Development of "Risk Assessment Guidelines"

Toshiro Arima, Yoshiaki Kenmochi***

1. INTRODUCTION

The use of risk assessment is essential in the design and operation of offshore structures used for oil development, nuclear power stations, and other facilities. In the maritime industry as well, the use of risk assessment has expanded, and risk assessment has already reached the level of practical application.

ClassNK has conducted research on risk assessment methods for many years, however in order to encourage the spread of knowledge and expertise related to practical risk assessment, the Society has recently implemented several practical research projects designed to address issues faced by the maritime industry. ClassNK's "Study on the Risk Assessment of LNG Carriers" is one such project. As part of this project, the Society developed a 10-year forecast for the operating environment of LNG carriers, and based upon this forecast, developed safety measures to address the expected changes in risk levels for the world LNG fleet over the next decade.

Using the knowledge and understanding or risk assessment gained from these projects, the Society developed the new "Risk Assessment Guidelines" as an introduction to risk assessment. This report gives an overview of both these "Risk Assessment Guidelines" and the "Study on Risk Assessment of LNG Carriers".

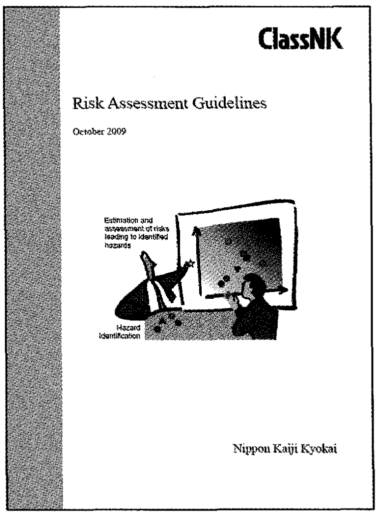

Figure 1 Risk Assessment Guidelines

2. Overview of "Risk Assessment Guidelines"

The ClassNK "Risk Assessment Guidelines" (see Fig. 1) were developed by summarizing the findings obtained from the implementation of problem-solving risk assessment projects and studies related to risk assessment methods. These new Guidelines are designed to provide a thorough introduction to risk assessment methodology.

The Guidelines were developed based on the concepts underlying the IMO's Formal Safety Assessment (FSA) Guidelines, and efforts were made to describe information related to risk and risk assessment as simply as possible. The guidelines are designed to serve as a valuable reference those staff in the shipping and shipbuilding industry involved in risk assessment activities. The contents of the Guidelines are as follows:

Chapter 1 Overview

Chapter 2 Basic concepts

Chapter 3 Explanations on risk assessment

Chapter 4 Formal Safety Assessment (FSA)

Chapters 1 and 2 of the guidelines describe the basic concepts of risk assessment, and summarize the terms and definitions used in risk management. Chapter 3 describes risk assessment methods and the FSA methodology developed by the IMO is published in Chapter 4. An overview of each chapter in these guidelines is given below.

2.1 "Chapter 1 Overview"

2.1.1 Safety and risk

The word "risk" has various meanings depending on viewpoint, as well as the field, and scope of its application. As these guidelines are intended primarily for the management of safety-related risks, in these guidelines risk is defined as the "combination of the possibility of loss of life, physical injury, accident or disaster, and the extent of the loss or damage". Further, safety is defined in accordance with the international standard given in ISO/IEC Guide 51 (1999) as the "absence of unacceptable risk".

* External Affairs Division, Nippon Kaiji Kyokai (ClassNK)
** Research Institute, Nippon Kaiji Kyokai (ClassNK)

2.1.2 Risk management and risk assessment

Much as with the term risk itself, the meaning of risk management differs depending on the field, scope and intent of its use. These Guidelines make use of the definition of risk management used in system and machinery safety management. That is, in these Guidelines risk management refers to the continual process of estimating current risk (in an organization, system, or individual activity), developing and implementing effective measures to reduce that risk to allowable levels, confirming the effects of those measures, and if necessary developing and implementing new risk reduction measures. This can be easily adapted to fit the PDCA cycle (see Fig. 2).

If we consider risk assessment from the perspective of risk management, it can seen as a tool for estimating the magnitude of the risk, and then formulating measures to reduce risk to acceptable levels.

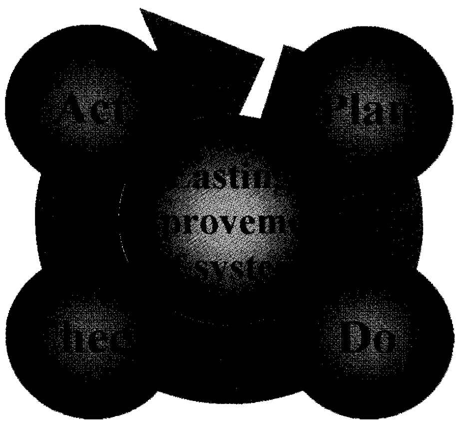

Figure 2 Conceptual sketch of PDCA cycle

2.1.3 Need for risk management and risk assessment

At present, when an accident occurs, the resulting damage and aftereffects may be extremely large. Some common scenarios include stock market system crashes, or train delays; or in the maritime field, oil spills.

Such accidents that have a wide-ranging influence on health, property, or the environment can be judged to be unacceptable by society at large. In such cases, it is necessary to adopt pro-active measures to prevent such accidents, rather than "re-active" measures that are adopted after an accident occurs in order to prevent a future recurrence. Risk management and risk assessment are the necessary tools for implementing such pro-active measures. (see Fig. 3)

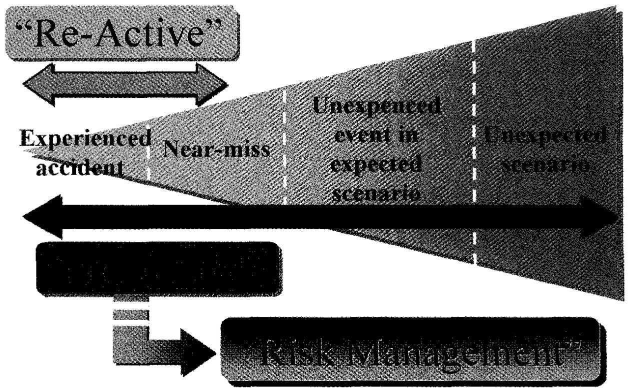

Figure 3 Re-active and Pro-active Measures

2.2 "Chapter 2 Basic concepts"

2.2.1 What is risk?

In these Guidelines, as risk is defined as the "combination of the possibility of loss of life, physical injury, accident or disaster, and the extent of the loss or damage". In order to express this risk quantitatively, we adopt the following definition common to the engineering field: Magnitude of risk = Level of damage x frequency of occurrence.

2.2.2 Approach based on risk

Recently, it has become widely accepted that it is better to understand the inherent risk in a system and make efforts to maintain that risk below a certain level, than it is to prevent damage that occurred because of a particular technical condition. This concept is called a risk-based approach, or more simply risk management.

2.2.3 Determination of risk

To assess the risk in a system, the risk level has to be expressed using some method. That is, the loss has to be estimated quantitatively.

For this reason, we have to detect the hazards or factors in the current system that could potentially cause harm, and further, develop accident scenarios for the series of events that occur as result of these hazards, estimate risk by calculating the frequency of occurrence and the magnitude of loss or damage, and assess the results.

2.2.4 Is the risk acceptable?

Once the risk is quantitatively established, the next step is to judge whether the risk is acceptable. In order to reduce risk, it is necessary to either stop using the system, or invest resources such as money, time, or labor in the system. If the benefits obtained from using the system and the magnitude of the risk are compared, and the use of the system is determined to be unavoidable or necessary, then the risk may be judged as acceptable. Based on this concept, the level of the risk to be aimed for is called the safety target.

2.3 "Chapter 3 Explanations on risk assessment"

2.3.1 What is risk assessment?

Risk assessment is a series of procedures consisting of risk analysis, assessment of risk magnitude, and risk reduction measures. In other words, risk assessment involves detecting the hazards in a system, determining the frequency of occurrence and magnitude of loss or damage, estimating the risk, assessing the results of the estimation, and then proposing and implementing measures based on the assessed results. Risk assessment can be an important tool for the practice of rational risk management as part of organization's decision making process.

2.3.2 Risk assessment process

Risk assessment can be thought of as a five-step process: "hazard identification", "risk analysis", "estimation of risk", "assessment of risk magnitude", "risk reduction measures" and "cost benefit assessment". "Cost benefit assessment" may or may not be implemented, based on economic necessity.

2.4 "Chapter 4 Formal Safety Assessment (FSA)"

2.4.1 Overview of FSA

Formal Safety Assessment (FSA) [1] is a risk assessment methodology used in the rule-making process of the IMO, a special organization of the United Nations. The FSA procedure (see Fig. 4) consists of five steps, namely: "hazard identification", "risk analysis", "study of Risk Control Options (RCO)", "cost benefit assessment of RCO", and "recommendations for decision-making". The inclusion of cost benefit assessment and recommendations for decision-making are characteristics particular to FSA.

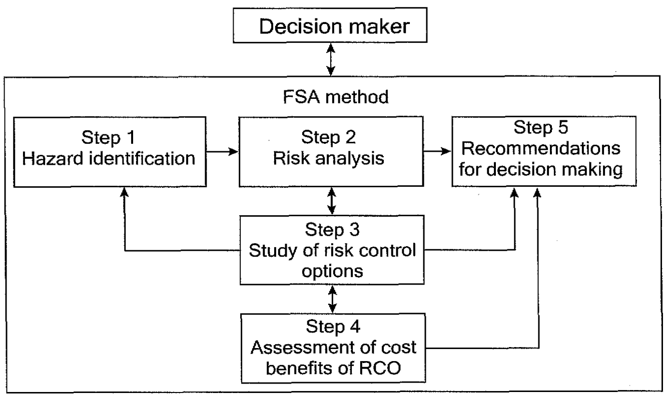

Figure 4 FSA implementation steps

2.4.2 Objectives and characteristics of FSA

The most important objective of FSA is to allow the IMO to develop rules in a forward thinking and systematic manner. In other words, the objective of FSA is not to develop rules in response to accidents, but rather to develop rational procedures based upon risk assessment. In addition to the inclusion of cost benefit analysis, one of the protocols in each step of FSA is that the assessment procedure is clearly laid out. Thus by following the FSA procedures, it is possible to develop more rational and transparent safety procedures than were previously possible.

2.4.3 Definition of the problem

In order to define a problem, all of the factors related to the problem must be considered. The IMO's FSA Guidelines include the following ship-related factors

(1) Ship category (for example: ship type, length capacity (gross tonnage), newbuilding or ship in service, cargo type)

(2) Ship operations (for instance, maneuvering in port, maneuvering during voyage)

(3) External influences on the ship (for instance, ship traffic system, weather prediction, warning, route selection)

(4) Accident category (for instance, collision, explosion, fire)

(5) Risk related to injuries or fatalities among the passengers or crew members, environmental effects, damage to the ship or port equipment and facilities, and the impact of such events business.

2.4.4 FSA Step 1 "Hazard Identification"

For the problem being considered, the series of hazards, as well as the risk level for each hazard, based on the scenario resulting in damage for each hazard, are to be identified. Hazard identification is a standard method, and screening is conducted based on available data and the judgment of experts. Hazards are then ranked using the severity and frequency data shown in Tables 1 and 2, and hazards with low rankings are excluded from the following steps.

2.4.5 FSA Step 2 "Risk Analysis"

The causes and effects of the important scenarios identified in Step 1 are studied in detail. More specifically, a risk model is constructed and explored in greater detail, and the factors affecting the risk level are made clear. The level of each risk is also determined in this step.

Table 1 Example of severity index (SI) for ships

SI	Qualitative expression	Effect on human beings	Effect on ships	death toll conversion
1	Minor effect	Single casualty or multiple persons with slight injuries	Local damage	0.01
2	Large effect	Multiple casualties or severely wounded persons	Non-severe damage	0.1
3	Severe effect	Single fatality or many severely wounded persons	Severe damage	1
4	Catastrophic effect	Multiple fatalities	Total loss	10

Table 2 Example of frequency index (FI) for ships

FI	Frequency	Definition	ships affected per year
7	Frequent	Could occur once a month per ship	10
5	Sometimes	Could occur once a year in a convoy of 10 ships. Several times in the lifetime of one ship	0.1
3	Rarely	Once a year in a convoy of 1000 ships. May or may not occur in the lifetime of several similar ships	0.001
1	Extremely rare	If a convoy of 5000 ships exists in the whole world, a one-time occurrence in the lifetime of all these ships	0.00001

2.4.6 FSA Step 3 "Risk Control Options"

Once the high risk areas to be analyzed are identified, measures to control risk are studied. Measures to control single elements of risk are called Risk Control Measures (RCM); while sets of RCM are called Risk Control Options (RCO). The objective of Step 3 is to propose effective and practical RCO for problems in the identified high risk area.

2.4.7 FSA Step 4 "Cost Benefit Assessment"

For implementing RCO defined and identified in Step 3, cost benefits are assessed and compared. Under FSA, the cost benefit of each RCO is assessed using two indices: Gross Cost of Averting a Fatality (GCAF), that is, total cost required for averting loss of life, and the Net Cost of Averting a Fatality (NCAF), that is, the cost required for averting loss of life minus the benefits gained from implementing the RCO.

These indices may be expressed as below.

$$GCAF = \Delta C / \Delta R \quad (1)$$

$$NCAF = (\Delta C - \Delta B) / \Delta R \quad (2)$$

Here,

ΔC is the cost required for implementing RCO per ship

ΔB is the economic effect per ship obtained from the result of implementing RCO

ΔR is the risk reduction per ship obtained from the result of implementing RCO

In order to determine whether cost benefit based on GCAF is positive or negative, MSC 72/16 established a GACF of less than 3 billion dollars as a standard criterion.

Other indices based on the damage and effects to property or environmental issues may also be used.

2.4.8 FSA Step 5 "Recommendations for Decision Making"

The objective of Step 5 is to provide decision makers with recommendations via a transparent and auditable process. Recommendations to be based on RCOs, and are only to be made after all hazards and their underlying causes, as well as the accompanying cost benefit and risk control options, have been compared and ranked, and the RCO has been judged to reduce risk to rational and practical levels.

3. Overview of "Study on Risk Assessment of LNG Carriers"

As can bee seen in Fig. 5, LNG carriers (LNGC) have better safety records than other kinds of ships. [4]

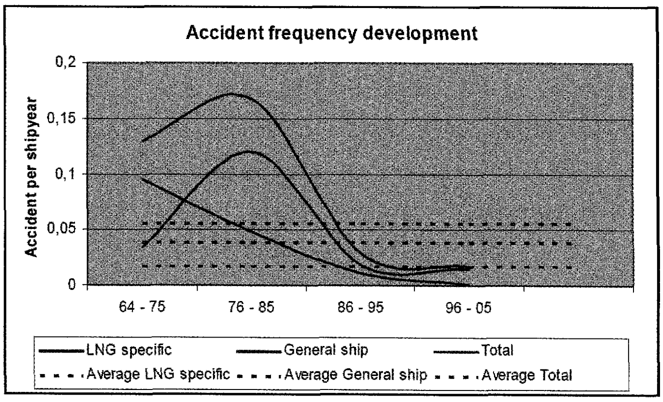

Figure 5 Accident frequency over time[4]

However, the operational environment of the LNGC fleet is rapidly changing. Some of the factors contributing to this change include:

- Expansion of the LNG market and an increase in the number of LNG carriers. There are currently about 200 LNG carriers in operation and roughly 140 more ships on order.
- Entry of new ship operators into the LNG field.
- Increased ship size.
- Increase use of spot chartering.

These changes raise not only economic and environmental issues, but manning issues as well. For example, there is a shortage in the number of ship personnel who can handle the turbines commonly used in LNG carriers. It is therefore imperative that the risk levels of LNG carriers be estimated to reflect these changes, so that proactive safety measures can be formulated, studied and evaluated.

ClassNK is currently actively pursing this task in an extensive ongoing research project on the risk assessment of LNG carriers.

3.1 Objectives

The main objectives of the risk assessment of the hull structures of LNG carriers is to estimate the anticipated changes to the safety level of LNG carriers after 10 years (see Fig. 6), and to investigate proactive measures to maintain the highest safety level for LNG carriers, with a specific focus on LNGC hull structures (see Fig. 7). The risk assessment is being conducted in accordance with the FSA methodology developed by the IMO and shown in Fig. 8. This methodology is composed of five clearly defined steps:

Step 1. Hazard Identification (HAZID)

Step 2. Risk Analysis

Step 3. Risk Control Options

Step 4. Cost Benefit Assessment

Step 5. Recommendations for Decision Making

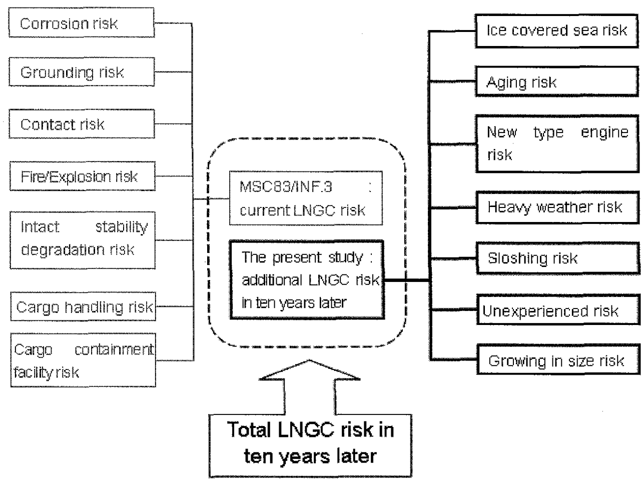

Figure 6 Conceptual risk model for evaluation of LNGC risk ten years later

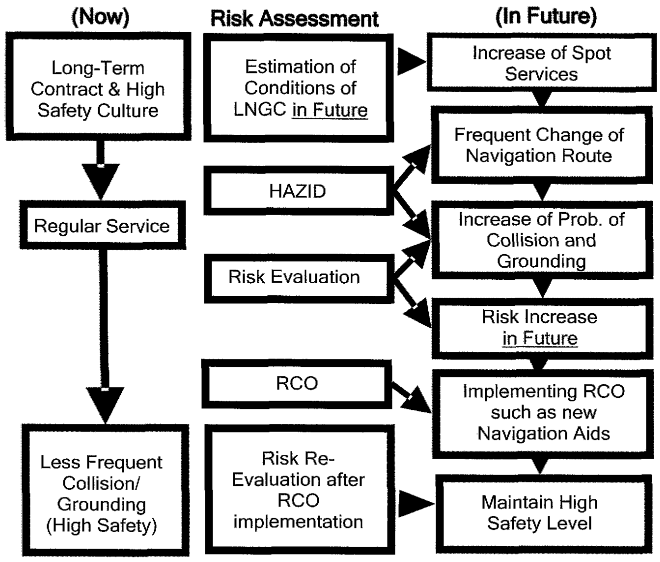

Figure 7 Conceptual risk assessment flow for collision and grounding scenarios

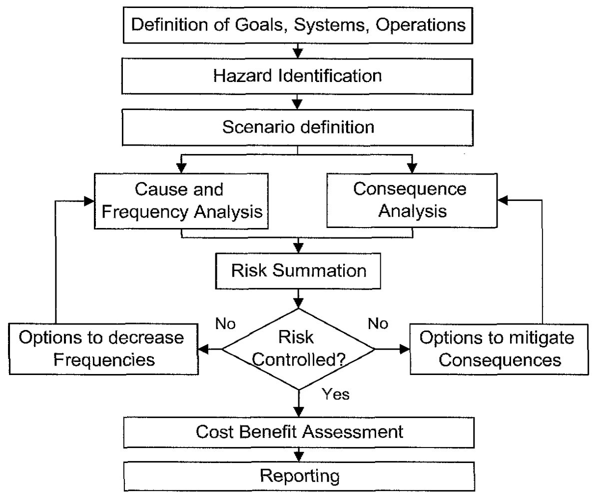

Figure 8 FSA risk assessment flow chart [1)]

3.2 Step 1 "Hazard Identification"

The LNG operational environment ten years from now is being forecast based on anticipated market changes, as well as historical casualty data, etc. A hazard identification exercise was conducted by means of a HAZID meeting attended by a multidisciplinary group of experts. In this step, the scope was extended to cover not only LNGC hull structures, but also other factors such as machinery. Accordingly, identified hazards were prioritized in terms of risk through the use of a Risk Index (RI), and were associated with hazards and possible accident scenarios.

Seven major hazards likely to increase the risk levels of LNG carriers in the future were identified as shown in Table 3. It should be noted that the HAZID meeting was conducted with a view towards identifying future hazards, based on the anticipated changes to the operational environment of the LNGC fleet.

3.3 Step 2 "Risk Analysis"

A quantitative risk analysis was carried out in accordance with prioritized accident scenarios in order to estimate the changes to LNG carrier risk levels over the next ten years. Accordingly, a statistical estimation of the changes in risk level is being investigated in conjunction with the identification of probable new risks that arise due to the changes. The evaluation of risk assessment for LNG carriers was estimated by comparing the "Cumulative Occurrence Frequency" and the "Number of fatalities" (F-N).

Figs. 9 and 10 show the F-N curves which are based on the outcomes of Step 2. The former shows the F-N curves of each accident scenario and the latter shows F-N curves for the estimated risk level 10 years later, as well as the present risk level given in Reference (4). In these figures, the upper and lower limits of the ALARP (As Low as Reasonably Practicable) Region are indicated with reference to those in Reference (4).

3.4 Step 3 "Risk Control Options"

This step includes the Risk Control Options (RCO), which correspond to the particular high risks that could affect the hull structure, in order to determinate the countermeasures that should be taken into consideration to avoid this from happening. Also, by using the Risk Control Measures (RCM), it is possible to control the risk as a simple factor. Effective measures are implemented in order to control risks, or to prevent increases in risk level or the development of new risks in the future.

Table 3 Major identified hazards in the future

Hazard	Detailed Description/Accident Scenario
a. Navigation in ice covered seas	1. Jeopardized by ice coating in terms of stability 2. Jeopardized by ice coating in terms of dropped ice 3. Propeller damage due to floating ice 4. Collision due to continuous navigation under the midnight sun 5. Collision due to navigation at sunrise after the midnight sun 6. Damage to windows in wheelhouse 7. Ballast water freezing 8. Failure of starting emergency electric generator 9. Ice forces on hull structure
b. Aged ships	1. Age deterioration of the boiler and high steam pressure lines 2. SCC of SUS plumbing 3. Corrosion of outer shell in way of ballast tanks 4. Corrosion of inner shell in way of ballast tanks
c. New-type engine	1. LNG tank problems caused by diesel engine vibration 2. Gas and/or oil leakage in engine rooms due to main engine vibration 3. Failure of all main engines
d. Navigation in rough seas	1. Sloshing in rough seas 2. Failure due to accumulated fatigue damage from navigation in rough seas
e. Sloshing	1. Sloshing in membrane tanks 2. Sloshing during re-gasification 3. Sloshing during loading/unloading
f. Navigation in unfamiliar seas	1. Human Errors due to unfamiliarity in un-experienced seas
g. Larger-size LNG	1. Human errors related to higher voltage systems 2. Short circuit due to higher voltage

Table 4 Major effective RCOs in the future

RCO	GCAF	NCAF	Hazard Category
	(million US$)		
Sunglasses on the bridge	0.004	Negative	Ice covered seas, Polar night
Search Lights for Icebergs	0.2	Negative	
Providing Mental Support/Care to crew against stresses due to Polar night	0.4	Negative	
Freezing-prevention measures on deck	0.8	Negative	
Warning system by means of automatic analysis of images obtained from night vision	0.8	Negative	
Weather information service for ice covered seas	0.9	Negative	
Radar for iceberg detection	1.0	Negative	
Night vision	2.7	Negative	
Thickness measurements of specified area of high risk	2.3	Negative	Aged ships, main engine failure
Wide area application of strengthened insulation box	1.8	Negative	Sloshing and unloading with re-gasification

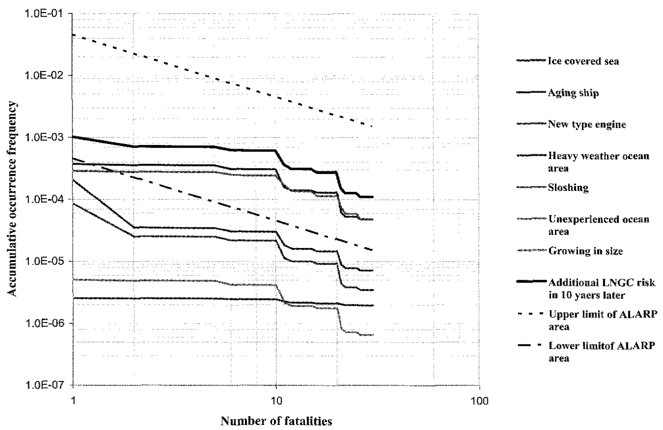

Figure 9 F-N curves of LNG carriers of individual accident scenarios

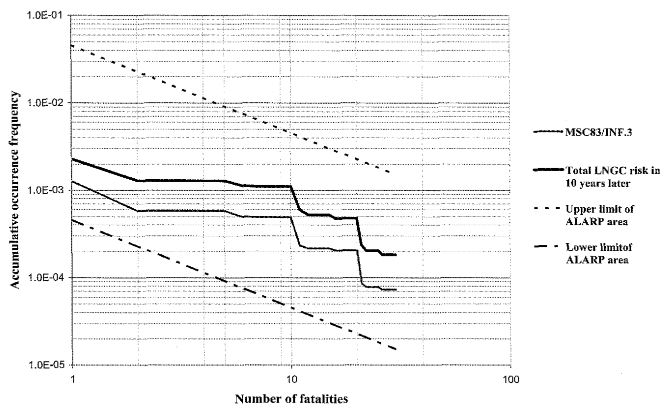

Figure 10 F-N curves showing total risk levels

3.5 Step 4 "Cost Benefit Assessment"

In the 4th step, the cost benefit assessments were conducted for each identified RCO. According to the IMO FSA Guidelines, the Gross Cost of Averting and Fatality (GCAF) were used as a cost-effectiveness index. The major cost effective RCOs are shown in Table 4.

3.6 Step 5 "Recommendations for Decision Making"

As described in 3.3, the estimated risk level 10 years later is in the ALARP region. In addition, cost-effective RCOs are identified in Step 4. Accordingly, it can be concluded that the risk level of LNG carriers 10 years later could be ALARP provided that cost effective RCOs, such as those identified in this study, are implemented properly in accordance with future changes to the LNG carrier operational environment.

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