THE ROYAL INSTITUTION
OF
NAVAL ARCHITECTS

Safety Guidance for Members of The Royal Institution of Naval Architects

Third Edition
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Contents

1 Introduction

1.1 Overview

1.1.1 "Safety Guidance for Members of RINA" has been produced by the Safety Committee of the Royal Institution of Naval Architects to provide information and guidance to members on safety management and associated methods. Initially published in 1993 as "Guidance for Members Concerning Safety Assurance", this third edition reflects the latest developments in ship safety.

1.1.2 Chapters 2, 3 and 4 contain some theory, definitions of safety and the regulatory approach. Chapter 5 addresses safety management considerations over the project life cycle. Chapter 6 suggests some practical risk assessment and risk management methods that can be applied beneficially to projects of a wide range of complexities. This is supplemented by further detail on risk assessment techniques in Appendix C. Concluding advice is provided in Chapter 7. Appendix A contains recommendations for further reading, and Appendix B provides a tabular summary of some notable marine accidents.

1.2 Scope of Guidance

1.2.1 The word "guidance" is appropriate to this document because although many experts and respected authorities have attempted to define rules and measure safety performance, the approach taken will need to vary to best suit the case being considered, taking into account issues such as the complexity of the ship, the role for which it is intended, the degree of innovation, the context specific requirements of the client and the Classification Society, and applicable regulations.

1.3 Professional Obligations

1.3.1 In the course of their professional activities, members are obliged to ensure that human life, the environment and property are properly safeguarded.

1.3.2 The Conventions of the International Maritime Organization provide the starting point for achieving this objective. Members must also comply with national statutes and appropriate Port and Coastal State regulations of the country in which they are working. Contained within them is the knowledge and experience of seafarers, surveyors, designers and repairers, compiled over more than a century of world-wide shipping history. These regulations and ship Classification Society Rules, continuously updated in the light of advances in technology and service experience, provide the foundation of established good practice.

1.3.3 However, compliance with such regulations and standards cannot be relied upon to achieve an optimally safe outcome, particularly where systems or their mode of operation are novel or complex. A systematic, risk-based, approach to safety enables complex safety issues to be addressed explicitly and in doing so enables innovation while ensuring that safety goals are achieved. It can also provide a basis for demonstrating that levels of safety at least equivalent to those required by prescriptive requirements are achieved.

1.4 Duty of Care

1.4.1 Members must be aware of the particular conditions of their contracts, the safety duties placed on them by their employers and, above all, the personal obligation to exercise a duty of care in their work towards their employees and others. Personal care applies to members at all levels; from those directly involved in applying the rules, regulations and systematic risk-based methods, to those involved in management who must ensure, amongst other things, that there are adequate manpower and other resources and systems properly organised to undertake the work involved. This is necessary to avoid undue stress on staff which can have an adverse effect on their health and give rise to errors which jeopardise safety.

1.5 Further Reading

1.5.1 These guidelines can do no more than provide an introduction to the principles and methods of risk assessment and risk management. Many good books on safety and risk management have been published but there is no single textbook that practitioners can refer to as the standard work. The techniques and processes outlined are examples of best practice that is evolving. However, to become fully competent the reader will need to undertake additional study and practice. Recommendations for further reading are given in Appendix A.

1.6 Feedback

1.6.1 The Royal Institution of Naval Architects welcomes constructive comments and suggestions for improving these guidelines. These should be submitted by email to hq@rina.org.uk.

2 The Member's Responsibility for Safety

2.1 Overview

2.1.1 There are many stakeholders involved with the safety of ships and the environment, and the links between them are complex. Consistent use of terminology is needed to ensure that essential safety issues are readily and reliably communicated both within and between organisations.

2.1.2 Members are involved in a wide range of organisations having diverse roles within the maritime industries. The member may be held personally accountable for specified aspects of safety in the design, construction and operation; sometimes as part of a team, at other times supervising or advising on the work of others. These responsibilities can be summarised as:

a. To exercise a professional „duty of care‟ towards all colleagues, employees and customers, in accordance with health, safety and environmental protection legislation, and

b. To act in the best interests of seafarers and the public to assure their health and safety, and to protect the environment.

2.1.3 To this end, and as members of the Royal Institution of Naval Architects, they are required to comply with the Institution's Code of Professional Conduct and the requirements of national and international law.

2.2 Requirements of the Institution

The By-Laws of the Institution stipulate that:

"Every member shall at all times so order his/her conduct as to uphold the dignity and reputation of their profession and to safeguard the public interest in matters of safety and health and otherwise. They shall exercise their professional skill and judgement to the best of his/her ability and discharge his/her professional responsibilities with integrity."

The Institution's Code of Professional Conduct requires that:

"Every member shall, at all times and in all respects, take all reasonable care to prevent danger of death, injury or ill-health to any person or of damage to property, whilst carrying out his/her work or as a consequence of it."

and that:

"Every member shall, at all times and in all respects, take all reasonable care to prevent adverse impact on the working environment of himself/herself and others, and on the wider environment as a consequence of his/her work."

and that:

"In the course of his/her professional work, every member shall carefully assess possible hazards, their mitigation and counter-measures in order to minimise risk, particularly to the public and the environment."

and that:

"Every member shall only undertake work which he/she has sufficient competence, time and authority to perform".

and that:

"Should a member's professional advice be rejected by his/her employer or customer, the member should take all reasonable steps to ensure that the person who overrules or

disregards such advice is made fully aware of the possible consequences. Where the advice concerns the safety or health of people or of the environment, the member should make clear his/her concerns in writing and request written acknowledgement. He/she should also consider taking further action, for example through his/her employer, relevant national regulators or by seeking the advice of the Institution ..."

2.3 Compliance with the Law

2.3.1 Members must obey the law of the countries where they are employed and recognise the laws and standards of countries where ships may visit or be used. Although there are many legal variations and complexities to be found, most countries have enacted similar maritime safety legislation in two areas, namely:

a. Minimum standards for the design, construction and operation of ships, and

b. Laws providing protection to the users of equipment during construction, maintenance and operation of vessels.

National Legislation for Ships

2.3.2 National shipping laws lay down the minimum design, construction and seaworthiness requirements for the registration of ships within the country and embody recommendations, codes of practice and conventions agreed at the International Maritime Organization (IMO). In some cases statutes may require higher safety standards than are required by IMO convention. It is often the case that national authorities delegate to Recognised Organisations some of their functions concerned with ascertaining compliance with defined regulations and standards.

2.3.3 Other regulations provide for the health and safety of those working in or around a ship whilst building. There may be an extension of essentially land-based safety law to cover activities in territorial waters (such as loading and discharging cargo and for diving operations), or whilst undergoing maintenance and repair.

Classification Societies

2.3.4 Classification Societies are organisations that were established from the eighteenth century to provide independent assurance of the integrity of ship's hulls and machinery. Today, they provide extensive independent technical, research and survey services to the marine industry, to Flag Administrations and to the IMO. The major Classification Societies are members of the International Association of Classification Societies (IACS) which serves to combine their resources to develop unified requirements that ensure a consistent proven level of safety for ship's hulls, machinery and equipment. IACS is represented at the IMO as a non-governmental organisation, where it brings the combined technical and service experience of the Classification Societies to the proceedings.

Recreational Craft

2.3.5 Private recreational craft are not generally subject to national or international legislation except under laws providing for consumer protection. The EC Directive on Recreational Craft is one such example. However, recreational craft used for commercial purposes, such as for charter, are often subject to national legislation. An example of this is the requirement by the UK and Red Ensign Administrations for charter yachts to comply with the MCA Large Commercial Yacht Code.

Consumer protection

2.3.6 Many countries have legislation providing protection to the consumer. The general aim is to ensure that products are "fit-for-purpose". Legal obligations apply to those involved in design, manufacture, installation and testing etc. Those who observe malpractice and take no action become accessories.

Offshore

2.3.7 Offshore installations are usually subject to a specific regulatory regime. This is often a combination of onshore requirements extended to apply offshore, and requirements specific to offshore installations and pipelines; some of which are similar to, or derived from, merchant shipping regulations.

2.3.8 The operator is often required to produce and maintain a safety case, and to operate the installation in accordance with it. The safety case usually:

- describes the installation and its design, construction and operating philosophies.
- identifies the major hazards and describes the associated risks and risk management measures.
- describes the associated safety management arrangements.

Naval Vessels

2.3.9 Naval vessels are not generally subject to international regulations such as SOLAS and MARPOL, but this exemption is under increasing scrutiny. As a consequence, most defence forces require their ships to be designed, built and operated to civil standards, or at least to standards that have been demonstrated to be equivalent to those required under civil legislation. Where a departure from civil practice is required, account will be made of the risk of military operations balanced against the need to take reasonable care of the safety of people, equipment and the environment. In such cases the justification for the impracticality of compliance with civil practice, or necessity to use a military standard, must be recorded.

2.3.10 To assist national Naval Administrations, a number of the Classification Societies have developed, with them, Rules for the design, construction and survey of naval vessels.

Personal liability

2.3.11 Most employers will protect their employees in the event of civil claims for compensation in the event of loss. However, in some countries, employers cannot relieve employees of personal responsibility in regard to criminal negligence or other offence. Members who are self-employed should obtain professional indemnity cover to safeguard themselves from civil claims for compensation. All members should familiarise themselves with national safety legislation and liability insurance in the countries in which they are working.

2.3.12 Other obligations arise through contracts, or through the operation of vessels without due diligence, or inadequate levels of competence.

2.3.13 The scope of the above laws should not be underestimated. They presume an adequate degree of competence in those responsible and supporting evidence that they have kept themselves up to date in their profession by being fully informed of new developments and aware of the centres of expertise available to them.

The Institution's Code of Professional Conduct requires that:

> *"Every member shall only undertake work which he/she has sufficient competence, time and authority to perform."*

and that:

> *"Every member shall take all reasonable steps to maintain and develop his/her professional competence in relation to new developments relevant to his/her field of professional activity"*

3 What is Safety? – Concepts and Definitions

3.1 Overview

3.1.1 Everybody has some understanding of the term safety but its interpretation can vary widely. Safety is the converse of danger, which is a measure people use to judge the perceived level of potential for harm. Safety is often measured subjectively. In some situations it can be appropriate to quantify the level of safety. This is explained later in this and subsequent chapters.

3.1.2 In the context of this guide, harm is concerned with:

- Death
- Physical or mental injury
- Physical or mental ill health, whether short term, long term, or delayed
- Damage to property
- Pollution of the environment

3.1.3 The associated terms “hazard” and “risk” are defined later in this chapter.

3.1.4 Several definitions of safety are in common use:

a. A state of freedom from risk (i.e. absolute safety). This popular definition implies that risk can somehow be avoided altogether.

b. A state of freedom from unacceptable risk (i.e. adequate safety). This technical definition implies that safety is achieved once risk has been made low enough.

c. The degree of freedom from risk (i.e. safety level). This defines safety as the inverse of risk, and implies that safety can always be improved with further effort.

3.1.5 The term is also used to describe equipment or activities that contribute to safety, such as “safety valve”, “safety regulations”, and “safety management”.

3.1.6 Until recently, members addressed safety through the subjects of stability, strength and seaworthiness. Many had the impression that adequate safety was achieved through compliance with rules and regulations, such as SOLAS. Investigations of accidents such as the Herald of Free Enterprise made clear that the safety level depends on human factors and management, not just on technical matters. Furthermore, adequate safety requires continual improvement as part of the „duty of care‟, not simply compliance with regulations.

3.1.7 Safety usually refers to the protection of people from risk of injury or death. This is reflected in the view that health, safety and the environment are mutually exclusive subjects. However, technical safety refers to protection of people, property and the environment from any source of harm. This includes not only pollution of the marine environment in accidents, but also chronic pollution that may affect air quality and ultimately may contribute to harmful climate change. The safety role of the member therefore embraces safety of the ship, the crew, third parties, property and the environment.

3.1.8 A member’s education will include design theory and methods. Subsequent training will usually consider these in the context of the owner’s requirement. During career development, academic achievement and training are complemented by increasing practical experience in designing to time and cost, meeting or formulating rules and regulations, methods of construction and outfit, in service maintenance and operation through the ship‟s life.

3.1.9 Safety is a key ingredient to be included at each of these stages but the aim must be to keep a balance between risk reduction measures that might exceed regulatory minima and other business imperatives.

3.1.10 Prescriptive regulations are best for routine situations and well-established practices. They provide a datum based on experience and a means of steadily improving baseline safety standards. They are also a sound reference against which statutory authorities can measure the compliance of operators. However it is difficult to keep rules up to date with developing technology and impracticable to write a rule for every eventuality. For example the SOLAS regulations include a standard fire test that takes 60 minutes to reach maximum temperature. There have been many recorded fires in ships where this condition was exceeded.

3.1.11 In order to achieve more effective safety assurance, designers and ship operators should look beyond the minimum requirements of the statutory safety certificate, and adopt a goal-setting methodology to take account of hazards that are not adequately addressed through prescription.

3.1.12 The prescriptive approach is discussed in Chapter 4. The risk-based methodology is outlined below, and further expanded in Chapter 6 and Appendix C.

3.2 Risk-Based Methodology

3.2.1 Risk-based methodology is based on finding answers to five basic questions:

a.	What can go wrong?	(Hazard Identification)
b.	What are the chances and effects of this?	(Risk Assessment)
c.	How can we reduce this?	(Risk Reduction)
d.	What will we do if an accident occurs?	(Emergency Preparedness)
e.	How can safety be managed?	(Safety Management)

Definitions

3.2.2 Hazard

A hazard is something with the potential to cause harm, and is normally described qualitatively.

The concept that a hazard has the potential for something undesirable to happen rather than the actual event itself is important in understanding the approach to be adopted toward hazard identification and risk assessment.

The terms acute and chronic are often used to differentiate between hazards with the potential to cause harm as a result of relatively short-term events such as oil spills, fires and explosions (acute hazards), and hazards which arise from long-term events such as continuous discharges and occupational exposure (chronic hazards).

A hazardous event occurs when the hazard‟s potential to cause harm is realized.

3.2.3 Risk

> *"Risk is the combination of frequency, or probability and the consequence of a specified hazardous event."*
> ISO/IEC Guide51

Risk is a measure of the threat posed by a hazard. It is considered as a combination of the likelihood of a particular hazardous event occurring, and the potential consequences of its occurrence.

Risks arising from discrete hazards can be combined to provide a measure of total risk; e.g. the risk to which a person or group of people may be exposed over a period of time from a range of hazards.

3.2.4 Risk Assessment

The Royal Academy of Engineering defines risk assessment as the process which determines where a hazard will be located on a risk scale, which is not a clear cut pass/fail test and by convention normally comprises intolerable, tolerable and negligible regions.

Alternatively, according to ISO/IEC Guide 51: "Risk assessment is the overall process comprising **risk analysis** (systematic use of available information to identify hazards and to estimate their risk) and **risk evaluation** (procedure based on the risk analysis to determine whether the tolerable risk has been achieved)".

3.2.5 Safety Management

Theorists continue to argue about the efficacy of managing risk since it would seem human intervention by redesign, introduction of rules or safer working practices only deals with risk identified by experience but cannot predict or control unexpected risks that seem to continuously arise as conditions change. The best approach is therefore to treat the process of safety management holistically, commencing at the first concept of design, iterating (as illustrated in Figure 1) and continuing the process throughout the life of the vessel. As time passes, new hazards that arise from changes and modifications (both material and procedural) must be continuously reassessed, and the baseline safety justification and management system reviewed to assure that safety is maintained within acceptable limits.

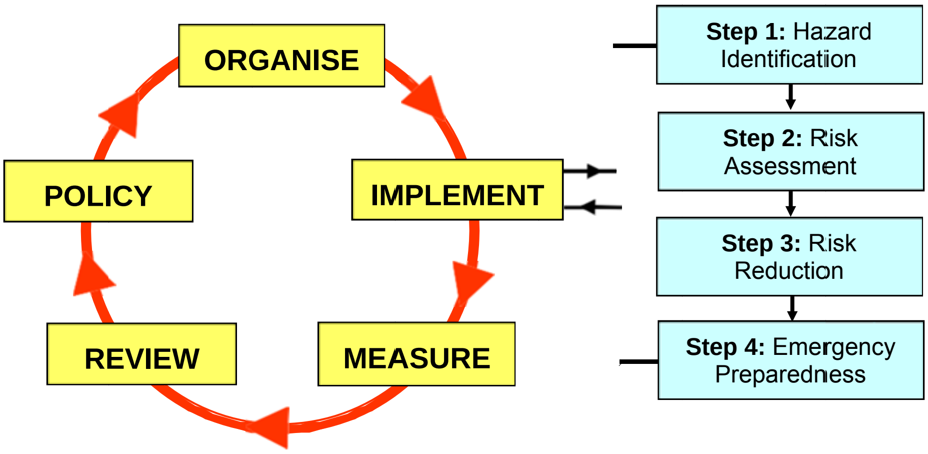


Figure 1: Risk based management system approach

3.2.6 Safety Case

In many countries, those industries having the potential to give rise to a major accident involving multiple fatalities have adopted the use of the Safety Case to formally document safety management arrangements. Examples of these industrial sectors are offshore oil and gas, nuclear, process chemical, defence, rail transportation and civil aviation.

Although requirements vary, a safety case usually consists of:

a. A description of the facility, its constituent systems, and their modes of operation.

b. A safety management system or plan

c. Risk assessment and associated risk management arrangements

d. Emergency / contingency planning

e. Supporting documentation

3.3 Human Factors

3.3.1 Mankind has a propensity to take risks, weighing the benefits to be gained against the perceived dangers. Cultural background, knowledge and experience continuously influence this behaviour. Behaviour is also subject to the physical limitations and frailties of the human body, errors of judgement and action, bravado (often relevant to the armed forces) and rarely malevolence. Poor design will contribute to accident causation not only by miscalculation leading, for example, to failure of the ship‟s structure, but also because sometimes insufficient attention is given to the key role played by the crew. Since accidents are mostly initiated either directly or indirectly by people, safety is inextricably linked to human attitudes, behaviour, decisions, actions and errors.

3.3.2 Statistics on marine accident claims recorded by P&I Clubs suggest that human error (mainly the crew) is responsible directly for 60% of accidents and indirectly (such as quality faults in build, poor maintenance and perhaps mismanagement ashore) for a further 30%. Thus addressing engineering details alone will not resolve all safety risks. Some of the key factors to recognise are:

a. The culture and economic pressures within organisations will have a significant effect on the management and undertaking of ship design, maintenance and operation.

b. Individual professionalism and care is needed in design and procurement to avoid building in safety errors, and also to record safety criteria, risk arguments and decisions.

c. Compliance with standards, regulations and procedures will not allow for every eventuality and the many opportunities for human error in all areas of the maritime community.

d. The physical and cognitive interfaces that exist between the ship‟s crew and their working environment, including equipment, communication systems, training, documentation and software are intrinsic to any safety assessment.

3.3.3 Operators hold the key to avoiding hazards during their daily duties and provide the last layer of safety in managing emergencies and the unexpected.

3.3.4 Human physical characteristics and behaviour contain greater statistical variation than any other design parameter. A number of books and standards on human factors have been written to provide suitable data for use in safety management.

3.4 The As Low As Reasonably Practicable (ALARP) Principle

3.4.1 ALARP is the main test applied by safety authorities such as the United Kingdom Health and Safety Executive, and seeks to determine that:

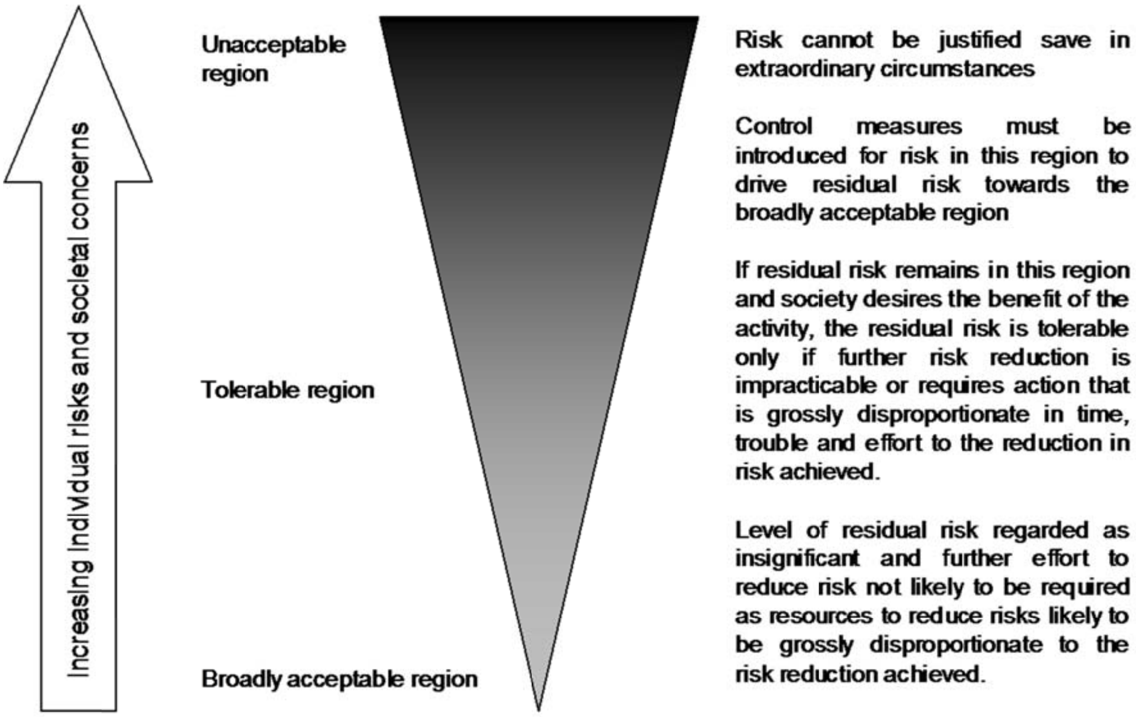
a. It has been demonstrated that all reasonably practicable risk control measures have been taken, and that;

b. Further action would be grossly disproportionate (in cost, disruption etc,) to the amount of risk reduction, (see Figure 2) and that;

c. Current industry practice risk control measures are also to be in place.

3.4.2 The ALARP principle recognises that it is unreasonable to demand that every conceivable risk reduction measure is adopted, regardless of cost. It accepts that a balance needs to be struck between potential benefit, in safety terms, and cost. Also, the higher the risk, the greater is the imperative to implement risk reduction measures. Where risks are low and well understood, compliance with relevant good practice is likely to be adequate to meet the ALARP obligation. However, where risks are high or less well understood, compliance with relevant good practice cannot be assumed to be sufficient in itself, and explicit consideration needs to be given to potential further risk reduction measures. This is explained further in "Reducing risks, protecting people" by the Health and Safety Executive (see Appendix A for details).

3.4.3 ALARP is not yet embodied generally into maritime legislation. However the IMO has accepted a risk-based methodology known as Formal Safety Assessment (FSA) as part of the future rule-making process, and this includes cost-benefit analysis (see Section 4.4).



UK HSE "Reducing Risks, Protecting People" 2001

Figure 2: Criteria for the tolerability of risk

4 The Regulatory Framework

4.1 Overview

4.1.1 The main motivation for improving maritime safety and environmental protection, as in other industries, is widespread public aversion to loss of life and environmental pollution. The effects of disasters outside the marine field can have repercussions in maritime safety. New approaches for assessing risks involved in shipping have long been advocated, but it is only relatively recently that a risk based approach has been adopted.

4.1.2 The nuclear industry after the Windscale disaster, the chemical industry after Flixborough and Bhopal, and the offshore oil and gas industry after Piper Alpha all adopted the use of risk assessments in a safety case regime, where the operator took responsibility for managing the risks of his plant and demonstrating its safety to the regulator.

4.1.3 The shipping industry is unlikely to follow this path to the same degree without a major change in culture, due to its diverse management structures, and the mobile nature of its assets.

4.1.4 Successful ship safety management comprises a holistic approach that recognises the role of the ship and how it will be operated, risk assessment of complex aspects (including innovation), all underpinned by pragmatic compliance with the more prescriptive criteria and methods of regulation that address safety assurance throughout the supply chain into ship operation. This Chapter outlines the latter, regulation, and what the member needs to take into account.

4.2 Organisations

4.2.1 The International Maritime Organization (IMO) is an agency of the United Nations whose mission is “Safe, Secure and Efficient Shipping on Clean Oceans”. It was formed in 1948 and now has about 170 members. Over 300 permanent members of staff work at the headquarters in London. The standards to which ships must be designed, constructed, operated and maintained are set out in International Conventions (such as the Safety of Life at Sea Convention and the International Convention on Load Lines) adopted at the IMO and implemented through national legislation. Member states of IMO are entitled to interpret the requirements of Conventions but are required to inform the IMO Secretariat of any exemptions they grant. These Conventions can be supported by IMO Codes or guidelines, the adoption of which may be at the discretion of Flag States.

4.2.2 The International Labour Organisation (ILO) is also a United Nations body. It was founded in 1919 and now has 183 member countries. In connection with ships, the ILO sets out requirements for seafarer living and working conditions. In 2006, the ILO adopted the Maritime Labour Convention, which came into force on 20th August 2013. This brings together and consolidates at least thirty seven existing Conventions covering a wide range of issues relating to crew welfare, health and safety, and the design and construction of crew accommodation. Members should pay particular attention to those aspects relating to the design of ships and health and safety. ILO standards are decided on the basis of tri-partite agreement between Governments and ship owner and seafarer (union) representatives. Exemptions or substantial equivalents may need to be agreed by all three parties.

4.2.3 Flag Administrations may give exemptions from the prescriptive requirements of Conventions by establishing equivalent levels of safety. This can be achieved in a variety of ways. For example, operational limitations can be applied to compensate for a vessel's limited ability to withstand extreme sea conditions. It is not uncommon to grant time limited exemptions from the Load Line Convention to enable ships without Load Lines to proceed to sea under fair weather conditions for purposes such as a voyage to a repair dock.

4.2.4 To ensure that visiting ships are safe, it has become necessary for nations to seek positive assurance that the ships visiting their ports do not impose a risk to safety and the environment. Thus Port State Control Inspections are carried out by the National Regulatory Authorities to check that such vessels comply with the international regulations; including but not limited to a check of valid certificates, the general condition of the hull, machinery, electrical and control systems, safety equipment, charts, publications, navigation and radio equipment, equipment and systems to prevent pollution and the working and living conditions for seafarers.

4.2.5 Classification Societies were first established in the eighteenth century to provide independent assurance to the marine insurance industry on the integrity of ship hulls and machinery. These societies develop and publish technical criteria in the form of rules for the design, construction and survey of ships.

4.2.6 Verification of the integrity of a ship"s hull and machinery via compliance with these Rules is a legal requirement enforced by Flag Administrations, and is necessary to obtain insurance of the hull, machinery and cargoes. The Rules are also referred to for guidance by designers, builders and operators of ships.

4.2.7 When the Classification Society is satisfied, through plan approval and survey, that the Rule requirements have been met, the society will issue a Class certificate formally confirming compliance with the relevant Rules. Each society has its own set of Rules which are updated in the light of experience, advances in technology and understanding, changes in marine legislation, and developments in ship design, construction and operation. Rules and Rule amendments are developed by the staff of the society and are subject to review by a panel of independent experts before adoption by the society. The societies cooperate, through the International Association of Classification Societies, in the development of common Rules which all agree to adopt, and in operating certain reciprocal arrangements. Classification Societies may also be appointed by Flag Administrations to carry out delegated functions on their behalf (e.g. to conduct surveys of fire-fighting equipment and life-saving appliances and issue certificates of regulatory compliance on behalf of the Flag state).

4.3 Regulation

4.3.1 Regulation makes a significant contribution to ship safety and environmental protection. Many safety regulations can be traced to their social or national origins, or are directed towards functional or operational features, whilst others are brought about by changes in new types of ship, new materials, and new philosophies. Although technology has provided for some international regulations, the majority of them rely on engineering judgement and expedient compromise. If regulation is to successfully evolve, it must be more flexible than that identified with prescriptive legislation, and be more suited to dealing with ongoing developments.

4.3.2 Key IMO conventions include:

a. The International Convention for the Safety of Life at Sea (SOLAS) forms the basis for ship safety. With origins in the Titanic disaster, SOLAS has evolved over many years and encompasses all subjects that have an impact on ship safety including subdivision and stability, structure, machinery and electrical installations, fire safety, lifesaving, radio-communications, safety of navigation, carriage of cargoes, carriage of dangerous goods, nuclear ships, management of the safe operation of ships, safety measures for high speed craft, and special measures to enhance maritime security.

b. The International Convention on Load Lines addresses buoyancy, strength and watertight integrity.

c. International Regulations for Preventing Collisions at Sea (COLREG).

d. The International Convention for the Prevention of Pollution from Ships (MARPOL) addresses environmental protection and has its origins in the 1954 International Convention for the Prevention of Pollution of the Sea by Oil (OILPOL) convention, although it was the Torrey Canyon accident in 1967 that gave the convention greater prominence. It covers oil, noxious liquids, harmful substances, sewage, garbage, and air pollution. Recent amendments will lead to the phasing out of single hull tankers and the protection of oil fuel tanks.

e. The International Convention on the Standards of Training, Certification and Watchkeeping for Seafarers (STCW) covers minimum competence for seafarers.

4.3.3 The Maritime Labour Convention (2006) of the ILO came into force on 20th August 2013. This has replaced many existing Conventions. The most important of these for the member are C.92 and C.133 (crew accommodation), C.134 (health and safety, and prevention of accidents), and C.147 (minimum standards).

4.4 Formal Safety Assessment

4.4.1 In 1997 the International Maritime Organization (IMO) recognised Formal Safety Assessment as the basis for developing future regulations. Its purpose is to assess and develop more rational safety and environmental protection regulations that are cost effective and appropriate to the risks.

4.4.2 Significant progress has been made in the development of FSA for the adoption and application by maritime regulators. It considers all the stakeholders and allows the systematic assessment of the risks associated with shipping activity and evaluation of the costs and benefits of different regulatory options for reducing those risks.

4.4.3 The FSA process comprises five steps as follows:

a. Identification and ranking of hazards

b. Quantified assessment of the risks associated with those hazards

c. Consideration of alternative regulatory options for managing the risks.

d. Cost-benefit assessment of alternative risk-management options.

e. Recommendations for regulatory decision-making.

4.5 Goal-Based Approach to Regulation

4.5.1 More recently, IMO has begun developing a goal-based approach to regulations. Some goal based standards are being developed, and any application of these standards will be voluntary until they are ratified by member states and mandated by the Organisation.

4.5.2 The basic principle of a goal-based approach is that the goals represent the top tier of the regulatory framework, against which a ship is verified both at design and construction stages, and which continues to be applicable during ship operation.

4.5.3 In comparison to prescriptive safety regulations the advantage of a goal-based approach is that it more readily allows for innovative designs, alternative arrangements and new technology to be adopted to achieve the required safety outcome (the “goal”).

4.5.4 The framework adopted for IMO goal-based standards is as follows:

- Tier I - Goals. The goals are safety of ship, safety of life, and safety of the environment.
- Tier II - Functional Requirements. These establish, for each functional area of the ship, the criteria to be met to satisfy the Tier 1 goals. These are developed from experience, current rules and regulations, and systematic analysis of hazards and risks.

- Tier III - Verification. This defines the process for verifying and demonstrating that the Tier IV rules and regulations comply with the Tier I goals and Tier II functional requirements.

Tiers I to III can be regarded as “rules for rules”.

- Tier IV - Rules and Regulations. This contains the Classification Society Rules and national regulations that have been demonstrated by the Tier III verification process to comply with the Tier I goals and Tier II functional requirements. Compliance is required for the Classification Society to be recognised by the IMO.
- Tier V – Standards. This covers international and national standards and industry codes of practice. Where these standards or codes of practice are referred to in Classification Society Rules or in national or international regulations, it is the responsibility of the owners of the Rules and regulations to determine that the standard referred to is fit for the purpose for which it is used.

4.6 Strengths and Weaknesses of Regulation

4.6.1 Prescriptive regulations define, sometimes in great detail, the required means of achieving safety objectives, whereas “goal setting” regulations define the safety objectives to be achieved, but not the means by which they are to be achieved. In a “goal setting” regime, those responsible for complying with the regulations need to be able to show how the arrangements they have adopted meet the safety objectives defined in the regulations (e.g. by reference to risk assessments and relevant standards of good practice). In some industry sectors where there are major hazards this may need to be formally documented in the form of a safety case.

4.6.2 Prescriptive regulation is most effective at addressing well-understood and commonly occurring hazards. In these areas, it is cost-effective and robust. However, there are strengths and weaknesses that need to be understood by the member.

Strengths	Issue	Impact on member
Well established	Derive from a substantial body of experience for well established circumstances, and provide a mechanism for accumulated knowledge to be passed on in the form of recognised good practice.	Ensure that applicability is reviewed for unusual circumstances
Robust	Compliance with prescriptive criteria can be readily demonstrated and confirmed by a third party.	Ensure there is a clear audit trail
Readily understood	The international system involving the “ensurers” (owners, operators, designers, shipbuilders and equipment suppliers) and the “assurers” (Flag Administrations, Port States, Classification Societies) may at first appear complex, but is actually consistently understood around the globe.	Understand the roles and responsibilities
Assurance throughout the supply chain	Regulation starts at equipment and material assurance through Type Approval schemes, and progressively involves all subsequent activities from ship and system design, to ship construction, tests and trials through to in-service operation and maintenance, and ultimately disposal.	Understand the process

Weaknesses	**Issue**	**Impact on the member**
Sets a minimum	Regulation ensures all owners and operators provide a minimum level of safety to personnel, the public and the environment. In all cases, owners must address all safety aspects under their duty of care and be able to demonstrate this, possibly in a court of law.	Ensure appropriate regulation is applied
Currency	Regulation, agreed on an international basis in large forums evolves progressively, often in response to maritime accidents (e.g. Titanic leading to SOLAS, Estonia leading to improvements in RoRo stability, Herald of Free Enterprise leading to the ISM Code). Inevitably this means that hazards may be known about that have yet to be addressed by regulation.	Recognise the latest regulatory developments and future direction
Inhibits innovation	Can engender reluctance to move away from well established arrangements as the prescriptive requirements may no longer be valid.	Be open to alternative approaches
Compliance culture	Can induce an excessive reliance on prescriptive rules and a lack of ownership of safety.	Consider safety beyond rule compliance

Table 1 : Strengths and Weakness of Regulation

5 Safety Management

5.1 General

5.1.1 Members should be guided by the objectives of the ISM Code, as follows:

ISM Objectives *(from section 1.2 of the ISM Code)*

1 *The objectives of the Code are to ensure safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, in particular, to the marine environment, and to property.*

2 *Safety management objectives of the Company should, inter alia:*

.1 provide for safe practices in ship operation and a safe working environment;

.2 assess all identified risks to its ships, personnel and the environment and establish appropriate safeguards; and

.3 continuously improve safety management skills of personnel ashore and aboard ships, including preparing for emergencies related both to safety and environmental protection.

3 *The safety and management system should ensure:*

.1 compliance with mandatory rules and regulations; and

.2 that applicable codes, guidelines and standards recommended by the Organization, Administrations, classification societies and maritime industry organizations are taken into account.*

**Refer to the List of codes, recommendations, guidelines and other safety and security-related non-mandatory instruments (MSC.1/Circ.1371).*

5.1.2 Safety management is the process which coordinates resources and activities to ensure that defined safety objectives are achieved for a situation or system. Arrangements for the management of safety need to be embedded within the management system as a whole. Organisations may employ risk analysts and other safety professionals to provide expert advice, but responsibility for safety cannot be hived off as if it were a standalone function. Everyone involved in an enterprise carries some responsibility for safety, but the primary responsibility rests with management.

5.1.3 As has been pointed out elsewhere, accidents are more often the result of management failure than as a result of technical failure or wilful negligence by individuals. Accidents and incidents which may, at first sight, appear to arise from technical or human failure are often more fundamentally attributable to management failure.

5.1.4 The management of health and safety is a broad subject which cannot be satisfactorily addressed within the confines of these guidelines. Readers are strongly recommended to study “Successful health and safety management” by the UK Health and Safety Executive (see Annex A: General Reading).

5.1.5 It should be noted that hazard identification, risk assessment and risk management form part of the wider safety management regime (see Figure 1).

5.1.6 More specifically, ships in operation are subject to the IMO International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code). This code applies to arrangements for the management of safety in ships, including related shore based aspects. It requires the effective operation of a safety management system which it defines as “a structured and documented system enabling Company personnel to implement effectively the Company safety and environmental protection policy”. These arrangements onboard ship and ashore are subject to certification on the basis of independent third party audit by the Flag Administration or other bodies which it has authorised as being competent to do so. (See Annex A: General Reading).

5.1.7 In addition, some ILO Conventions refer to health and safety management issues.

5.2 A life-cycle approach to safety

5.2.1 Ideally, safety considerations should embrace the whole life-cycle of a project, from design through to construction and operation until the end of service life. For example, at the design stage it is necessary to consider and provide for anticipated equipment or operational changes (e.g. by retrofitting). It is useful to identify some safety management considerations which might arise at different stages of the life-cycle of a project.

5.3 Design, construction and commissioning

5.3.1 Effective risk management at the design stage is extremely important. At this stage, commencing with concept development or selection, there is the greatest scope to adopt or devise arrangements which will reduce, or even eliminate, particular risks. Risk assessment should be undertaken as an integral part of the design process, so that risk management decisions can be taken in good time. Much of the potential benefit of risk assessment of the design will be lost if it takes place after the design has been firmed up. It should not simply be used to retrospectively justify design decisions already taken.

5.3.2 Safety features incorporated into the design will be more secure, long lasting, and effective than those that rely upon the use of safety equipment or the adoption of operating procedures intended to compensate for design deficiencies. Furthermore, as the design and construction work progress, it will become increasingly difficult and costly to incorporate safety related features

5.3.3 Safety considerations in design can be considered in the following hierarchy:

- Eliminate the hazard.
- Reduce the likelihood of a hazardous event, giving preference to inherent safety over operational safeguards (e.g. procedures).
- Reduce the consequences of a hazardous event, e.g. by reducing combustible fuel inventory; by adopting fail-safe or fault tolerant systems; by protecting structure and equipment from fire.
- Protect people from the effects; collective protection in preference to individual protection.
- Provide means of escape and evacuation.

5.3.4 The management system for the design, construction and commissioning will need to include provision for:

- Quality assurance.
- Clear policies, criteria and allocated responsibilities for safety.
- Means to ensure competence in the execution of the design, construction and commissioning, including the execution of associated risk assessments, at both an individual and organisational level (e.g. sufficiency of resources, facilities and design systems).
- Application of relevant and current good practice.
- Effective approval processes, including interaction with risk assessment.
- Effective change control procedures, including proper consideration of safety

implications.

- Application of formal and structured risk assessments, including the identification, tracking and resolution of risks.
- Identification of safety-critical systems and equipment, and determination of their required standards of performance.
- Assessment of operability for normal operations and emergency response.
- Proper consideration of the human and machine interface.
- Proper consideration of maintainability.
- Development and promulgation of information and instructions to enable safe operation, maintenance and repair, including emergency procedures. This should include the definition, by the design authority, of safe operating limitations for equipment, systems, and the vessel. (Note that SOLAS requires certain information, including construction drawings, to be held on board and ashore).
- The setting of safety related system performance standards.
- Arrangements for monitoring the status and performance of safety-critical systems.
- Safeguards to be implemented in the event of degraded availability or performance of safety-critical systems.
- Conformity to design.
- Effective material control.
- Effective commissioning and testing processes, including verification of safety related system performance standards and validation of emergency procedures.
- Due consideration and allowance in the design for probable future retrofit equipment or systems, where these are envisaged at the design stage, including associated risk assessment.
- Due consideration of end of life decommissioning and re-cycling, including material selection criteria to enable re-cycling to be carried out safely without damaging the environment. The presence of potentially hazardous materials should be identified and documented to enable safe removal at the end of life or during repairs and modifications.

5.4 Operation

5.4.1 The management system for operation will need to include provision for:

- Assurance of the competence of operating staff, including competence in risk assessment and management, and understanding of operating procedures, safe operating limitations, and the potential consequences of violations of procedure and operating limitations.
- Provision and maintenance of documentation, developed or approved by the design authority, defining operating procedures and operating limitations.
- Arrangements for assuring and monitoring compliance with operating procedures and operating limitations.
- Assessment and monitoring of the status and performance of safety-critical systems.
- Safeguards to be implemented in the event of degraded availability or performance of safety-critical systems.
- Periodic testing of emergency systems and emergency procedures.
- Reporting and investigation of accidental and undesirable events, including violations of operating procedures and operating limitations.
- Control of modifications.

5.5 Repair and Maintenance

5.5.1 The management system for repair and maintenance will need to include provision for:

- Maintenance planning, execution and recording, including instructions for maintenance and provision of maintenance equipment and spares.
- Prioritisation of maintenance and repair of safety-critical systems and equipment.
- Reporting of the status of the maintenance programme; in particular the status and performance of safety-critical systems.

5.6 Modifications

5.6.1 Modifications should be controlled, be subject to prior approval by the design authority, and involve reassessment of risk where appropriate. Modifications include changes to hardware, software, operating procedures, operating parameters (e.g. safe operating limitations), mode of operation and change of use.

5.6.2 Suitability for change of use should be assessed against standards applicable to the proposed new use.

5.7 Re-assessment

5.7.1 Periodic re-assessment of safety should be undertaken to take account of the cumulative effect of changes, changes in standards (particularly where the standards to which the system was designed are later shown to be deficient), changes in system condition (e.g. due to deterioration), performance history (e.g. system reliability, evidence of fatigue cracking), and anticipated changes in performance or operating conditions.

5.7.2 Where consideration is being given to an extension of service life beyond that for which the system was designed, a more rigorous re-assessment will be required to demonstrate that safe operations can be maintained for the extended period.

6 Risk Assessment

6.1 Overview

6.1.1 Risk assessment entails systematically analysing the risks arising from identified hazards, and evaluating their significance in order to provide input to a decision-making process. It can be purely qualitative, semi-quantitative, or fully quantitative, and the structure shown in Figure C-1 of Appendix C is applicable to all three. In general, qualitative approaches are easiest to apply and most widely used, but provide the least degree of insight. Conversely Quantitative Risk Assessment (QRA) is the most demanding on resources and specialist skills, but potentially delivers the most detailed understanding and provides the best basis if significant expenditure is involved. Semi-quantitative approaches use ranking and limited quantification to help guide qualitative reasoning. In choosing an approach for any project, the key test is one of reasonable practicability in understanding and reducing risks.

6.1.2 It is increasingly recognised that risk is not easily measured. The 1992 Royal Society Report on “Risk analysis, perception and management” could not reconcile the different opinions of physical scientists, some of whom suggested that risk obeys the formal laws of statistical theory, and social scientists who favour the theory of subjective risk which varies depending on individual perception.

6.1.3 The UK Interdepartmental Liaison Group on Risk Assessment in 1996 reported that subjective or “qualitative” risk perception would usually conflict with the objective view of the scientist. A more coherent and consistent approach, better cross-use of available data and a common criteria for comparing risks (both real and perceived) was called for.

6.2 Risk - actual or perceived?

6.2.1 Unfortunately for the physical scientist, accident data is frequently unreliable in accurately recording the past, and poor at predicting the future. The problem is essentially one of change. Technology is constantly advancing with new materials, methods of manufacture, improved reliability and performance, and society continuously modifies its amusements, economies, politics and philosophies. As time moves on risk arises in new environments out of situations never quite the same as before. Furthermore the very process of collecting data tends to alert those people at risk (and their managers) with the result that both the perception of risk and behaviour will be modified.

6.2.2 Surveys can be used to decide the priority for regulation by satisfying public concern even though expert opinion based on collected data does not always support prescriptive controls. Risk perception varies according to one‟s viewpoint. For example in a US survey, college students feared nuclear power more than any other risk, whereas safety experts rated it only 20th out of 30 listed alternatives.

6.2.3 For the risk analyst, violent death is a convenient metric. It is accurately recorded and as a consequence of an accident it is unambiguous. However the incidence of accidental death is often very low. Collecting injury and near-miss information will yield a mass of data but is liable to give misleading results because of variations in categorisation and reporting. Only a fraction of what happens is ever recorded. So what approach can be taken to allow for variables in quantification, so as to demonstrate that risk is as low as reasonably practicable?

6.3 Hazard Identification

6.3.1 Before starting to consider risk an attempt must be made to identify all potential hazards. The process (often called HAZID) uses a variety of techniques e.g.:

- FMEA (Failure Modes and Effects Analysis). This is well suited to reliability studies in electrical and mechanical systems but less easily adapted to deal with human error.
- HAZOP (Hazard and Operability Study). HAZOP uses guide words systematically to test the result of deviations from intended procedure or operations. This is a “brain-storming” process that defines the boundaries to a system and asks „what can go wrong?‟
- SWIFT (Structured What If Technique). The Structured What If Technique (SWIFT) uses checklists constructed specifically for the system and tests for hazards resulting from deviations from normal. As its name suggests SWIFT will generate answers more quickly than HAZOP but is less thorough in looking at the detail. The SWIFT technique is also a brain-storming team activity allowing discussion of regulations, requirements and past experience.

6.4 Risk Ranking

6.4.1 A qualitative ranking of both frequency (from frequent through to incredible) and severity (from catastrophic to negligible) of each hazard is deduced by consensus.

6.4.2 These can be amalgamated in matrix form where the risk categories are:

A = Intolerable

B = Undesirable and only accepted when risk reduction is impracticable

C = Tolerable with the endorsement of the project safety review committee

D = Tolerable subject to normal project review

6.4.3 Further information on qualitative risk ranking and an example of a risk matrix is given in Appendix C.

6.5 Quantitative Risk Assessment

6.5.1 Quantitative risk assessment (QRA) is the term most often used to describe the use of statistical or more properly “quantitative” methods in safety management. Further information on the QRA process can be found in Appendix C.

6.5.2 Quantitative techniques widely used under the QRA umbrella include:

- Failure Modes, Effects and Criticality Analysis (FMECA)
- Fault Tree Analysis (FTA)
- Event Tree Analysis (ETA)
- Statistical analysis of historical accident data
- Reliability analysis of component failure data
- Data elucidation from structured expert judgement
- Human error analysis
- Cost Benefit Analysis (CBA)

6.5.3 QRA is underpinned by statistical analysis of previous accidents but is necessarily more than this, since statistics about past events provides only limited guidance about the future. QRA provides a structured framework for combining statistics with theoretical models and expert judgements. QRA may be appropriate in the following circumstances:

- Where it is specified by regulations or by company procedures - e.g. in the offshore industry.
- Where good safety management requires a detailed, systematic analysis of risks, to understand the significance of different hazards.

- Where there is the potential for infrequent, but severe, accidents - these are difficult to address by judgement alone and quantitative analysis may give useful help - e.g. in the nuclear industry.
- Where risks are to be assessed against numerical acceptability targets.
- Where risk reduction measures are to be evaluated using cost-benefit analysis - e.g. as in the IMO guidelines for FSA.
- Where there is sufficient statistical data to provide a basis for the assessment.

6.5.4 In combination with cost-benefit analysis, QRA can provide measures of cost-effectiveness for benefit decisions such as net-present values, implied cost of averting fatalities, etc.

6.5.5 QRA is arguably the most sophisticated technique available to predict the risk of accidents and give guidance on appropriate means to minimise them. In combination with cost-benefit analysis, it is able to give consistent guidance on the difficult balance between economics and safety.

6.5.6 However, while it uses scientific methods and verifiable data, QRA is a rather immature and highly judgmental technique and its results have a large degree of uncertainty. In unskilled hands QRA may be dangerously misleading.

6.5.7 Despite its limitations, QRA has proved to be useful in many applications. However, it should not be the only input to decision-making about safety, as other techniques based on experience and judgement may be appropriate as well.

6.6 Decision Making

6.6.1 So far the assessment and ranking of risk has been considered. The final stage involves hard decisions where the proposed safety improvements may be difficult and the cost to implement considerable.

6.6.2 The principle of As Low As Reasonably Practicable ALARP (see Chapter 3) shows that tolerable risk is not a simple pass/fail test. The majority of risks are in the ALARP region where work should be done to reduce the risk further.

6.6.3 The owners of each risk must be satisfied that safety arguments, criteria and decisions are sound and documented so as to provide an audit trail. Peer review and the use of independent safety assessment/audit are also valuable in giving strength to decisions and actions, particularly if later challenged.

6.7 Cost Benefit Analysis

6.7.1 It is inevitable that the management of risk will cost money and the monetarisation of risk absorbs great effort by risk analysts who will use cost benefit to justify the measures proposed. Cost benefit analysis (CBA) is not well suited to environmental risk where putting a value on the loss of nature assets such as a green valley for the construction of a by-pass poses great difficulty and disagreement between developers and protesters. It is also difficult, sometimes distasteful, to attempt to value life.

6.7.2 Some companies use high figures for Value of Life and increasingly it is recognised that serious disability can attract even higher compensation awards than are routinely paid for death. In other parts of the world compensation pay-outs for accidental death will produce different values of life. Generally, in the developed western world, with a sophisticated legal system, court settlements are substantial and continuously increasing.

6.7.3 Total loss control, that is the summation of consequential cost of an accident – human, asset, environmental and political, offset against the up-front capital expenditure of a proposed safety measure - is increasingly suggested. But those who have to foot the bill may take some convincing that the risks identified and the consequential costs of accidents are realistic. In the case of large projects the solution could be to prioritise and develop time-at-risk arguments to spread the work over an acceptable time-span. The justification must be made openly and the logic defensible when challenged or in the case of a subsequent accident occurring before the safety measures have been carried out.

6.8 Risk Criteria

6.8.1 Where the risk analyst has carried out a numerical risk estimate, it is often necessary to present the argument in qualitative terms. Risk criteria are used to translate a quantitative measure (e.g. 10^{-7} per year) into value judgements (e.g. negligible risk). These can be set against other value judgements (such as "environmentally friendly" or "desirable employment prospects") in a decision-making process and are often presented in this form to the public to sell products or justify actions.

6.8.2 Words like "acceptable, tolerable, justified" are sometimes interchanged. A tolerable risk usually means a residual risk that remains after all reasonably practicable efforts have been made to eliminate or reduce it. It is accepted with some reluctance. The justification is the argument in support of the concluding position. It should satisfy those involved in the activity, the statutory authorities and others including the public.

6.8.3 There are no universal risk criteria. This is a social and political judgement that can be guided but not entirely defined by expert evidence or advice. A few sectors of industry (such as nuclear power) have specified numeric targets but for most other industries the safety regulators offer only broad guidance.

6.8.4 The reasons for this are:

- Every activity is unique and subject to many variables such as the operating environment and tasking, differences in design and equipment fit, organization, material state and maintenance routines.
- Value judgements on acceptable risk alter with time, vary between individuals and groups, and are subject to accident experience and changing sociological expectations including the perception of risk by others and the willingness to pay.
- Where compliance with prescriptive regulations is insufficient line managers should take responsibility to define the scope, criteria and tolerability of risk arguments used to arrive at safety decisions.

6.9 Data Sources

6.9.1 There are many sources of data recording reported incidents and ship losses. The oldest is probably that maintained by Lloyd"s Register of Shipping, the most recent (since 1993) by the UK Marine Accident Investigation Branch (MAIB). The Maritime Accident Reporting System (MARS), run by the Nautical Institute, logs anonymous incidents. A wider list of data sources is given in Appendix A.

6.9.2 The risk manager should always seek relevant incident and accident data to understand the frequency of past events which will help in the assessment of probability of future events. Collected data must be carefully used because accidents rarely provide statistical significance and is often not relevant to the present or the anticipated future. Where data is scant and/or the circumstances are unusual, it may sometimes be necessary to resort to anecdotal evidence and consensus opinion to obtain a qualitative assessment of probability.

7 Words of Advice and Warning

7.1 Responsibility for safety

7.1.1 The professional member often has more to worry about with regard to safety than do many other professional engineers. In addition to the traditional science of hydrodynamics, structures and powering, members have commonly taken a lead in co-ordinating the overall design and integrating the work of many other disciplines to deliver the ship to time and cost. In modern parlance this is the role of the project manager. As well as a designer, either individually or in a team, elsewhere the member may be a consultant, surveyor or regulator providing expert oversight, policy and advice. In each position the responsibility for safety will vary according to the job description. In general personal responsibility for safety will lie where financial accountability has been authorised. Such authorisation should be formally recorded so that scope and duties are clearly defined.

7.2 Reliance on data

7.2.1 The member should be cautious about placing total reliance on data and compliance with rules, regulations and industry standards, while recognising that such compliance is a legal obligation for Classed vessels. However, when used as part of the classification process, and provided that the Rules are correctly applied, the suitability of the Rules is the responsibility of the Classification Society.

7.2.2 The member should understand that Classification Society Rules are legally valid only when they are used in the classification process. The Rules are published solely for the classification of vessels, and are not legally valid when used as design criteria outside the classification process for unclassed vessels.

7.2.3 The member should also be careful about reliance on national and international industry standards such as ISO, IEC, BS, DIN and JIS. As industry standards they are optional. Where they are specified to be complied with in rules, regulations, codes or specifications, it is the responsibility of the owner of the rule, regulation or code, or the author of the specification to ensure that the standard is suitable for the application. A member who opts to use a standard is responsible for ensuring that the standard is suitable for the intended use.

7.2.4 Technology is constantly improving, bringing novelty in design, materials and the need for new operating methods. Everyone learns from mistakes, so that modifications to equipment, procedures and behaviour all contribute to a new set of circumstances in which care needs to be taken in the use of trends from past data.

7.3 Compliance with rules and regulations

7.3.1 Compliance with international and national safety legislation is an absolute minimum, as well as being a legal obligation. Classification Society Rules have been developed over many years based on a vast amount of ship-years service experience. Classification Societies provide the means, through advanced analysis methods, to assess less conventional designs of ships. However, neither statutory regulations nor Class Rules can give assurance that every legally certificated ship will always be safe in all respects. Members should therefore consider drawing to the attention of the Classification Society or Flag Administration any issues that are of concern to them and their reasons for this.

7.4 Liability

7.4.1 Any individual given safety responsibility is liable to prosecution for criminal negligence where it might be claimed there has been gross dereliction of duty or professional incompetence. Company employees are vicariously protected against civil claims for compensation but the self-employed consultant is particularly vulnerable and personal indemnity cover is essential.

7.5 Best practice

7.5.1 Corporate membership of the Institution demonstrates the attainment of professional competence, with experience and qualifications commensurate to the task required to authorise and sign principal safety documents. It is prudent to refer to best practice, seek third party agreement on difficult decisions and to submit to independent audit. Where the professional judgement of the member is questioned, peer advice should be sought.

7.6 Common sense

7.6.1 As well as good qualifications and experience, an essential component of the competent safety manager is common sense. The community at large may not understand detailed calculations but everyone has their own ideas of risk and will not accept argument that seems out of step with commonly held perceptions measured in everyday terms. It is therefore essential and good sense to record and communicate safety assessment methods, assumptions and conclusions as clearly and concisely as possible.

7.7 Planning

7.7.1 Tools are available to identify hazards, compute some measure of risk and argue what should be done. Above all the member must have a plan and ensure that the scope, objectives and methods used are available for inspection. Thus armed, the discussion on what is reasonably safe can confidently begin.

7.8 Recording Decisions

7.8.1 The rationale for safety related decisions should be properly recorded so that those involved in the design and those responsible for the subsequent operation, maintenance or alteration of the ship are aware of the design intent. Such records will also assist decision makers to defend their decisions, should they be subsequently called into question. This will be particularly important where difficult decisions have to be taken (e.g. for novel or unusual situations where full compliance with normal standards proves to be impractical and alternative means of achieving safety objectives are adopted).

Appendix A: Further Reading

Incident Data Sources

Lloyd‟s Casualty Reports and Databases (Lloyd‟s Maritime Information Services)
World-wide Offshore Accident Database (Det Norske Veritas)
Major Hazard Incident Data Service (AEA Technology)
United Kingdom Marine Accident Investigation Branch, Annual Reports of marine casualties
United States Naval Safety Center Accident/Incident Database
UK Ministry of Defence Combined Services Accident Project (CHASP)

General Reading

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Appendix B: Notable Accidents

Vessel	Year	Event	Reference
Derbyshire	1980	Bulk carrier lost in typhoon	Report of the re-opened formal investigation into the loss of the MV Derbyshire. The Honourable Mr. Justice Colman. London: TSO, 2000. ISBN 9780117025301
Herald of Free Enterprise	1987	Ro-Ro ferry left port with bow doors open	MV Herald of Free Enterprise. Report of Court no. 8074. Formal investigation. The Merchant Shipping Act 1894. Department of Transport. London: HMSO, 1987 http://www.maib.gov.uk/cms_resources/HofFE%20part%201.pdf
Exxon Valdez	1989	Grounding of tanker	Marine accident report: Grounding of the U.S. tankership Exxon Valdez on blight reef, Prince William Sound near Valdez, Alaska March 24, 1989. NTSB Report MAR-90-04. National Transportation Safety Board. 1990
Marchioness	1989	Passenger launch collided with dredger	Marchioness/Bowbelle - Formal investigation under the Merchant Shipping Act 1995. The Rt Hon Lord Justice Clarke. London: TSO, 2001 http://www.maib.gov.uk/publications/investigation_reports/popular_reports/marchioness_bowbelle.cfm
Braer	1993	Tanker lost power and grounded	Report of the Chief Inspector of Marine Accidents into the engine failure and subsequent grounding of the motor tanker Braer at Garths Ness, Shetland on 5 January 1993. Marine Accident Investigation Branch. London: HMSO, 1994 http://www.maib.gov.uk/cms_resources/braer-text.pdf
Estonia	1994	Ro-Ro ferry lost bow door in heavy seas and sank	Final report on the capsizing on 28 September 1994 in the Baltic Sea of the Ro-Ro passenger vessel MV Estonia. The Joint Accident Investigation Commission of Estonia, Finland and Sweden. Helsinki, Edita,1997 http://www.safety-at-sea.co.uk/mvestonia/
Saint Malo	1995	Grounding of high speed catamaran	Preliminary enquiry into the grounding and evacuation of the high speed catamaran 'Saint Malo' off Corbiere Point, Jersey, 17 April 1995. Harbours Dept, States of Jersey. Marine Accident Investigation Branch. 1995
Sea Empress	1996	Grounding of tanker	Report of the Chief Inspector of Marine Accidents into the grounding and subsequent salvage of the tanker Sea Empress at Milford Haven between 15 and 21 February 1996. Marine Accident Investigation Branch. London: TSO, 1997 http://www.archive.official-documents.co.uk/document/dot/seaemp/seaemp.htm
Erika	1999	Tanker broke up in heavy seas	Report of the Investigation into the loss of the motor tanker Erika on Sunday 12 December 1999. Merchant Shipping Directorate, Malta Maritime Authority. 2000
Prestige	2002	Tanker structural failure	Report of the investigation into the loss of the Bahamian registered tanker "Prestige" off the northwest coast of Spain on 19th November 2002. Bahamas Maritime Authority. 2004
Star Princess	2006	External fire on cruise liner	Report on the investigation of the fire onboard Star Princess off Jamaica on 23 March 2006. Report no. 28/2006. Marine Accident Investigation Branch. Department of Maritime Administration, Bermuda Government. 2006 http://www.maib.gov.uk/publications/investigation_reports/2006/star_princess.cfm
MSC Napoli	2008	Structural failure of container ship	Report on the investigation of the structural failure of MSC Napoli, in the English Channel on 18 January 2007. Marine Accident Investigation Branch Report no 9/2008. Published 22 April 2008. http://www.maib.gov.uk/publications/investigation_reports/2008/msc_napoli.cfm

Mol Comfort	2013	Destroyed by fire	Report of the investigation into the sinking of the "Mol Comfort" in the Indian Ocean. http://www.bahamasmaritime.com/wp-content/uploads/2015/08/MOL-Comfort-investigation-final-September-2015.pdf
Hoegh Osaka	2015	Intentionally grounded	Report of the car carrier Hoegh Osaka developing severe list and intentionally grounded in the Solent on the 3rd January 2015. MAIB report 6/2016. https://www.gov.uk/maib-reports/listing-flooding-and-grounding-of-vehicle-carrier-hoegh-osaka

Note: References to the World Wide Web were validated in September 2018.

Appendix C: Risk Assessment Techniques

HAZOP

The most commonly used hazard identification technique today is Hazard and Operability Study (HAZOP), which was developed in the mid-1960s for the process industry but is readily adapted for marine systems. It can be used for simple engineering systems but is also appropriate for large complex operations where a preliminary overview may be necessary.

HAZOP needs a team, ideally about five or six people prepared to spend enough time together in preparation (which may require visiting the ship or facility), data collection and by a process of reasoning must identify as many potential hazards as they can. The team needs a facilitator practised in the technique and a good mix of stakeholder representatives drawn for example from:

- Master / crew
- Passenger / consumer representative
- Owner / agent / shipper
- Trade association
- Designer / builder
- Equipment supplier
- Classification Society / insurer
- Regulator / legislator
- Specialist/interest group

Types of hazard that should be considered are:

- Historical events.
- Inherent design, system and material hazards.
- Accidents inferred from the above.
- Simple combinations of events.
- Complex combinations not previously experienced.
- Recognised hazards, with designed-in countermeasures.
- Conceivable but previously unknown/unprepared for hazards.

HAZOP uses guide words systematically to test the result of deviations from intended procedure or operations. This is a “brain-storming” process that defines the boundaries to a system and asks „what can go wrong?“ The following basic guide words are applied to each element of the system (with typical meanings applicable to a marine engineering system):

• NO	e.g. no flow, no vent.
• MORE	e.g. more speed/temperature.
• LESS	e.g. less pressure/power.
• AS WELL AS	quantitative e.g. contamination.
• PART OF	qualitative e.g. less additive.
• REVERSE	e.g. reverse flow from design intent.
• OTHER THAN	different from design intent e.g. product delivered to wrong tank

HAZOP works well for human operations with slight modification of the guide-words that are then applied to „actions“, „sequence“, „time“ and „information“. The process of HAZOP is thorough but laborious until the team is practised.

SWIFT

Structured What If Technique (SWIFT) uses checklists constructed specifically for the system and tests for hazards resulting from deviations from normal. As its name suggests SWIFT will generate answers more quickly than HAZOP but is less thorough in looking at the detail. The SWIFT technique is also a brain-storming team activity allowing discussion of regulations, requirements and past experience.

As an example, the following SWIFT checklist headings could be used in an analysis of passenger ship operations:

- Wind
- Sea state/current/tide
- Visibility / night / day
- Precipitation
- Air temperature / wind chill
- Trim
- Draught
- Heave, pitch, yaw, sway, roll, surge
- Human error
- Utility or equipment failure

This checklist can be applied to assess each stage of the operation such as during:

- Passenger embarkation/disembarkation (by tender or gangway).
- Securing for sea/letting go from the pier.
- Manoeuvring prior to sailing from harbour.
- Exiting via channel.
- Open sea passage.

The information can conveniently be recorded on a computer database. Two simplified lines of the hazard log for embarking or disembarking passengers at a terminal are shown in Table C-1.

GUIDE WORD	HAZARD	CONSEQUENCE	SAFEGUARD
Night	Poor lighting conditions on ramp / link-span	Injury to occupants of vehicles/damage to vehicles crossing ramp	Improve lighting on ship and / or terminal
Surge	Movement of ship / link-span / shore.	Injury to passengers / damage to vehicles	Procedure to monitor and adjust using springs and ship‟s engines

Table C-1: Extract from Hazard Log

FMEA/FMECA

In recent times the team approach has gained favour over more individualistic techniques such as Failure Modes and Effects Analysis (FMEA) or Failure Modes Effects and Criticality Analysis (FMECA). FMEA/FMECA is well suited to reliability studies in electrical and mechanical systems but less easily adapted to deal with human error.

Risk Ranking

Hazard identification techniques such as HAZOP, SWIFT and FMEA will generate a large number of potential hazards. The Hazard Log should serve as a means of recording decisions, actions and status of each identified hazard through to its resolution. It will provide an audit trail and at future safety reviews allows development of previously closed out actions where some change in procedure or equipment fit may have occurred.

The next stage is to consider risk i.e. the combination of the frequency and severity of these hazards.

A qualitative ranking of both frequency and severity of each hazard is deduced by consensus, typically using definitions such as shown in Tables C-2 and C-3.

FREQUENCY	DEFINITION
Frequent	Continuously occurs
Probable	Likely to occur repeatedly
Occasional	Likely to occur several times during operational life of system
Remote	Likely to occur at some time in the system life-cycle
Improbable	Unlikely to occur during operational life
Incredible	Extremely unlikely to occur (but beware assuming this means never)

Table C-2: Frequency of Hazard

SEVERITY		PERSONAL	SHIP	ENVIRONMENTAL
Catastrophic	1	Multiple violent deaths and / or widespread fatal disease	Total loss	Uncontained or Widespread damage
Fatal / Critical	2	Single death and / or multiple severe injuries or severe occupational illness	Major system loss	Major damage
Severe / Marginal	3	Single severe injury or occupational illness and / or multiple minor injuries	Controlled system damage	Controlled short-term damage
Minor / Negligible	4	Minor injury / occupational Illness	Minor damage	Minor local damage

Table C-3: Severity of uncontrolled Hazard Consequence

To aid understanding of the terms used in the qualitative assessment it is sometimes helpful to add a numeric scale. Thus for severity of consequence we may use a financial measure e.g.:

Negligible	<£10,000
Marginal	£10.000 - £100,000
Critical	£100,000 - £1 million
Catastrophic	>£1 million

These can be amalgamated in matrix form, as shown in Table C-4, where the risk categories are:

- A = Intolerable
- B = Undesirable and only accepted when risk reduction is impracticable
- C = Tolerable with the endorsement of the project safety review committee
- D = Tolerable subject to normal project review

	ACCIDENT SEVERITY			
FREQUENCY	Catastrophic	Critical	Marginal	Negligible
Frequent	A	A	A	B
Probable	A	A	B	C
Occasional	A	B	C	C
Remote	B	C	C	D
Improbable	C	C	D	D
Incredible	C	D	D	D

Table C-4: Frequency v Accident Severity

The matrix shown in Table C-4 is only illustrative and does not represent a standard for every situation. For example the „B" for catastrophic/remote might not be acceptable if it was judged that multiple (i.e. 2 or more) violent deaths were likely to occur once in the lifetime of a ferry. However this could be realistic in the case of deep sea fishing vessels – where there are fewer practicable means of reducing the risk further.

Consequence Analysis

Whereas frequency is deduced either from data or by debate, the consequences of an accident can be analysed by modelling with the results fed into the group HAZID and incorporated into the risk matrix. Consequence Analysis is used to define design accident thresholds for emergency systems such as control or communication equipment, firewalls or sprinkler systems that have to survive and continue to operate in severe conditions. The process may be iterated - design criteria specified at concept stage may have to be revised as a result of risk assessment and the subsequent cost benefit analysis.

To survive a major ship accident the integrity of the hull to resist flooding will be a primary objective. Subsequently stability after damage and finally the ability for those on board to make a successful evacuation and/or the assistance of rescue forces must be assessed.

Damage to property and the environment may be considered depending on the type of ship, its cargo and the severity of the incident. An example for assessing whole ship safety could be to analyse the (separate or combined) consequences of collision, grounding, flooding and fire. Generic data is input where this is available, to construct a mathematical model using for example a probabilistic distribution of the location and extent of damage from which possible evacuation options can then be developed.

To explain the qualitative terms used in the risk matrix for frequency, events per year can be shown as follows:

Incredible	$<10^{-6}$
Improbable	$10^{-4} – 10^{-6}$
Remote	$10^{-2} – 10^{-4}$
Occasional	$10^{-1} – 10^{-2}$
Probable	$1 - 10^{-1}$
Frequent	>1

The terms and definitions given above, including the numbers of frequency and severity bands and allocation of risk categories are typical but must be confirmed as appropriate to the application. It will however be rarely possible to verify these figures with any precision and therefore their use is for comparison purposes only.

Quantitative Risk Assessment

Quantitative risk assessment (QRA) is the term most often used to describe the use of statistical or more properly “quantitative” methods applied in safety management. It can be defined as a systematic analysis of the risks from a hazardous activity and evaluating their significance in order to provide input to a decision-making process. Figure C-1 shows the general structure of a Quantitative Risk Assessment Study.

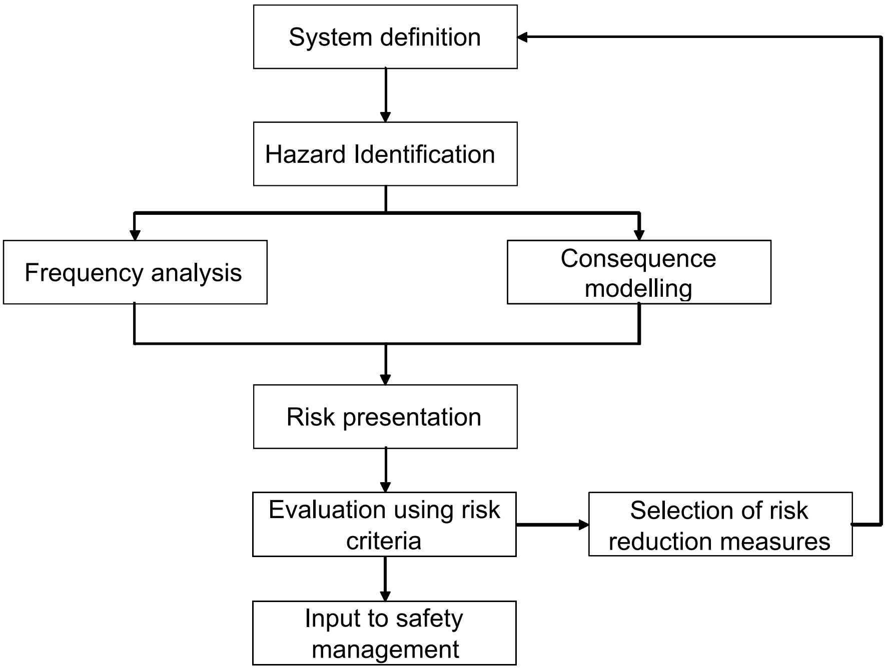

Figure C-1: General Structure of a QRA Study

Quantitative techniques widely used under the QRA umbrella include:

- Failure Modes, Effects and Criticality Analysis (FMECA)
- Fault Tree Analysis (FTA)
- Event Tree Analysis (ETA)
- Statistical analysis of historical accident data
- Reliability analysis of component failure data
- Data elucidation from structured expert judgement
- Human error analysis
- Cost Benefit Analysis (CBA)

QRA is underpinned by statistical analysis of previous accidents but is necessarily more than this, since statistics about past events provide only limited guidance about the future. QRA provides a structured framework for combining statistics with theoretical models and expert judgements.

QRA may be appropriate in the following circumstances:

- Where it is specified by regulations or by company procedures - e.g. in the offshore industry.
- Where good safety management requires a detailed, systematic analysis of risks, to understand the significance of different hazards.
- Where there is the potential for infrequent, but severe accidents - these are difficult to address by judgement alone and quantitative analysis may give useful help - e.g. in the nuclear industry.
- Where risks are to be assessed against numerical acceptability targets.
- Where risk reduction measures are to be evaluated using cost-benefit analysis -

e.g. as in the IMO guidelines for FSA.
- Where there is sufficient statistical data to provide a basis for the assessment.

QRA provides measures of risk to people, property, business and to the environment. These can be in various formats, dependant on the nature of the risk e.g. simple single-figure measures, risk contour maps, frequency-consequence (FN) curves etc., as illustrated in Figures C-2, C-3 and C-4.

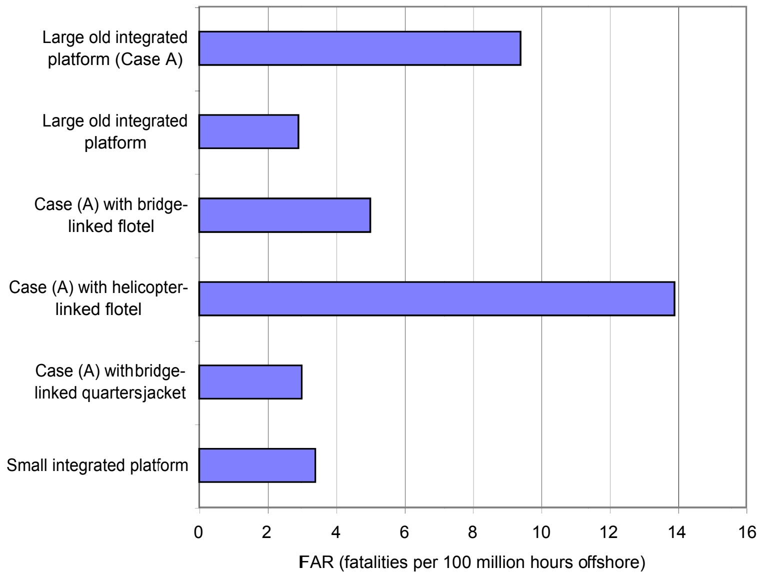

Figure C-2: Example of Individual Risk Results for Offshore Platform Concepts

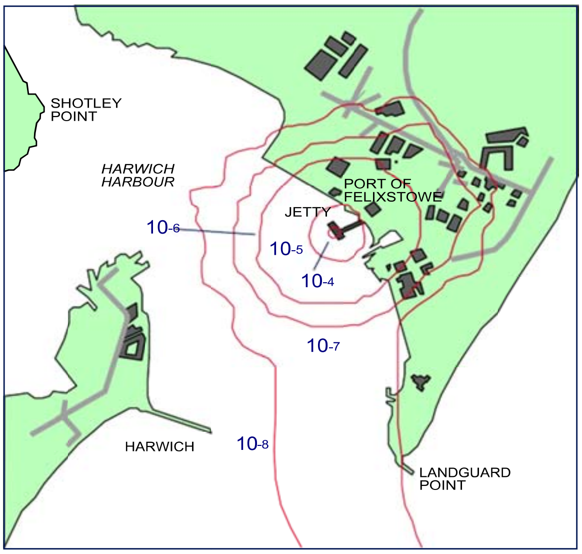

Figure C-3: Example of Individual Risk Contours for Liquefied Gas Carriers

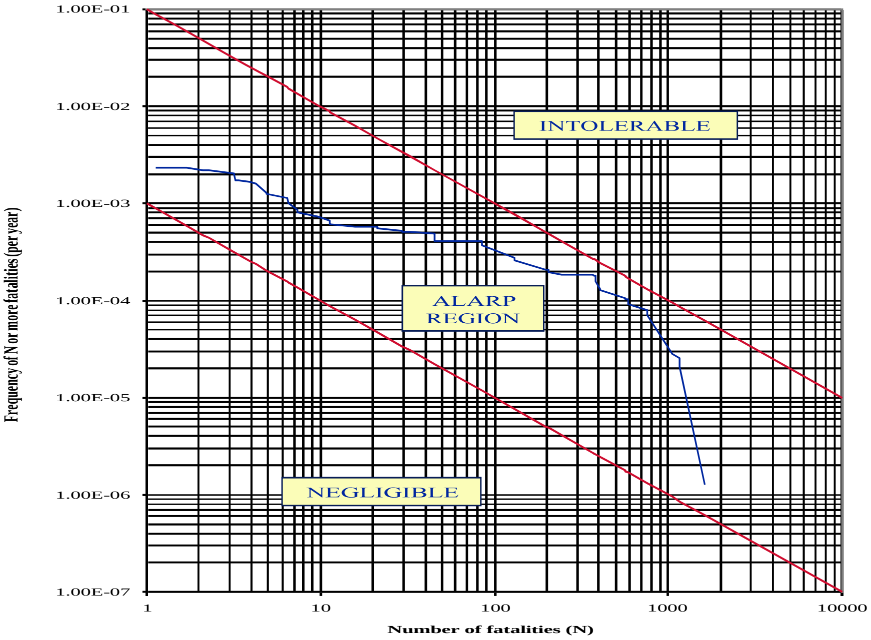

Figure C-4: Example of FN Curve Results and Risk Criteria for a Passenger/Ro-Ro Ship

In combination with cost-benefit analysis, QRA can provide measures of cost-effectiveness for benefit decisions such as net-present values, implied cost of averting fatalities, etc

Cost Benefit Analysis

It is inevitable that the management of risk will cost money and the monetarisation of risk absorbs great effort by risk analysts who will use cost benefit to justify the measures proposed. Cost benefit analysis (CBA) is not well suited to environmental risk where putting a value in the loss of nature assets such as a green valley for the construction of a by-pass poses great difficulty and disagreement between developers and protesters. It is also difficult, sometimes distasteful, to attempt to value life.

> *"There are strong reasons to suggest that a value of £200 – 300 for each change in the risk of mortality of 1 in 10,000 would be a sensible value. Expressing the same value in the conventional and more convenient way (although misleading if used carelessly) the value of a statistical life to be used in cost benefit of risk changes would be £2-3m."*
>
> *The Royal Society's 1992 report on risk*

Incidentally £2-3m works out to be the current average UK settlement for loss of life. Some companies use higher figures for Value of Life and increasingly it is recognised that serious disability can attract even higher compensation awards than are routinely paid for death. In other parts of the world compensation pay-outs for accidental death will produce different values of life. Generally in the developed western world, with a sophisticated legal system, court settlements are substantial and continuously increasing.

A balance must also be made between different safety improvements, as illustrated in Table C-5.

Basic Risk (fatalities per year)	1×10^{-2}	
Risk reduction Measure	Relocation	Safety training
Reduction in Risk (%)	90	20
Reduction in Risk (fatalities per year)	9×10^{-3}	2×10^{-3}
Value of life	£2m	
Total accident cost per fatality	£4m	
Value of risk Reduction (£ per year)	36,000	8,000
Cost of measure (£ per year)	60,000	6,000
Conclusion	Reject	Adopt

Table C-5: Example of Cost Benefit Analysis of alternative Risk Reduction Measures

Overview

The risk analysis, assessment and management process is illustrated in Figure C-5.

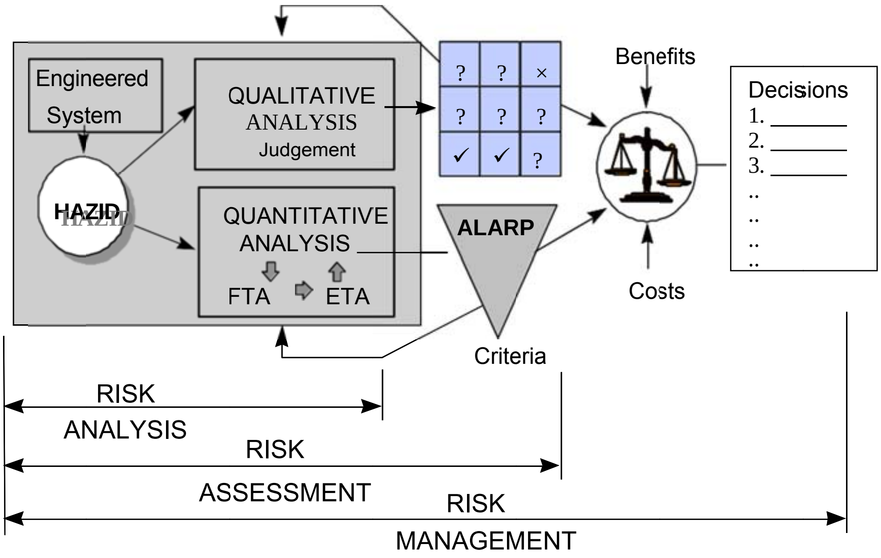

Figure C-5: Risk management and its component processes summarised (Det Norske Veritas)