origins (statistics based on about 150 fire *outbreaks* for a major cruise liner):

Incinerator	30-35 %
Galleys and pantries:	20-25 %
Stairways and corridors:	5-10 %
Engine rooms, machinery spaces:	5-10 %
Crew cabins:	5-10 %
Pass. Cabins:	5-10 %
Restaurants:	4-6 %
Decks (open):	3-6 %
Laundry:	3-6 %
Other spaces (Casino, medical, spa, bridge,..):	5-10 %

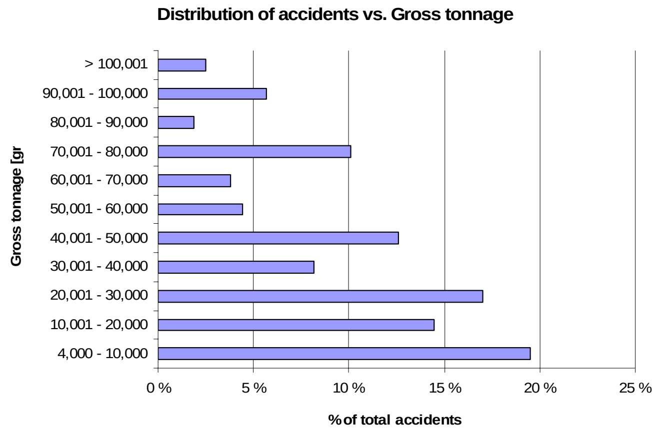
By analysing the LMIS database, the following results can be presented:

Engine rooms:	**60-70 %**
Accommodation areas (crew + pax):	10-15 %
Provision/storage:	5-10 %
Galley:	5-10 %
Laundry:	5-10 %
Smokestack:	5-10 %
Unknown:	~10 %

Hence, the two information sources lead to approximately the same conclusions; fires are most likely to originate in the engine room, galleys and pantries and accommodation area (crew cabins as much as passenger cabins). Note that the statistics from the confidential company is structured somewhat different than the LMIS records. “Engine” in the LMIS records are comparable to “Engine” + “Incinerator” for the confidential company records. In total the fire outbreak frequency distribution is quite similar for the two different sources.

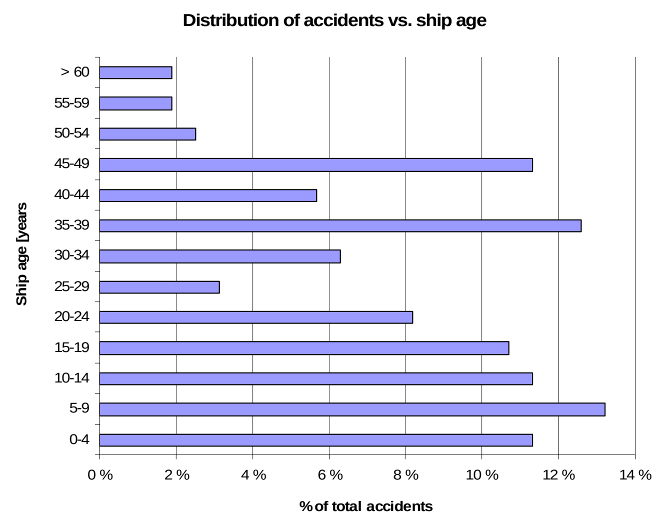
Additional information on cruise ships accidents

Further, by analyzing the accidents (1990-2004; source LMIS) for cruise ships, the following distribution on size can be made:



As can be seen, smaller vessels are most exposed for accidents.

Similar for age distribution:



Surprisingly maybe, also newer cruise ships have a significant accident record.

Conclusions on historical risk picture

1. Compared to other ship types, cruise vessels have experienced a *high rate* of serious accidents and total losses.
2. The *individual fatality rate* level is nevertheless by far the *lowest* of all ship types. This is due to the fact that there have been no big-scale accidents with large numbers of fatalities, and at the same time the individual risk exposure has not been significant due to the many passengers onboard cruise vessel.
3. When measuring the *loss of life per vessel year* the cruise industry comes out far worse than for individual risk. The explanation is that the fatalities are divided by a small number of vessel years (compared to a very high number of person years for individual risk).

4. "*Serious" accidents* are distributed on several accident types with hull/machinery/equipment the single largest category with 34% out of the 8 accident categories
5. Of the 19 *total losses* recorded, fire/explosion is the single largest category of the total 8 accident categories with almost 50% of ship lost.
6. Of the 22 fatalities recorded [1990-2004], *all* but one has occurred as a result of a collision or a fire/explosion accident.

It should also be stressed the age of the vessels when these accidents occurred. The Achille Lauro was built in 1947 and the Royal Pacific in 1965; Appendix 2

It is important to notice that the cruise industry has been spared for disastrous accidents with high number of fatalities. A single major accident tomorrow would change the statistical picture completely. However, according to the ice-berg theory (many "small" incidents will eventually lead to a "major" accident) special attention should be devoted to:

- Fire/explosion accidents
- Collision and grounding
- Hull & machinery problems, and
- Structural integrity (foundering)

Issues from these accident categories seem to dominate the risk picture even if the major cruise disaster is yet to occur. **Relevant for this project is the focus on fire/explosions and collisions.**

In Appendix 1, all the recorded total losses for the period 1990-2004 are presented individually. The information is reproduced to give insight in what kind of problems and challenges the cruise industry has faced during the last decade and a half.

4 HAZID process – risk evaluation

This section evaluates relevant hazards for a “typical” cruise ship.

4.1 *Identification of fire and explosion hazards*

Scope of the HAZID (Hazard Identification)

An important part of this project is to identify various fire hazards that could lead to a large-scale incident.

In order to carry out this task, the 4.1 project team conducted two HAZID sessions. The specific aims of the HAZID exercise were:

- To Identify credible accident hazards
- To prioritize the hazards
- For each selected area, determine a range of preventive safety measures, or RCOs (risk control options).

Methodology

A HAZID is a thorough, systematic, multidisciplinary team oriented analytical brainstorming session. It requires the input of team experts to evaluate consequences of hazards that might result from various potential failures or errors. When answering all the questions raised about realistic deviations from the normal intended operations of a system, design or operation – in this case the proposed alternative design – the team assesses the likelihood of an (fire) incident, the potential consequences, and the adequacy of safeguards to prevent or mitigate the consequences should it occur.

The use of group-based HAZID techniques is widely accepted as best practice to ensure validity, accuracy, and completeness of a study of this kind. This type of exercise is commonly used in the industry for identification and assessment of hazardous scenarios.

The HAZID process

The HAZID process was carried out in two steps:

- The first HAZID (March 21-22) focused on the daily operation of a cruise ship
- The second HAZID (Sept 13-14) focused on cruise ship design

Each HAZID lasted for 1½-2 days. In order to facilitate the HAZID discussion, a working sheet, or checklist, was prepared to identify the range of potential hazards, which in a simplified version looked like this:

Incident causes	*Potential incident*	*Consequences from incident*	*Preventive safeguards (frequency)*	*Mitigating safeguards (consequence)*

What can go wrong?

Why can it go wrong?

What does it lead to?

How can it be prevented?

The completed checklists from the (2x) workshops are enclosed in Appendix 1. We have not made any efforts in combining the checklists, yet while adding up the conclusions from the HAZIDS we have combined the results from the two sessions.

The cruise ship operation and design was systematically "hazard reviewed" by using recording sheets as in Appendix 1. The HAZID team has also referred to other studies and projects where similar issues have been faced.

Additionally, key/trigger words were used to facilitate the discussion, such as:

*Accidents**
- Collision/Contact
- Grounding
- Fire/Explosion
- Foundering
- Hull/Machinery failure
- Terror/Sabotage
- Occupational accidents

Causes
- Weather conditions
- Processes and procedures
- Human factors
- Organizational factors
- Equipment/instr./systems – machinery
- Equipment/instr./systems – bridge/deck
- Equipment/instr./systems – hotel
- Service and maintenance

Operational modes
- Planning of voyage
- Departure/arrival to port (reduced speed)
- Voyage (open sea)
- Tender operations
- Emergency operations

* However, focus was kept on fire/explosions and collisions.

Minor hazard scenarios were discarded by using judgement and available data on the frequency of different outcomes of accident categories.

The hazard workshop identified hazards related to property damage and individual damage, but not **environmental damage**. The hazard team, as well as the authors of this report, did not consider it relevant to consider environmental damages for cruise ships for the following reasons:

- The potential consequences are miniscule compared to other vessel types (true, a fuel oil tank can crack in a cruise ship too, but the amount of oil therein is limited.
- The probability for en environmental incident with cruise ship is very remote, indeed. Throughout the history of modern cruising, no oil spills from cruise ships have occurred (not counting some splash and operational incidents related to bunkering etc).

To concentrate on what is essential, environmental incidents are therefore not considered in this report.

Project constraints/HAZID limitations

The following operations, or activities, are not included in this scope, and were consequently not part of the HAZID workshop:

- Docking, building process (construction phase)
- Terminal gangway (the land based terminal, gangway)

The selected cruise ship was not a particular ship, but rather a generic, average-sized cruise ship.

The HAZID teams

A critical feature determining the quality of the output from a HAZID session is the expertise that is gathered for the meeting. For this project, HAZID teams were assembled in order to ensure that a full and representative range of disciplines and experience was present. Two (2) workshops were organized to make sure no issues were forgotten, and to make sure the breadth and depth of expertise were full utilized. The HAZID sessions included experts in various appropriate disciplines, such as:

- Cruise ship operation
- Hull/machinery expert
- Designer
- Construction
- Class, statutory

- Flag administration
- Risk experts

The HAZID teams comprised the following experts; *focus on operation*:

HAZID session, March 21-22:

- Tom Strang - Carnival, Director, Maritime Affairs (Technical)
- Stuart Greenfield - Carnival, Director, Maritime affairs (Operations)
- Chris Metson - P&O Cruises, Marine safety manager
- Timothy Wride - P&O Cruises, 1st engineer officer
- Martyn Knight - Carnival, risk analyst
- Ole Vidar Nilsen - DNV, risk expert (hazid facilitator)
- Christoffer Borge Johansen - DNV, risk expert (recorder)

For the second workshop, we had assembled a more *design-focused* expert team:

HAZID session, September 13-14:

- Polly Morris - Carnival, risk analyst
- Martyn Knight - Carnival, risk analyst
- Chris Balls - Maritime Coastguard Agency (UK)
- Tore Baunan - DNV, cruise/design expert, regulatory expert
- Giovanni Delise - Fincantieri, Ship safety department
- Ole Vidar Nilsen - DNV, risk expert (hazid facilitator)
- Christoffer Borge Johansen - DNV, risk expert (recorder)

Or, to put another way, the first workshop focused on high-frequency and low consequence incidents (i.e., occupational incidents, fire outbreaks etc), while the second workshop had focus on low-frequency and high consequence incidents (grounding, collision).

4.2 Key Findings from HAZID – scenario description

Appendix 1 contains the full HAZID reports for the two sessions, while a brief is included below.

From the 1st hazard brainstorming session – focused on ship operation, from owner's perspective – the following number of hazards where identified:

Planning of voyage:	18 hazards
Arrival/dept to/from port:	10
Voyage (open sea):	13
Tender operations:	15
Emergency operations:	19
Other hazards:	3
Common for all operations modes:	6
Total, 1st workshop:	*84*

From the 2nd hazard session – focused on ship design in general and flooding and structural integrity in particular – the following hazards where identified:

Collision hazards:	13
Fire/explosion:	13
Contact:	7
Grounding:	1
Total, 2nd workshop:	*34*

After the HAZID sessions, some of the hazards were merged into other hazards as they were quite similar. Then, the hazards were rated by the group in order of importance; that is, according to perceived frequency and consequence. Where disagreements occurred between the different hazards, average scores were used.

In the overview below, the hazards marked in **bold** were rated as the most important ones (from a consequence/frequency perspective). The frequency/consequence categories were as described in Section 2.7 of this report.

a. Three (3) major hazards identified related to operation (from first workshop, and not included in below fire- and explosion, and collision hazards) – here rated according to low frequency–high consequences:

1. Tender boat failure – structural failure
2. Tender boat operations, in particular related to launching/heaving
3. Tender boat davit failure

Other incidents identified, but typically with high frequency-low consequence character:

4. People injured in swimming pool
5. Unsecured equipment/items (deck chairs, cooking utilities etc)
6. Crew behavior and reaction at emergency situation (which is merely a consequence reducing event rather an incident in itself)
7. (In)ability to handle disabled passengers in an emergency situation, e.g. mustering (same: more of a consequence reducing event)

More spectacular incidents, which, for various reasons, we have not been further included in this project:

8. Helicopter crashing on deck/into the ship
9. Terrorism
10. Failure of steering gear/maneuvering systems (included in below grounding/collision incidents)

Comments to the other hazards:

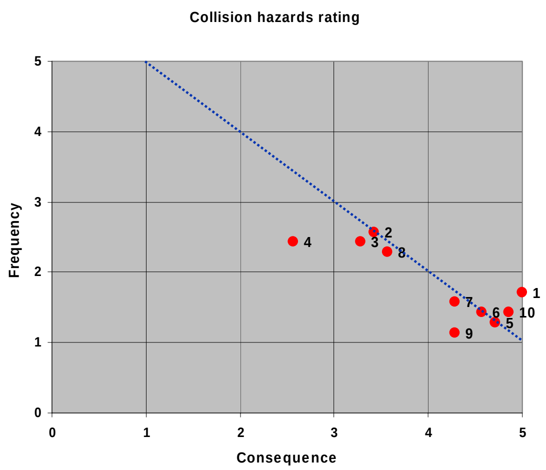
The “operational hazards” turned out to be concentrated around hazards leading to personal injury, fire, and tender operations. The latter turned out to be a bigger subject than expected, and should not be ignored in further analysis. The fire-related and grounding/collision-related hazards were, without exception, re-visited in the 2nd HAZID session (see below).

We did not perform a quantitative evaluation of the hazards from this session, yet a qualitative rating was performed with the results as shown above.

b. Five (5) major collision hazards identified:

The following collision hazards were identified as most relevant (the dotted line on the figure is added just to make it easier to identify the “top five” cases):

1. Officer on duty not watch-keeping
2. Failure of critical navigational aids (in fog)



3. Severe loss of functionality (e.g. loss of rudder/steering at full speed, failure of shaft bearings)
4. Lack of knowledge of navigating procedures
5. Misinterpretation of bridge information

Then, the next five hazards (with lower risk):

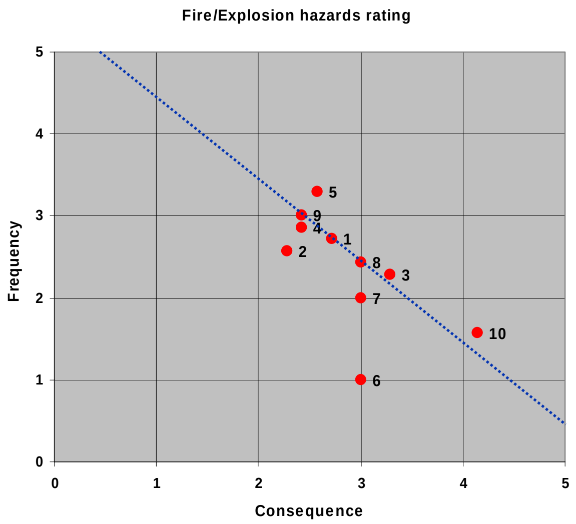
- Collision between two ships (cruise - other) where cruise ship is not at fault
- Wrong pilot intervention
- Lack of interpersonal communication on bridge
- Severe loss of functionality (e.g. loss of power, blackout etc)
- Contamination of fuel tanks

Comments to the collision hazards:

It is remarkable that the majority of the "collision hazards" are related to bridge management (responsibility, organization, communication, competence) and not hardware issues (structural integrity, redundancy, etc.). The hazards with the highest consequences are also the ones which are placed on the top of the list. It should further be noted that most collisions happen in daylight under good conditions with no technical problems (ref: NMD, for example).

c. Five (5) major *fire/explosion* hazards identified:

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



Then, the next five (with lower risk):

- Hot work procedures (including engine room)
- Mooring deck - mooring ropes catch fire
- Bunkering - leakage whilst bunkering, ignition through sparks, etc.
- Theatre (front stage + backstage) - hot lights and flammable materials
- Storage areas - self ignition (chemical reactions)

Comments to the fire/explosion hazards:

The fire-explosion hazards were elaborated in great detail by the workshop participants, and fires in the galley, engine room, laundry, and cabins were all placed high up on the list. The arson scenario is included for reasons of completeness.

Application of human factors in cruise ships

[We are not planning to apply human factor analysis, and this section may be considered removed from the report. Should probably be discussed together with rest of Task 4.1 participants].

The discussion below sets out the general principles that should be applied in evaluating the contribution of human factors to the risks associated with large cruise ship operation.

4.2.1 General Principles

1. For many years the Marine Sector in general has acknowledged the significance of human factors as contributors to accidents/incidents and in operational management. Much useful research work has been carried out and reported on the subject, notably in the area of offshore safety.

2. Operation of a large cruise vessel involves management of a very large number of systems that require different levels of human interaction. Many of these systems are intrinsically linked; hence human factors evaluation and management must consider the single systems perspective and must also consider system interfaces. This leads to some important principles in order to properly analyse and evaluate the role of human factors in cruise ship design and operation:
   (a) Management arrangements for system and interface operation must be developed and implemented in a controlled manner. This ensures that risk arising from management system shortfall is controlled.
   (b) The process for selection, training and appointment of individuals with key responsibilities must consider human factors issues associated with individual systems and with system interfaces.
   (c) Formal processes must be in place for evaluating the capability of individuals to perform the specific tasks within their remit; both at initial appointment and for ongoing performance.

3. Points (a) and (b) above are matters that must be addressed within the management systems of an individual company. Broad guidance could be produced here to encourage robust and thorough development, review and implementation of management systems. However this is largely a matter for operators and will not be able to be prescribed. It would however be possible for a regulator to introduce an ***accreditation*** requirement for management systems.

4. Point (c) is far more pertinent to real time human factors issues. Here the issue is one of assuring operator ***competence certification*** both at initial appointment and as part of ongoing performance review.

5. The above principles, if followed through in application, would ensure that the management system is accredited and hence we are assured of safety performance so long as operators operate in accordance with the system; and also that individual competence is certified, hence reducing the likelihood of a critical or significant human error. Issues within human factors such as human/system interface etc should be considered within this framework.

6. An important point to note from this discussion is that a post is accredited as part of a management system whereas an operator is competence certified as an individual. This leads to the conclusion that a ‘ticket’ does not by right provide a certification of competence for an individual.

4.2.2 Human Error Categories

7. Research work completed for UKHSE listed four different types of human error. These are not claimed to be complete but are used as the basis for discussion here. The types of error are:
   - An unintended action through lack of attention or skill (slip).
   - Unintended action through memory failure (lapse).

- An intended but incorrect action (mistake).
- A deliberate deviation from standard practice (violation).

8. These provide a useful starting point for evaluation of human factors in cruise ship design and operation and must be considered within the principles outlined above. Clearly there is a risk management hierarchy that would be applied to human factors in design and operation; this could be (for example):
   - Removal of the potential for error through design (including system integrity and interlocks).
   - Reduction in the potential for error through system interface design.
   - Reduction in the potential for error through accreditation of the management system.
   - Reduction of potential operator error through competence certification of individuals.

Appendix

Appendix 1: Recorded total losses for cruise ships 1990-2004

Appendix 2: Fatalities in cruise ship incidents, 1990-2004

Appendix 3: Summary HAZID workshop nr 1 (May 2005)

Appendix 4: Summary HAZID workshop nr 2 (Sept 2005)

Appendix 1: Recorded total losses for cruise ship, 1990-2004

	Date	IMO no	Vessel name	Class	Built year	Type of casualty	Fatalities	Course of event	Complementery text
1		5335319	**OCEANBREEZE**	LR	1955	Hull/Machinery		SUSTAINED INGRESS OF WATER ON VOYAGE TO BREAKERS ATCHITTAGONG, BANGLADESH ON 12/10/03. PORT AUTHORITY AND 25CREW ON BOARD HELPED PUMP OUT THE VESSEL WHICH HAD BEGUNTO LIST. CONTINUED ON VOYAGE AFTER LEAK WAS REPAIRED.	NO INJURIES OR POLLUTION REPORTED.
2	06.07.1990	5091016	**MELODY**	BV	1948	Fire/Explosion		CAUGHT FIRE WHILST UNDER REPAIR AT KERATSINI ON 6/7/90.TAKEN IN TOW AND BEACHED OFF ATALANTI ISLAND, NEAR	
3	04.08.1991	5170991	**OCEANOS**	LR	1952	Foundered		FOUNDERED 1.5 MILES OFF THE TRANSKEI COAST, IN LAT. 3206S., LONG. 29 06E., ON 4/8/91 IN HEAVY SEAS AFTER ENGINEROOM FLOODED.	ALL PASSENGERS AND CREW RESCUED.
4	14.10.1991	5358361	**THE FIESTA**	BV	1957	Fire/Explosion		CAUGHT FIRE, LISTED AND SANK AT DRAPETZONA SHIPYARD ON14/10/91 WHILST BEING REFURBISHED; SUBSEQUENTLY CUT INTO	
5	23.08.1992	6405434	**ROYAL PACIFIC**	LR	1965	Collision	9	IN COLLISION WITH MFV 'TE FU NO. 51' OFF PORT DICKSON,IN THE STRAIT OF MALACCA, IN LAT. 02 20.4N., LONG. 10130.2E., ON 23/8/92; SUBSEQUENTLY SANK IN LAT. 02 27.4N.,LONG. 101 36.3E., LATER SAME DAY.	VESSEL CONTACTED ON PORT SIDE AFT, AREA EXTENDED TO WELLABOVE LEVEL OF WATERTIGHT BULKHEADS. ENGINE ROOM FLOODEDRAPIDLY AND SEAWATER GUSHED IN THROUGH CABINS AFTER LISTDEVELOPED. THREE PEOPLE DEAD AND SIX MISSING.
6	31.01.1993	5113436	**EXCELSIOR NEPTUNE**	RI	1958	Wreck/Stranded		REPORTED STRANDED/SANK WHILST IN TOW OFF CANTON INJANUARY, 1993.	
7	18.01.1994	5014123	**AMERICAN STAR**	AB	1940	Wreck/Stranded		STRANDED AT FUERTAVENTURA ISLAND IN LAT. 28 20N., LONG.14 10W., ON 18/1/94 AFTER TOW BROKE DURING A HURRICANE.	
8	24.03.1994	5116098	**PALLAS ATHENA**	RI	1952	Fire/Explosion		CAUGHT FIRE WHILST MOORED AT PIRAEUS ON 24/3/94. VESSELTOWED OUT AND BEACHED AT ATALANTI ISLAND; SUBSEQUENTLYREFLOATED AND TAKEN TO ELEUSIS ROADS AND THENCE TOALIAGA, SOLD AND BROKEN UP.	VESSEL TOWED OUT, DUE FEARS OF EXPLOSION. LARGE AREA OFACCOMMODATION DESTROYED.
9	30.11.1994	5390008	**ACHILLE LAURO**	RI	1947	Fire/Explosion	4	CAUGHT FIRE AND LISTED 250 MILES S. OF THE HORN OF AFRICAIN LAT. 08 00N., LONG. 52 20E., ON 30/11/94 IN GOODWEATHER. VESSEL TAKEN IN TOW 2/12/94 BUT SANK AFTER ANEXPLOSION IN LAT. 07 14N., LONG. 51 19E., THE SAME DAY.	3 PERSONS DEAD AND 1 MISSING.

	Date	IMO no	Vessel name	Class	Built year	Type of casualty	Fatalities	Course of event	Complementery text
10	15.10.1995	5284704	**PRINCE GEORGE**		1948	Fire/Explosion		CAUGHT FIRE WHILST BERTHED AT BRITANNIA BEACH, BC, ON15/10/95. FIRE EXTINGUISHED ON 3/11/95. SOLD FOR BREAK-UPAND TAKEN IN TOW FOR SHANGHAI. FOUNDERED OFF DUTCH HARBOR,IN LAT. 53 58N., LONG. 166 30W., ON 25/10/96.	FIRE BROKE OUT IN PASSENGER ACCOMMODATION AREA.
11	08.05.1996	7008001	**DISCOVERY I**	NV	1970	Fire/Explosion		CAUGHT FIRE IN ENGINE ROOM 3 MILES OFF BAHAMAS ON8/5/96. TOWED TO FREEPORT AND ASSISTED BY PORT FIRE-	
12	04.10.1997	5030854	**ROMANTICA**	LR	1939	Fire/Explosion		CAUHGT FIRE IN LAT. 33 47N., LONG. 32 52E., ON 4/10/97.TOWED TO LIMASSOL. FIRE PUT OUT ON 8/10/97. BROKE ANCHORAND STRANDED ON 9/2/98 IN BAD WEATHER. REFLOATED. ARRIVEDALEXANDRIA IN TOW ON 15/4/98, WHERE BROKEN UP.	FIRE BROKE OUT IN ENGINE ROOM AND SPREAD THROUGHOUTVESSEL. ALL 487 PASSENGERS AND 186 CREW RESCUED.
13	17.11.1997	5078882	**CONSTITUTION**	AB	1951	Foundered		FOUNDERED ABOUT 700 MILES N. OF HONOLULU ON 17/11/97 AFTERTAKING WATER AND LISTING IN HEAVY WEATHER WHILST UNDERTOW.	VESSEL WAS BEING TOWED FOR DEMOLITION.
14	21.05.1999	5411254	**SUN VISTA**	AB	1963	Fire/Explosion		CAUGHT FIRE IN ENGINE ROOM 60 MILES SOUTH OF PENANG ISLANDIN LAT 04 36N LONG 99 52E., ON 20/5/99 IN GOOD WEATHER.SUBSEQUENTLY SANK ON 21/5/99.	ALL PASSENGERS AND CREW RESCUED. ALL LIFEBOATS AND FOURLIFERAFTS USED IN EVACUATION. REPORTEDLY THE FIRE STARTEDIN THE MAIN SWITCHBOARD.
15	21.10.2000	5229223	**BELOFIN I**	AB	1932	Foundered		FOUNDERED 52 NAUTICAL MILES OFF ROBBEN ISLAND ON 21/10/00WHILE IN TOW TO INDIA FOR BREAKING UP.	ALL CREW RESCUED. VESSEL SANK IN 1650 METRES OF WATER.
16	17.12.2000	5113230	**SEABREEZE I**	BV	1958	Foundered		TOOK WATER AND LISTED IN LAT. 37 37N., LONG. 71 24W., ON17/12/00, IN HEAVY WEATHER. SUBSEQUENTLY SANK.	ALL CREW RESCUED.
17	06.07.2001	5136361	**SEA**	LR	1957	Foundered		DEVELOPED LIST WHILE ROUNDING THE CAPE ON OR ABOUT 6/7/01,WHILST IN TOW FOR DEMOLITION. REFUSED ENTRY TO ALGOA BAY	
18	25.07.2001	5321679	**SUN**	AB	1964	Foundered		DEVELOPED LIST NEAR CAPE ST. FRANCIS ON 25/7/01 WHILST INTOW FOR DEMOLITION. FOUNDERED ABOUT 216 KM SOUTH OF CAPE	
19	01.12.2002	8420880	**WIND SONG**	BV	1987	Fire/Explosion		CAUGHT FIRE IN ER MORNING OF 01/12/02 10 N.MILES OFFTAHAA, TAHITI. PASSENGERS AND CREW EVACUATED BY LOCALFERRY. TOWED TO PAPEETE BY FRENCH NAVY SUPPLY SHIP 'REVI'.CTL. SCUTTLED IN 2000 METRES OF WATER OFF TAHITI 23/01/03.	SERIOUS FIRE IN ER CAUSING SIGNIFICANT DAMAGE, CAUSEUNKNOWN. 127 PASSENGERS AND 92 CREW RESCUED BY FERRY"AREMITI" AND TAKEN TO THE ISLAND OF RAIATEA. FIRSTPASSENGER SHIP LOSS IN THE HISTORY OF CARNIVALCORPORATION.

Appendix 2: Fatalities for cruise ships, 1990-2004

Date	IMO no	Vessel name	Class	Built year	Type of casualty	Fatalities	Course of event	Complementery text
18.03.1990	5267732	**FAIRSTAR**	LR	1957	Fire/ Explosion	1	CAUGHT FIRE IN ENGINE ROOM FOLLOWING AUXILIARY BOILER EXPLOSION WHILST ON VOYAGE FROM PORT VILLA TO SYDNEY, N.S.W., ON 18/3/90. ARRIVED SYDNEY, N.S.W., 19/3/90 AND SAILED SAME DAY FOR NEW CALEDONIA.	ONE SEAMAN KILLED. SUSTAINED EXTENSIVE DAMAGE TO BOILER.
30.11.1994	5390008	**ACHILLE LAURO**	RI	1947	Fire/ Explosion	4	CAUGHT FIRE AND LISTED 250 MILES S. OF THE HORN OF AFRICAIN LAT. 08 00N., LONG. 52 20E., ON 30/11/94 IN GOODWEATHER. VESSEL TAKEN IN TOW 2/12/94 BUT SANK AFTER ANEXPLOSION IN LAT. 07 14N., LONG. 51 19E., THE SAME DAY.	3 PERSONS DEAD AND 1 MISSING.
28.02.1997	9000687	**SUPERSTAR GEMINI**	NV	1992	Fire/ Explosion	1	CAUGHT FIRE IN ENGINE ROOM FOLLOWED BY ELECTRICAL FAILURE IN LAT. 01 11N., LONG. 103 40E., ON 28/2/97. FIRE PUT OUT SAME DAY. VESSEL TOWED TO SINGAPORE ON 1/3/97, WHERE REPAIRS WERE EFFECTED. SAILED SINGAPORE ON 15/5/97.	1 CREW DEAD.
28.05.1999	5119143	**NORWAY**	BV	1961	Fire/ Explosion	8	CAUGHT FIRE IN ENGINE ROOM WHILST ENTERING BARCELONA UNDER TOW ON 28/5/99. FIRE EXTINGUISHED BY OWN MEANS. BERTHED IN PORT AND CRUISE TERMINATED. SAILED 15/6/99 FOR MADEIRA AFTER REPAIRS.	FIRE BROKE OUT IN THE AFT TURBO-CHARGER ROOM.
25.05.2003	5119143	**NORWAY**	BV	1961	Fire/ Explosion	8	CAUGHT FIRE IN ENGINE ROOM FOLLOWING A BOILER EXPLOSION AT 0630 EDT ON 25/05/03 WHILST MOORED AT MIAMI, FLORIDA. 8 DIED. TOWED TO LLOYD WERFT, BREMERHAVEN ON 24/07/03 FOR DECISION ON REPAIR.	LONG CARIBBEAN CRUISE. THREE OF FOUR BOILERS WERE OPERATING WHEN THE EXPLOSION OCCURRED. 8 CREW DIED, 16 INJURED. NO INJURIES TO PASSENGERS. THE EXPLOSION SHOOK THE SHIP AND EXTINGUISHED ALL POWER ON BOARD. NTSB INVESTIGATED

Appendix 3: Summary of workshop I (March 2005)

Operation mode:	**Planning**					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
Dummy	A cabin catches fire	- someone dropped a match in the litter bin - emptying ashtrays in litter bins	- cabin burns - heat and smoke develops - people panic	- little combustible material - non smoking cabins	- water mist systems - main vertical fire zones	
1.1	Personnel injuries (occupational accidents) (hotel)	- Lack of crew training (normal operation) - Incorrect techniques - Unfamiliarity - Wrongful handling of chemicals and hot water (“storage and labelling..”)	- Injury to personnel/work colleague	- On board training - Dedicated full-time on board trainer* - Safety training - Pick the appropriate technology that fits the task best	- Continuing review of training methods - Good selection of equipment - Safety culture	
1.2	- Lack of or delay of appropriate response	- Lack of type/ship specific training (equipment familiarity) - Over-automated system settings	- Machinery/ navigational failure - Collision/grounding/ contact	- Proper handover period (beyond 2 weeks?) - Pick the appropriate technology that fits the task best	- Advanced planning (up to date leave plans)	
1.3	Appropriate redundancy available				- Loss of redundancy (machinery)	
1.4	Navigational failure	- Incorrect electronic charts (unreliable) Manual charts outdated - Missing warnings that can come up under a voyage planning	- Collision/or near miss - Grounding - Pollution	- Regular chart updates - Use of paper charts - Correct selection of support services	- Continue review of support services - Onboard auditing	

Operation mode:	**Planning**					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
1.5	- Drifting - unable to maintain the vessel alongside (gangway)	- Strong offshore wind - Inadequate weather information /tidal information - Speed of passing traffic - Lack of available thruster power - No tug assistance (not all cruise ships are fitted with bow and stern thrusters)	- Gangway falling down - Lines parting - Collision/ contact - Slips, trips and falls	- Monitoring weather/tide conditions - Plan maintenance well - Monitor traffic - Gangway watch - Monitor the moorings	- Drop the anchor - Tug assistance - Immediate engine start-up - Engines on standby mode	
1.6	Sabotage caused by unauthorised access on board	- Insufficient access control / security to the vessel - Inadequate access control to sensitive areas (i.e crew or machinery areas)	- Loss of systems/ship - Loss of life/injuries	- Security controls on the vessel - Adequate security measures - Security patrol around the vessel - Sea side control - Luggage control - Checking of stores	- Contingency planning - Right security level for the area - Fit keypad locks to all sensitive areas. Codes to be changed frequently.	
1.7	Rope parting during mooring operations	- Poor working practices (including communication/inspection) - Inadequate mooring training - Unauthorised access - Mooring equipment failure - Speed of passing traffic	- Death/injury to crew members - Damage to ropes/other mooring equipment	- Correct training - Access control - Awareness training - Equipment maintenance	- Improve mooring deck design (designate safe areas on mooring deck) - Personnel Protective Equipment (PPE)	
1.8	Crew resource management					
1.9	Crew injuries	- Movement around the vessel in heavy weather - Carelessness and inattention	- Personnel injuries/fatalities - Potential to affect ship operation	- Local warnings over PA system - Notices - Training and awareness	- PPE - Correct securing of equipment	

Operation mode:	Planning					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
1.10	Crew injuries	- Dropped objects - Unfastened equipment	- Personnel injuries/fatalities - Potential to affect ship operation	- Work area isolation	- Correct securing of equipment	
1.11	Crew injuries	- Storing procedures (hotel/technical) (poor labelling, separation of fluids/goods)	- Personnel injuries/fatalities - Potential to affect ship operation	- Training and awareness - Provide sufficient storage area	- Seek advice from manufacturers - Correct packaging from on shore suppliers	
1.12	Crew injuries/equipment damage during maintenance activities	- Incorrect lifting/slinging operations - lack of headroom - lack of lifting points - Hot work / permit to work procedures not followed / enforced	- Personnel injuries/fatalities - Equipment malfunction - Equipment damage beyond repair (unavailable for future work)	- Slings are marked with colours and safe working loads - Lifting equipment is inspected - Comply to lifting and slinging procedures - Training and awareness	- Ensure a permit to work system is put in place where maintenance impinges on other shipboard activity.	
1.13	- Watertight integrity compromised	- Watertight doors are open when ship are in potential hazardous conditions (e.g. reduced visibility, restricted manoeuvring)	- Capsize, loss of ship - Flooding of compartments - Loss of ship systems	- Follow written procedures - Training and awareness - Only authorised personnel open/close doors - Testing and maintenance	- Announcement prior to testing of doors - Local sirens and alarms	

Operation mode:	Planning					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
1.14	Cross contamination and spills	- Incorrect bunkering procedures (FW/fuel oil, lube etc) - Bunkering procedures not adhered to	- Ill health/fatalities due to undetected contaminated FW - Machinery breakdown - If detected; delay to ship sailing	- Follow bunkering procedures - Complete and comply to items on checklists - FW and fuel oil sampling (during and after)	- Physical connection incompatibility	
1.15	Bunker spill fire	- Incorrect bunkering procedures (fuel oil, lube etc) - Bunkering procedures not adhered to	- Loss of ship - Physical damage and severe personnel injuries/fatalities - Delayed sailing and/or curtailment of cruise	- Follow bunkering procedures - Complete and comply to items on checklists - Drains (bunker station) - Watchman on station	- Fire fighting equipment in place - Physical barriers - Training and awareness	All fire hazards are valid for all modes of operation
1.16	Fire due to electrical fault	- Inappropriate use of electrical leads/equipment in cabins. - Overloading of circuits - Light fittings/bulbs - Subcontractors (ignores regulations? Non approved equipment?) - Water damage	- Loss of ship - Fire - Material damage and personnel injuries/fatalities	- PAT (Portable Appliance Testing) - Following company requirements - Weekly inspection of crew cabins - Regular passenger cabin inspections - Adherence to the fire testing procedures	- Fire fighting equipment (water mist etc) - Physical barriers - Evacuation - LSA	
1.17	Fire due to naked flames	- Improper use of naked flames (candles, etc) - Carelessly discarded cigarettes and matches - Any use of unauthorised naked flames	- Loss of ship - Fire - Material damage and personnel injuries/fatalities	- Adherence to the company regulations - Systems in place for safe/frequent disposal of combustible materials - Fire patrols -	- Fire fighting equipment (water mist etc) - Physical barriers - Evacuation - - LSA - Educate house keeping staff - Appropriate posters & signage	

Operation mode:	Planning					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
1.18	Fire in the laundry/laundry ducting	- Oil residual in the towels (from sun tan) - Tumble dryers operating at excessive temperatures - Accumulation of lint in filters and ducting		- Regular cleaning of ventilation trunks - Training and awareness in tumble dryer operations	- Fire fighting equipment (water mist etc) - Physical barriers - Evacuation - LSA - Educate staff/crew - Appropriate posters & signage	
1.19	Inappropriate planned maintenance (day/night considerations)	- Time line to sailing too small - Maintenance interrupts departure checks - Watchkeepers not appear of maintenance taking place.	- Increased potential for injury to crew members - Black outs - Unavailable power when required - Unavailable services when required.	- Ensure permit to work put in place. - Ensure work is authorised by watch keepers.	??	
1.20	Accidents related to maintenance activities/incorrect maintenance activities/no maintenance activities	??	??	??	??	

Operation mode:	Arrival/departure to/from port					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
2.1	Collision with other vessels	- High traffic density in port approaches - lack of pilot knowledge/ VTS information - Pilot incompetence - Bad pilot interface with master - Loss of manoeuvre and power control (equipment failure) - Heavy weather - Bridge layout/mgmt - Standard of tugs/availability - Pitch control failure - Steering gear / rudder failure	- loss of ship integrity - personnel injuries - environmental pollution - 3rd party damage - cruise cancelled - fire	- Monitoring vessel movement by OOW (Officer On Watch) - Ensure good communication between pilot and master - Pilot information card - Test manoeuvrability prior to arrival - Training on vessel manoeuvrability - Restricted access to bridge/ECR	- Physical barriers (bulkheads) - ship design (damage stability)	
2.2	Contact with pier/jetty/fixed objects	- lack of pilot knowledge / VTS information - Pilot incompetence - Bad pilot interface with master - Loss of manoeuvre and power control (equipment failure) - Heavy weather - Bridge layout/mgmt - Standard of tugs/availability - Pitch control failure - Striking submerged objects	loss of ship integrity - personnel injuries - environmental pollution - 3rd party damage - cruise cancelled - fire	- Monitoring vessel movement by OOW (Officer On Watch) - Ensure good communication between pilot and master - Pilot information card - Test manoeuvrability prior to arrival - Training on vessel manoeuvrability - Restricted access to bridge/ECR		

Operation mode:	Arrival/departure to/from port					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
2.3	Grounding	- lack of pilot knowledge / VTS information - Pilot incompetence - Bad pilot interface with master - Loss of manoeuvre and power control (equipment failure) - Heavy weather - Bridge layout/mgmt - Standard of tugs/availability - Pitch control failure - Striking submerged objects	-“-	-“-	-“-	-“-
2.4	Pilot injury during pilot transfer	- Pilot fitness/fatigue - Badly rigged transfer arrangements - Poor boarding area design - Weather conditions	- Personnel (crew/pilot) injury - Ship may not be able to enter the port	- Regular inspections of boarding arrangements (incl. ladders) - Pilot safety training - PPE - Good communication between pilot boat and ship	- Personal Protective Equipment (PPE)	
2.5	Personnel injury during anchor operations	- Anchor / brake jammed - Incorrect operation - Anchor equipment failure - Poor anchor system design	- Loss of anchor - Personnel injury - Unable to release anchor	- Training and awareness - PPE - Regular maintenance	-	
2.6	Inability to meet the anchor operation requirements	- Anchors jammed - Anchor equipment failure - Poor anchor system design	- Ship unable to make port call - Disruption of cruise itinerary	- Reduce pounding into heavy seas - Review design - Regular maintenance	-	

Operation mode:	Arrival/departure to/from port					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
2.7	Not acceptable smoke emissions	- Poor handling of main prime movers - Incinerators - Boilers	- Pollution - Fine - Port entry refusal - Bad press	- Training of relevant operators - Equipment design - Proper maintenance	- Monitoring systems of smoke emissions	
2.8	Main engine fire	- Change of fuel supply (HFO<->diesel) - Fuel/lube oil pipe failure - Flammable fluids on hot surfaces - Atmospheric build up of fuel/lube oil	- loss of propulsion - personnel injuries/fatalities	- Correct maintenance (incl. testing) - Oil mist detectors - Temperature monitoring - Visual inspections - Engine room watch keeping duties	- Local suppression systems - Remote shut-down and isolation - Global suppression systems - Physical barriers - Emergency Escape Breathing Devices (EEBD)	
2.9	Loss of bridge control systems	- Heavy weather/seas - Failure of bridge window securing devices	- Black-out - Loss of all ship services - Personnel injury	- Bridge design and location - Structural integrity of closing devices - Weather routing		Valid for Open waters mode
2.10	Failure of ship side fittings	- Corrosion - Improper fittings - Wrong item fitted in the wrong place - Valve failures	- Loss of ship - Ingress of water - delayed departure/arrival - Personnel injury	- Improve design - Correct fitting - Inspection and maintenance	- Physical barriers (bulkheads)	

Operation mode:	Voyage					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
3.1	Man overboard	- drugs and/or alcohol - suicide - playing - Inappropriate actions (climbing etc.)	- fatality - personnel injury - putting crew at risk - disruption of cruise itinerary	- physical barriers (railings, safety nets) - drug and alcohol policy for the crew - CCTV surveillance	- counselling - emergency response team (medical staff, psychiatry etc)	
3.2	Unsecured equipment/items	- time pressure - unawareness of procedures - ignorant attitude - lack of appropriate fastening accessories/equipment	- fatality - personnel injury	- adequate fastening equipment available - unambiguous procedures to secure items - develop a strong safety culture	- physical barriers - design	
3.3	Fire in public spaces	- dysfunctional or careless use of stage/show pyrotechnics - barbecue on deck - flambé in restaurant/galley - Open food warmers in buffet area - arson	- fire and/or explosion in a public space - personnel injury	- comply with prevailing procedures for usage of pyrotechnics - comply with individual instructions for each item of pyrotechnics	- Fire fighting equipment - PPE - Non-combustible materials in public space	
3.4	People injured in swimming pool	- movement of water in swimming pools - insufficient signage - inappropriate behaviour	- Personnel injury	- Safety net - Signage - Watch keeping	- Medical assistance located close to swimming pool	
3.5	Fire in accommodation area	- Smoking - Cigarettes not properly extinguished - Discarded cigarettes - Electrical equipment failure - Arson	- cabins catch fire - heat and smoke development - loss of structural strength	- non smoking in cabins - automatic electricity cut-off when cabins not in use	- reduce amount of combustible materials in accommodation area - smoke and heat detectors - fire fighting equipment	

Operation mode:	Voyage					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
3.6	Fire in galley	- Deep fat fryers - Flambé - Ignition of hot oil - Water damage to electrical equipment - Flour explosion	- galley catch fire - single personnel injury due to warm fat on exposed skin	- automatic shut down of fryers when not in use	- Fire fighting equipment - Dedicated fixed fire extinguishing equipment - Staff training	
3.7	Human error – operational	- inappropriate watch changeover - boredom (routine tasks) - complacency - over-reliance to automatic systems	- ship accidents - crew tasks not satisfactory carried out	- watch changeover procedures - watch overlap	- physical barriers - safety margins - operational ground rules	
3.8	Gastro-intestinal outbreak	- poor hygienic conditions - poor personnel hygienic - food poisoning - water contamination - poor food storage and/or preparation	- Sick crew and passengers - Disruption to ship operations - Bad publicity - Major disruption to the passengers enjoyment - Heavy workload for medical staff	- adherence to hygienic procedures - Training and awareness - Passenger screening - Sanitary standards - Sampling and testing of FW supply - Pre-checks of food	- increase sanitation levels (incl. hit-squads) - isolate sick passengers -	
3.9	Structural failure	- high stress levels in corners/doors etc - poor design - Inappropriate operation in heavy weather - corrosion - general fatigue - ballast and fuel management	- cracks - water ingress - loss of fire integrity	- design - weather routing - material choice - regular and inspection and maintenance - good seamanship practice	- increase safety margins - stress sensors	
3.10	Failure to house stabilizer	- control system failure - hydraulic problem - operator error (human)	- unable to enter port - heel angle - hydraulic leakage - pollution	- monitoring - operational practice		

Operation mode:	Voyage					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
3.11	Helicopter crashing on the deck Medical evacuation situation	- incorrect information to pilot - lose objects - operator error -	- fatalities - severe injuries - damage to ship - fire/explosion	- full operational procedures in place - well trained helicopter crew -		
3.12	Piracy	- valuables on board	- fatalities - severe property damage - downfall in cruise demand	- ISPS Code - anti piracy procedures to be in place - ship security	- insurance - alarms and warning systems	
3.13	Terrorism	- enormous media attention	- multiple fatalities - loss of ship - downfall in cruise demand	- ISPS Code - anti piracy procedures to be in place - ship security	- physical barriers/margins	

Operation mode:	Tender Operations					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
4.1	Conditions of the port – quay, water depth etc.	- Unsatisfactory tender berth allocated	- Damage to tender boats - Grounding of tender boats			
4.2	Port congestion	- huge number of tenders operating	- collision - unrest and safety issues - Man overboard (MOB)			
4.3	Unsuccessful boarding of tender boats	- age/mobility of passengers	- disembark failure			
4.4	Tender boat breakdown/structural failure	- tender design (some are better than others) - cabin design, seating arrangements	- MOB - personnel injuries			
4.5	Wrong tender operation actions	- tender crewing (lack of ability/ lack of experience) - competence and ability - ship-tender interface (communication side, pontoon design etc, securing arrangements) - fatigue when performing tender operations (large number of ports requiring tender use in a short space of time)	- Fatalities - MOB - Loss of tender boats			
4.6	Failure of davit (launching/recovery)	- technical failure of davit - breach of launching/recovery procedures	-			
4.7	Structural design (same as tender design)					
4.8	Design for purpose (same as tender design)					

Operation mode:	Tender Operations					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
4.9	Over-use of tender vessel – lack of time for maintenance (fatigue of people vs. fatigue of boat)?					
4.10	Returning to LSA mode (time consuming)					
4.11	Heavy weather recovery – ship positioning? (strops, getting the boat in etc)					
4.12	Internal environment – heating? Ventilation? (excessive CO2 levels, normally mechanical ventilation only)					
4.13	Fuelling/bunkering (potential for pollution, bunkering from the ship) minor issue		- Crew injury - Sea water contamination	- Strict re-fuelling procedures in place - Oil containment equipment stowed in vicinity		
4.14	Pilot transfer	Boat transfer in open waters (on/off) – look up "pilot transfer" hazard				
4.15	Failure of ship side connections/openings					

Operation mode:	Emergency Operations					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
5.1	Crew ability/training					
5.2	Passenger behaviour					
5.3	Crew behaviour/reaction/emergency handling					
5.4	Communication language					
5.5	Signage					
5.6	Decision support system onboard (failure to take correct action) (collection of documents to assist decision makers in emergency situations, or computerised systems)					
5.7	Knowledge of emergency procedures – training/drill of crew					
5.8	Accounting for passengers (counting passengers, cabin searches, mustering tasks)					
5.9	Lack of appropriate equipment (to handle the emergency in the best possible way) (technologies, fire fighting)					
5.10	Poor escape route design (signage, etc)					
5.11	Movement of physical disabled passengers (mustering)					

Operation mode:	Emergency Operations					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
5.12	Control personnel movement (linked with mustering, accounting for passengers)					
5.13	Smoke and heat					
5.14	Ship movement (list/trim, ref people movement control)					
5.15	Lack of or insufficient communication (- PA systems, - VHF dead zones - Lack of internal/ external communication)					
5.16	Shore support (emergency response service)					
5.17	Evacuation drills (increased risk to the crew during training)					
5.18	Lack of appropriate signage					
5.19	Knowledge of stability conditions (officers) (a cause more than a hazard)					

Operation mode:	Other/general Items					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
6.1	Access for inspection					
6.2	Compatibility of coating to fluids					
6.3	Maintenance of coating					

Operation mode:	Planning, departure/arrival & voyage					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
A	Black-out	- Human error - Fuel starvation - Poor system design - Power overload - Fire/flooding - Equipment failure (mechanical and electrical) - Sabotage	- Reduced capabilities - Reduced lighting - Personnel injuries - Equipment damage	- Maintenance - Redundancy - Adherence to procedures - System design - - Crew competence/training	- Redundancy - Emergency power supply system - Good documentation	
B	Fire in engine room	- Fuel/lube oil pipe failure - General housekeeping - Arson - Smoking - Hot work - Electrical faults - Flammable fluids on hot surfaces - Atmospheric build up of fuel/lube oil - Fuel/lube oil leaks	- personnel injuries/fatalities - loss of power (incl. propulsion) - potential loss of ship - pollution - passenger panic - -	- Correct maintenance (incl. testing) - Oil mist detectors - Temperature monitoring - Access control to machinery spaces - Visual inspections - Engine room watch keeping duties - Adherence to prevailing smoking procedures	- Local suppression systems - Remote shut-down and isolation - Global suppression systems - Physical barriers - Emergency Escape Breathing Devices (EEBD)	
C	Navigational equipment failure	- technical failure of electronic equipment - non calibrated equipment - external electronic/magnetic disturbances influencing the equipment (e.g. polar light)	- contact incident - collision incident	- redundant equipment - maintenance - testing and calibration routines	- manual navigational equipment (paper charts etc) - watch keeping on the bridge - hull material properties, hull design, and steel margins	

Operation mode:	Planning, departure/arrival & voyage					
ID No	**Hazard (What can go wrong)**	**Cause (Why can it go wrong)**	**Consequences (What does it lead to?)**	**Preventive safeguards (How can it be prevented?)**	**Mitigating safeguards (How can it be mitigated?)**	**Comments**
D	Failure of steering gear/manoeuvring systems	- mechanical failure of rudder/shaft/transmissions - technical failure of steering controls	- unable to control the position of the ship - grounding - collision	- redundant steering gear and manoeuvring systems - testing and inspections - maintenance	- power control systems - jury rudder - steel margins, double hull	
E	Slips, trips and falls	- stairways/ladders - doors - floor covering - lighting - carpet - working from heights - Ship motion (incl. weather)	- personnel injury - compensation claims - disruption to operation	- signage - training and awareness - PPE - improved design	- drugs and alcohol policy - improved design	
F	Missing a critical alarm	- operator fatigue - information overload - human-machine interface - complacency/boredom	- mechanical failure - fire/flooding	- correct setup of alarm set-points - training and awareness - manageable watch keeping routines - crew resource management		

Appendix 4: Summary of workshop II (Sept 2005)

☑ List	☑ List	☑ List	☐ List		☐ List			Personnel Risk			/Hazards	Basic Causes	Control
Id. No.	**Accident category**	**SWIFT category/ causes**	**Potential Incident**	**Consequence**	**Preventive safeguards (operations/design) - frequency related**	**Mitigating safeguards (operations/design) - consequence related**	**Comments**	**F**	**C**	**R**			
1	Collision	Human factors	Officer on duty not watchkeeping	Ship not under control - not noticing the other ship - alarms not reacted upon - collision at full speed (typical 20-24 knots)	- Two officers on watch* - 24 hours bridge supervision (CCTV) - Dedicated safety center separeted from navigation* (both eq & operational perspective) - Effective bridge mgmt (watchkeeping routines, communication, training,) - Manage culture diffrences (nationality, language, etc) - Nightvision, navigational aids	- Close watertight doors (general watertight integrity, remotely shut from bridge) - Manage culture diffrences (nationality, language, etc) - Crowd management		3	3	16			
2	Collision	Human factors	Lack of knowledege of navigating procedure	Wrong/unexpectd actions taken (e.g. steering to the wrong side) - collision at upper scale manoeuvering speed (typical 15-18 knots)	- Training (e.g. simulator) - Manning (minimum experience/competence requirements) - Bridge management/procedures	- "Last-minute" avoidance actions (e.g. manoeuvring) - Knowledge about the vessel/systems to ensure correct emergency actions - ++		2	4	16			
3	Collision	Human factors	Lack of interpersonal communication on bridge	Important information is not passed on/interperated correctly - incorrect actions taken (based on wrong information) - collision (typical 15-18 knots)	- Professionalism at work - Less dependency on verbal communication (could increase risks elsewhere) - Bridge layout and total intergration of alarm/control panel set-up			4	2	16			
4	Collision	Human factors	Wrong pilot intervention	Pilot does not know the vessel characteristics - wrong actions taken/safety compromised - collision in the lower speed range (typical 5-10 knots)	- Pilot training - Pilot on board earlier - Pilot protocol - More international regulated pilot services - Pilot information card (info on the vessel he/she is entering: propulsion, thrusters, etc)			1	1	1			
5	Collision		Collision between two ships (cruise - other) where cruise ship is not at fault (e.g. cruise ship information overload)	Heavy impact collision - larger than B/5 wide and 11m long (full height, at critical location) - water ingress (non-sustainable) - vessel sinking.	- AIS (Automatic Indentification Systems) (or other proactive anti-collision measures*)	- Increase the "safe" number of damaged compartments . - Crumple zones - Make cross flooding possible beyond 2 comp. damage				#N/A			
6	Collision	Equipment / Instr. / Systems - machinery	Severe loss of functionality (e.g. loss of rudder/steering at full speed, failure of shaft bearings)	Loss of rudder/steering - ship not under control - collision at full speed (20-24 knots)	- Redundancy in manoeuverability systems (steering gear, rudders,)		To which level should the redundancy be taken?			#N/A			
7	Collision	Equipment / Instr. / Systems - machinery	Severe loss of functionality (e.g. loss of power, blackout etc)	Loss of power - ship not under control - collision at full speed (20-24 knots)	- Software control routines - Compatability between systems throughout the life-cycle of the ship - Reduce time to restore functionality	- Separate engine systems				#N/A			
8	Collision	Organisation factors	Misinterpretation of bridge information	Important information (non-verbal) not obtained/interpretated correctly - incorrect actions taken - collision (typical 15-18 knots)	- Ergonomic bridge layout/design (layout of instruments, lighting, available space, amount of information presented, etc)					#N/A			
9	Collision	Equipment / Instr. / Systems - machinery	Contamination of fuel tanks	Losse of prime mover(s) - ship not under control - collision at full speed (20-24 knots)	- Redundant fuel systems - Bunker testing - Operational procedures					#N/A			
10	Collision	Equipment / Instr. / Systems - deck/bridge	Failure of critical naviational aids (in fog)	Unable to navigate - collision at full speed (20-24 knots)	- Redundancy of critical navigational aids - Redundancy in power supply					#N/A			
11	Collision		Redundancy failure				Transfer to fire/explosion			#N/A			
12	Collision		Mooring failure in heavy weather				Transfer to contact	Transfer to contact		#N/A			
13	Collision		Unsatisfactory berthing				Transfer to contact	Transfer to contact		#N/A			

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Id. No.	Accident category	SWIFT category/ causes	Potential Incident	Consequence	Preventive safeguards (operations/design) - frequency related	Mitigating safeguards (operations/design) - consequence related	Comments	Personnel Risk F	C	R	/Hazards	Basic Causes	Control
1	Fire/explosion	Procedures and routines	Laundry - Lint from tumble driers catching fire	Fire in laundry - fire spreading to exhaust channels - fire outbreaks elsewhere within the same fire zone	- Filters - Cleaning of filters and ducts - Inspection hatches for the ducts - Operational cleaning procedures	- Shut-off dampers for the laundry ducts - Fire suppression system(s) - Re-evaluate location of laundry				#N/A			
2	Fire/explosion	Procedures and routines	Mooring deck - mooring ropes catch fire	Fire on mooring deck (enclosed or open space) - fire spreads to adjacent spaces within the same fire zone (oxygen supply is good)	- Alternative mooring system (no use of ropes) - Fire-proof/fire protection around mooring ropes (drums/boxes) - No smoking/barbecues on mooring deck - Limited access to mooring deck	- Fire suppression system - Fire detection system - CCTV - Structural fire protection (fire insulated bulkheads and decks)	Mooring ropes represent quite a large quantity of combustible materials			#N/A			
3	Fire/explosion	Equipment / Instr. / Systems - machinery	Engine room - flammable fluids on hot surfaces	Engine room fire - loss of critical systems (e.g. propulsion and power) - fire contained within the engine room	- Proper maintenance - Shielding of flammable fluids (e.g. fuel pipes) - Good design (keep critical pipes away from hot surfaces) - Inspection routines	- Fuel shut-off valves - Fire, smoke and heat detection - Dedicated fire surpension system - Separate engine systems (does not solve the fire situation) - Structural fire protection - CCTV				#N/A			
4	Fire/explosion	Procedures and routines	Breach of hot work procedures (including engine room)	Hot work being carried out near critical equipment, local fire outbreak (e.g. close to the bridge)	- Hot work procedures in place for own crew - Hot work control and management of contractors - Testing of contractors equipment - Inspection to oversee adherence to procedures - Not carry out more hot work than necessary - Procedures and management	- Dedicated fire watch (independent of crew/contractors) - Portable extinguisher - Procedures and management				#N/A			
5	Fire/explosion	Equipment / Instr. / Systems - hotel	Galley - deep fat fryers/greasy cooking appliances catching fire (due to overheating)	Fire in galley spreading to the exhaust duct - fire outbreaks elsewhere within the same fire zone	- Filters - Cleaning of the deep fat fryers and/or cooking appliances - Cleaning of grease-filters and ducts - Inspection hatches for the ducts - Operational cleaning procedures - Safety thermostat on deep fat fryers	- Shut-off dampers for the galley ducts - Fire suppression system(s) - Fire blankets - Ventilation shut-off - Electric shut-off - Galley design/lay out (location of fryers, exits, etc)				#N/A			
6	Fire/explosion	Procedures and routines	Bunkering - leakage whilst bunkering, ignition through sparks, etc.	Worst case scenario: Sustainable fire that develops into a large scale fire	- MDO characteristics (high ignition temperature) - Operational procedures	- Fire surpression systems (sprinkler & fire hose)	More potential environmental consequences than fire/expl consequences			#N/A			
7	Fire/explosion	Human factors	Theatre (changing rooms + backstage) - hot lights and flammable materials (e.g. costumes)	Fire outbreak in theatre, contained within the fire zone	- More dedicated storage rooms of cat 13 - Low temperature bulbs	- Fire safety curtain - In addition to conventional sprinkler system, dedicated local nozzels - Smoke extraction				#N/A			
8	Fire/explosion	Human factors	Cabins - fire starts in cabin (cigarettes, candles, electrical equipment failure etc)	Fire starts in cabin, spreads to other cabins and corridors within the same fire zone	- Not allowed with cooking appliances in cabin - Keeping limited combustible materials in cabin - Educate and provide information to passenger on fire safety - Non-smoking cabins - Dedicated smoking areas	- Fire detection systems - Fire surppression systems - Fire insulation between cabins (structural measure) - Fire patrol - Redundancy in sprinkler/fog systems				#N/A			
9	Fire/explosion	Procedures and routines	Unauthorised storage of combustible materials (e.g. fluids, chemicals)	Unauthorised storage. Failure causing fire outbreak, fire in the unauthorised storage area	- Management and operational procedures - Proper storage & housekeeping - Sufficient storage spaces in appropriate loactions	- Allow sufficient space around sprinkler nozzels - Fire detection systems - Fire surppression systems				#N/A			
10	Fire/explosion	Procedures and routines	Arson - deliberate act resulting in a fire or fires	Fire not restricted to one single fire zone.	- Crew screening and awareness of dissatisfaction - Limit the amount of combustible material at any time (tidy, clean spaces etc) - Restrict physical access on a "need-to-know" basis - Routines and access control culture	Look at Engine Room fires				#N/A			
11	Fire/explosion		Boiler explosion - Safety valves not working properly - pressure increase beyond safe levels	Boiler explosion - immediate risk for life	- Testing and inspection of safety valves		Consult Carnival chief engineer -> Martyn Knight responsible			#N/A			
12	Fire/explosion		Crankcase explosion		- Oil mist detectors		Consult Carnival chief engineer -> Martyn Knight responsible			#N/A			
13	Fire/explosion		Incinerator							#N/A			

☑ List		☑ List	☑ List	☐ List	☐ List				Personnel Risk			/Hazards	Basic Causes	Control
Id. No.	Accident category	SWIFT category/ causes	Potential Incident	Consequence	Preventive safeguards (operations/design) - frequency related	Mitigating safeguards (operations/design) - consequence related	Comments	F	C	R				
1	Contact		Icebergs							#N/A				
2	Contact		Offshore production installations							#N/A				
3	Contact		Sea mammals							#N/A				
4	Contact		Ship hitting a solid quay when approaching port	Ship damage, water ingress. Passenger & crew injuries	- Operational procedures (close watertight doors when approaching shallow waters) - Training and simulation - Pilot - Ship design (bridge wings, bridge visibility, response and power availability, thrusters) - Tugboats	- Ship design (collision bulkheads,				#N/A				
5	Contact		Ship hits a bridge	Ship hit the bridge. Mast/funnel as first point of contact. Mast/funnel falls down, damage to superstructure.	- Pilots - Traffic Control Systems - Information on the maximum height of the ship able to pass through - Lighting, signals etc marked on the bridge - Voyage planning (e.g. Alternative routes to avoid the bridge)	- Mast design				#N/A				
6	Contact		Ship hits the one of the bridge pillar	Ship hit a bridge pillar. Ship bow as first point of contact. Breach of watertight integrity, damage below waterline	- Pilots - Traffic Control Systems - Lighting, signals etc marked on the bridge pillars - Voyage planning (e.g. Alternative routes to avoid the bridge pillar)	- Watertight bulkheads - Coillision bulkheads - Rules & Regulations (SOLAS: Crew memebers not allowed….)				#N/A				
7	Contact		Helicopter (operational: hot exhaust (from funnel) could cause problems for small helicopters)											
1	Grounding		Ship at full speed hitting hard sea-bottom (rock)	Hull penetration, water ingress, ship stops quickly, loose items falling down, passenger panic, ship gets the damage but continue to sail (deep water), maximum 3 compartments flooded.	- Navigational equipments - Updated and appropriate sea-charts - Trained and competent officer on watch - Pilot - Appropriate sea-keeping practices (speed vs water depth, etc)	- Watertight doors closed - Watertight compartments - Ship design (double bottom, cabin and corridor locations (corridors in the center are better when water ingress occurs) - Stronger ship bottoms				#N/A				