Risk Assessment and Management: ISM Code Perspective

By

Bijimon Punnoose,
Managing Director,
International Register of Shipping

1. Introduction:

1.1. **Introduction**:

1.1.1. We are not sure if Adam had performed risk assessment before accepting the forbidden apple, but the caveman definitely must have weighed the consequences of hunting wild animals.

1.1.2. Examples of structured risk assessment dating back to 3000 BC are available.

1.1.3. During the recent years IMO started the use of “Formal Safety Assessment” a form of structured risk assessment in the rule making process. High-speed craft code of IMO requires failure mode effect analysis to be done for all essential systems.

1.1.4. Now everybody accepts the fact that safety does not just happen because ships comply with certain prescriptive requirements and crewmembers hold the necessary certificates, but safety should be managed.

1.1.5. As defined in paragraph 1.2 of the Code, Objectives, the requirement for the assessment and management of risks is fundamental to the ISM code. The ISM Code specifically requires that the safety management objectives of the company should, inter alia:

- Provide for safe practices in ship operation and a safe working environment.
- Establish safeguards against all identified risks
- Continually improve safety management skills of personnel ashore and aboard ships.

1.1.6. The authority responsible for issuing the necessary Documents of Compliance and Safety Management Certificates, when carrying out their audits, looks for objective evidence that these objectives are met by the operator’s safety management system. Since there is a very clear requirement within the ISM Code for the operator to demonstrate that he has an effective safety management system in operation that addresses all identified risks, and provides proper controls for dealing with these risks, it follows that this can only be achieved satisfactorily if a substantive risk assessment approach is adopted.

1.1.7. It has to be emphasized that this should be an effective risk assessment strategy, not necessarily a highly complex quantitative evaluation. The risk assessment approach embraces a large number of techniques, all of which use a formality that makes documentation and rational analysis relatively straightforward. The current paper describes typical steps involved in structured risk assessment techniques and provides the delegates familiarity with the risk assessment concepts and their inter-relation with the implementation of the ISM Code.

1.2. Definitions:

1.2.1. Safety:

- "Ship safety is the quality that reflects a state of acceptable risk concerning humanware, hardware, software and the environment" (Definition put forward by Dracos Vassalos)
- Safety is a perceived quality that determines to what extent the management, engineering and operation of a system is free of danger to life, property and environment (Definition put forward by Chengi Kuo)

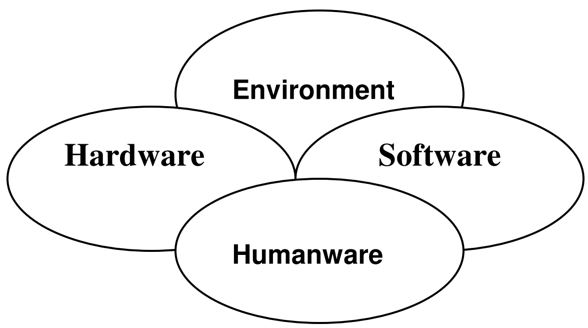

Fig 1: Elements of Ship Safety

1.2.2. *Risk Assessment Terminology*.

- Accident: An unintended event involving fatality, injury, ship loss or damage, other property loss or damage, or environmental damage
- Consequence: The outcome of an accident
- Frequency: The number of occurrences per unit time (e.g. per year)
- Hazard: A potential to threaten human life, health, property or the environment
- Risk: The combination of the frequency and the severity of the consequence.

2. Risk Assessment & Management

2.1. Principles:

2.1.1. The principle of Safety Management involves managing and controlling risks levels of hazards and keeping them within acceptable levels. This process involves seeking answers to following questions:

i. What could go wrong?
ii. What happens if it goes wrong?
iii. What are the chances of it going wrong?
iv. How could the chances/ effects be reduced?
v. What to do if it goes wrong?
vi. How can we Manage risk levels?

2.1.2. The first two questions involve identifying the hazards and prioritizing them based on the consequences. The third question determines the probability of occurrence or the frequency of occurrence, as applicable, of the hazard and Question number four involves risk reduction. Question number five involves emergency preparedness. Finally question number six involves safety Management.

2.1.3. Safety Case Approach: An approach based on systems engineering principles, primarily developed for dealing with safety of installations with little or no previous experience. The method comprises of seeking answers to the set of questions as above. On completion of the analysis a written report known as safety case is prepared which will show that all potential hazards have been reduced to risk levels as low as reasonably practicable and that they will be effectively Managed and controlled throughout the life cycle of the installation.

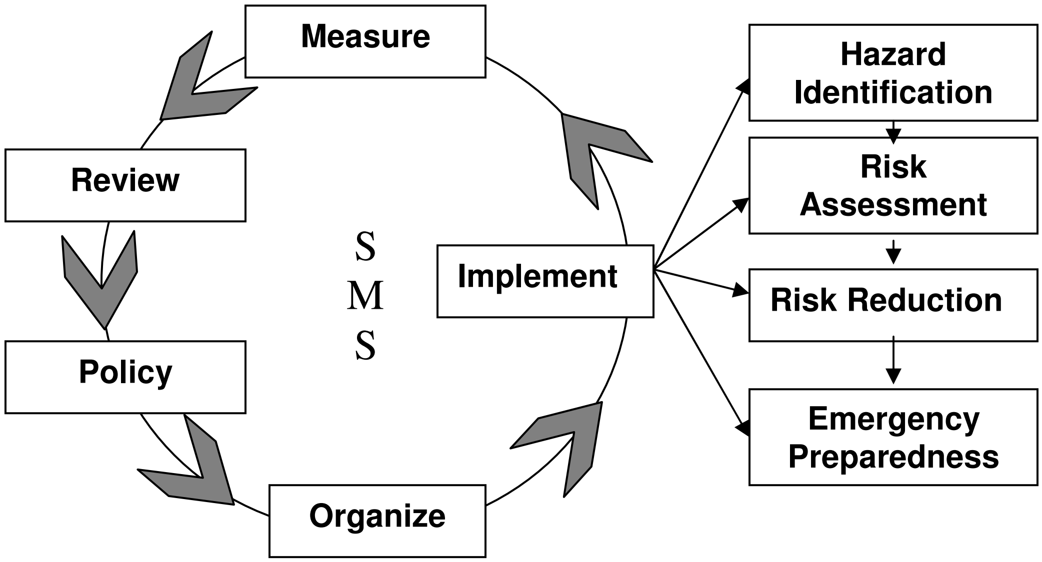

Fig. 2: Elements of Safety Case Concept

2.2. Hazard Identification:

2.2.1. The purpose of this step is to identify and generate a prioritized list of hazards, specific to the problem under review. This purpose is achieved by the use of standard techniques to identify hazards, which can contribute to accidents, and by screening these hazards using a combination of available data and judgment.

2.2.2. The approach used for hazard identification generally comprises a combination of both creative and analytical techniques, the aim being to identify as many relevant hazards as possible. The creative element is to ensure that the process is proactive, and not confined only to hazards that have materialized in the past. It typically consists of structured group reviews aiming at identifying the causes and effects of accidents and relevant hazards. Consideration of functional failure may assist in this process. The group carrying out such structured reviews should include experts in the various appropriate aspects, such as ship design and operations and specialists to assist in the hazard identification process and incorporation of the human element. The analytical element ensures that previous experience is properly taken into account, and should make use of background information (for example applicable regulations and codes, available statistical data on accident categories and lists of hazards to personnel, hazardous substances, ignition sources, etc.)

2.2.3. Following are some examples of Hazards:

- SHIPBOARD HAZARDS TO PERSONNEL
    - Asbestos inhalation
    - Burns from caustic liquids and acids
    - Electric shock and electrocution
    - Falling overboard
    - Pilot ladder/pilot hoist operation

- HAZARDOUS SUBSTANCES ON BOARD SHIP
    - Accommodation areas:
        - Combustible furnishings
        - Cleaning materials in stores
        - Oil/fat in galley equipment
    - Deck Areas:
        - Cargo
        - Paint, oils, greases etc. in deck stores
    - Machinery spaces:
        - Cabling
        - Fuel and diesel oil for engines, boilers and incinerators
        - Fuel, lubricating and hydraulic oil in bilges, save alls, etc.
        - Refrigerants
        - Thermal heating fluid systems

- POTENTIAL SOURCES OF IGNITION
    - General
        - Electrical arc
        - Friction
        - Incendive spark
        - Radio waves
    - Accommodation areas (including bridge):
        - Electronic navigation equipment
        - Laundry facilities - irons, washing machines, tumble driers, etc.
    - Deck areas:
        - Deck lighting
        - Funnel exhaust emissions

    - Hot work sparking
  - Machinery spaces:
    - Air compressor units
    - Generator engine exhaust manifold

- HAZARDS EXTERNAL TO THE SHIP
    - Storms
    - Lightning
    - Uncharted submerged objects
    - Other ships

2.2.4. A coarse analysis of possible causes and outcomes of each accident category should be made by using standard techniques (such as fault and event trees, HAZOPs, FMEAs, etc. as described below, to be chosen according to the problem under concern.

2.2.5. **Fault Tree Analysis:**

2.2.5.1. A Fault Tree is a logic diagram showing the causal relationship between events, which singly or in combination occur to cause the occurrence of a higher-level event. It is used in Fault Tree Analysis to determine the probability of a top event, which may be a type of accident or unintended hazardous outcome. Fault Tree Analysis can take account of common cause failures in systems with redundant or standby elements. Fault Trees can include failure events or causes related to human factors.

2.2.5.2. The development of a Fault Tree is by a top-down approach, systematically considering the causes or events at levels below the top level. If two or more lower events need to occur to cause the next higher event, this is shown by a logic `and' gate. If any one of two or more lower events can cause the next higher event, this is shown by a logic `or' gate. The logic gates determine the addition or multiplication of probabilities (assuming independence) to obtain the values for the top event.

2.2.6. **Event Tree Analysis**

2.2.6.1. An Event Tree is a logic diagram used to analyze the effects of an accident, a failure or an unintended event. The diagram shows probability or frequency of the accident linked to those safeguard actions required to be taken after occurrence of the event to mitigate or prevent escalation.

2.2.6.2. The probabilities of success or failure of these actions are analyzed. The success and failure paths lead to various consequences of differing severity or magnitude. Multiplying the likelihood of the accident by the probabilities of failure or success in each path gives the likelihood of each consequence.

2.2.7. **Failure Mode and Effect Analysis (FMEA)**

2.2.7.1. FMEA is a technique in which the system to be analyzed is defined in terms of functions or hardware. Each item in the system is identified at a required level of analysis. This may be at a replaceable item level. The effects of item failure at that level and at higher levels are analyzed to determine their severity on the system as a whole. Any compensating or mitigating provisions in the system are taken account of and recommendations for the reduction of the severity are determined.

2.2.8. The analysis indicates single failure modes, which may cause system failure.

2.2.9. **Hazard and Operability Studies (HAZOP)**

2.2.9.1. These studies are carried out to analyze the hazards in a system at progressive phases of its development from concept to operation. The aim is to eliminate or minimize potential hazards.

2.2.9.2. Teams of safety analysts and specialists in the subject system, such as designers, constructors and operators are formally constituted. The team members may change at successive phases depending on the expertise required. In examining designs they systematically consider deviations from the intended functions, looking at causes and effects.

2.2.9.3. They record the findings and recommendations and follow up actions required.

2.2.10. **Brain Storming** is also a commonly used Hazard identification technique, where a group of people with varying expertise and interests get together for a agreed duration and a target number of hazards. A coordinator encourages each one to contribute. No discussions are allowed at this stage. Best results of this procedure depend on having the right group with right attitudes. Advantage is that within a short duration a good amount of hazards from various perspectives are identified. Resulted list is subjected to a 'What if analysis'.

2.2.11. The human element is one of the most important contributory aspects to the causation and avoidance of accidents. Human element issues throughout the integrated system should be systematically treated. Appropriate techniques for incorporating human factors should be used.

2.2.12. The identified hazards relevant to the problem being considered, and established at an earlier stage, should be screened to prioritize them and to discard scenarios judged to be of minor significance. Screening is undertaken using available data, supported by judgment, on the frequency of different outcomes of accident categories. A risk matrix, as shown in figure 3, may be used.

2.2.13. The output from hazard identification comprises:
- A prioritized list of hazards; and
- Preliminary description of the development of hazards to final outcomes.

2.3. RISK ASSESSMENT

2.3.1. The purpose of 'Risk Assessment" is to determine the significance of the various hazards identified so that they can be placed on a scale. The current best practice is to recognize that there are three levels of risk: Intolerable, As Low As Reasonably Practicable (ALARP) and Negligible.

2.3.2. "Intolerable" means that the risk cannot be justified except in extraordinary circumstances, "Negligible" that the risk has been made so small that no further precaution is necessary, and "ALARP" that the risk falls between these two states.

2.3.3. Boundaries of these levels are not fixed but are determined by the societal perception of what is acceptable at a given point in time. What was acceptable 100 years ago are not acceptable now.

2.3.4. There are two fundamental measures of risk, individual risk and societal risk. It is necessary for the risk to be both tolerable to the individual and tolerable to society. Individual risk can be regarded as the risk to an individual in isolation while societal risk is the risk to society of a major accident. There is a clear perception in society that a single accident that kills 1,000 people is worse than 1,000 accidents that kill a single person. Therefore the tolerable level of societal risk is usually lower than the tolerable level of individual risk.

2.3.5. Individual risk is usually assessed by some form of a criticality matrix where the risk is assessed against frequency of occurrence (ranging from extremely remote to frequent) and severity of outcome (ranging from insignificant to catastrophic). Societal risk is usually assessed by a technique such as an FN curve where the acceptable level of frequency of an accident (F) is plotted against the number of people killed by the accident (N).

2.3.6. When each risk assessment is made, it will be necessary also to determine which assessment method should be used. Generally, accidents that cause one or two fatalities are best assessed by individual risk considerations, while accidents that cause the loss of a crew or the passengers are best assessed by societal risk considerations.

2.3.7. Whichever assessment method is used, the uncertainties of quantitative risk assessment must be balanced against the potential risk reduction. It is necessary to consider the uncertainty in the process in order to avoid premature judgments about the benefits of a particular Risk Control Option.

2.3.8. The extent to which risk exposure is involuntary (as opposed to voluntary) may also be relevant in determining the acceptability of risk. For example, a lower level of risk might be appropriate for people living near a port and unaware of the risks that shipping operations impose upon them, compared with the risks experienced by crewmembers who choose to continue their employment in a particular shipping trade.

2.3.9. Risk assessment could be done qualitatively or quantitatively. Qualitative methods depend on the combined expertise of the risk assessment team and making use of risk matrices. A typical example of a risk matrix is shown in figure 3.

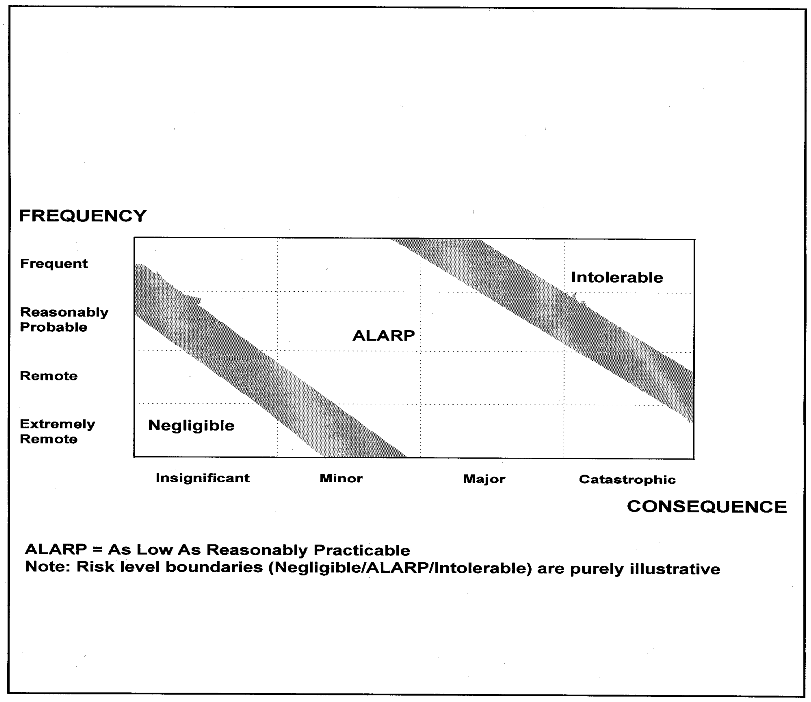

Fig. 3: Risk Matrix

2.3.10. Quantitative methods involve modeling of the system and analysis of statistical data on the consequences and probability of occurrence. This method in general utilizes event trees and fault trees.

2.3.11. Output from risk assessment comprises of:

- Hazards identified are classified based on their risk levels such as Intolerable, ALARP & Negligible.

2.4. Risk Reduction:

2.4.1. The purpose of this step is:

- Eliminate Hazards with intolerable risk at whatever cost. If this is not practicable abandoning the project should be considered.
- Reducing the risk of those in ALARP region if it is cost effective. Higher costs could be considered acceptable if the risk is close to the intolerable region.
- Reducing the risk levels of those in the negligible region with minimal effort.

2.4.2. Risk reduction options are as follows:

- Reduce the severity of the consequence.
- Reduce the probability of occurrence
- Reduce both

2.4.3. Risk reduction methods could be categorized as

- Management Method: Methods based on development of a safety culture, improved effectiveness of communication, training, etc.
- Engineering Method: Incorporate additional engineering features to enhance safety.
- Operational method: Devising right procedures
- Combination of all of above.

2.4.4. ALARP Principle: "The methods of reducing the risk level of a hazard can be put in one scale and balanced against efforts needed in another. This effort may be represented by money or time or a combination of the two. If it can be shown that there is a gross imbalance between the two, e.g. the reduction of risk level is insignificant compared to the cost of implementing the solution, it will not be reasonably practicable to go ahead." (HSE (1992-1).

2.5. Emergency Preparedness:

2.5.1. This is a requirement of ISM Code section 8. It is well known that accidents cannot be totally avoided. Hence it is necessary to be prepared for dealing with the emergencies.

2.5.2. The process involves:

- Identifying the emergencies
- Preparation of emergency response plans
- Training
- Drills and exercises.

2.5.3. SOPEP and Damage Control plans are typical emergency response plans.

2.6. Safety Management System:

2.6.1. Safety Management System is the systematic approach for ensuring that the various steps of risk assessment and Management as described above are implemented correctly and efficiently. Figure 2 illustrates the components of a Safety Management System:

2.6.2. Policy: Safety and Environmental Protection policies are formulated, which describes how the safety Management objectives are achieved. This is a requirement under ISM code section 2.

2.6.3. Organize: This involves organizing activities such a way that the policies can be implemented. ISM Code covers these aspects under sections 3, 4, 5, 6, and partly by section 10.

2.6.4. Implement: This component involves the process of Hazard identification, Risk assessment, risk reduction and Emergency preparedness. Sections 7, 8 and 10 of the code cover these aspects.

2.6.5. Measure: Process of obtaining data for ensuring that the policies are being implemented correctly and efficiently and the company policies are capable of achieving the Safety Management Objectives. Covered by ISM code requirements 9 & partly the requirement 11 and 12.

2.6.6. Review: Is the process of analyzing the data obtained through measurements and learning from the experiences. Necessary corrective/ preventive actions or revision of policies are identified during the review process. ISM code requirements 9, 10 & 12 addresses this aspect of Safety Management system.

3. Conclusion:

3.1. ISM Code:

3.1.1. ISM code introduced a new dimension to the way safety is considered in the marine industry. It is expected that the ISM code will increase the risk based thinking in considering safety and environment protection in this industry.

3.1.2. Use of off-the-shelf management systems, lack of management commitments could turn the implementation of the ISM code in to a costly paper exercise. Very often such systems fail to achieve the objectives of ISM code.

3.1.3. It shall be noted that this paper is only intended to show the inter-relation of ISM code and risk assessment and illustrating typical risk assessment methodology. While auditors should encourage use of scientific risk assessment methods in implementing ISM code, it shall be born in mind that ISM code does not specify any particular form of risk assessment, hence it would be adequate to ensure that the SMS provides for some form of identification of risks and implementation of necessary safe guards.

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