Risk Management

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Abstract

The paper addresses the problem of safety and risk management as both represent essential elements in environmental impact assessment. The main elements of the risk management system are outlined. The importance of hazard classification by type and frequency is stressed. The main types, causes, consequences and assessment of man-induced hazards and accidents are briefly considered. Special attention is placed on the hazards and accidents occurring in the maritime sector. Particular emphasis is placed on the role of human errors causing these accidents. Risk analysis and assessment are examined together with the methods commonly used to reduce risk. The main elements of safety assurance are given together with a method for calculating risk based on the demand and capability concept. The method presented is based on prior knowledge of the probability density functions of both demand and capability.

Introduction

Environmental impact assessment and life cycle analysis should include, among several other topics, risk analysis and assessment. Therefore, safety and risk management have received considerable attention and concern worldwide, especially after the well-known Bhopal catastrophic accident. The Middle East region, and Egypt in particular, has a large concentration of highly hazardous activities and industries and are planning to expand these facilities, such as petroleum extraction and processing facilities, LNG terminals, petrochemical processing plants, gas, oil and product pipelines, transport of oil and gas by tankers, sea terminals…etc. There are also long term plans to expand these activities and facilities. Hazardous and toxic releases from such facilities due to either accidents, sabotage,…etc. pose a significant threat to health, the environment and to the national economy. Serious accidents and toxic releases could also occur when using dangerous materials and substances in the production processes, during transport of these substances within the industrial plant…etc. A comprehensive risk assessment of such facilities should involve not only the regulatory authorities but should also involve the scientific and technical community and should be based on state-of-the-art codes and standards that greatly facilitate safety planning, build confidence, enhance security and reduce hazards and risk. The effectiveness of the safety management system could be significantly improved when both the quality management system and the environmental management system are both taken into consideration.

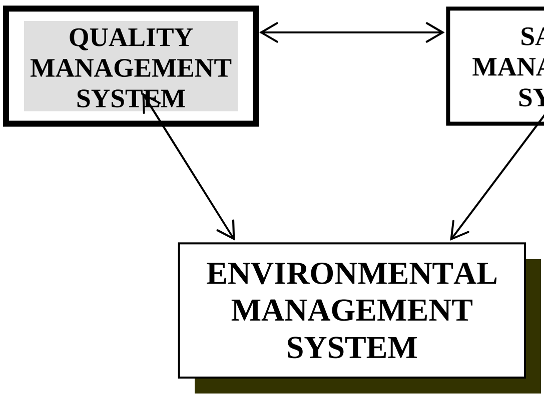

Fig. (1) Environment, Quality and Safety Management Systems

Safety Management System

Safety management is an essential tool required to ensure adequate safety, acceptable risk values and reduced hazards. Safety management not only deals with the analysis of the hazards but also gives proposals for the necessary actions to be taken to alleviate the causes of hazards and reduce the associated risks. In order to reduce hazards, improve safety, reduce risks and protect the environment, the interconnection among Environmental management system, Quality management system and the Safety management system, see Fig. (l), should be studied and examined thoroughly.

The safety management system should cover the following essential elements:

- Hazard type, frequency and degree of seriousness
- Accidents: causes and consequences
- Role of the human element in hazard creation and occurrence of accidents
- Role of the technical deficiencies in the creation of hazards and accidents
- Role of environmental conditions
- Risk analysis, assessment and methods of control and reduction
- Methods of ascertaining risk values
- Acceptable risk values for the particular industry or activity under consideration
- Economic considerations, etc.

The safety management system should include: the safety objectives, safety standards, safety procedures, performance measuring and monitoring, hazard identification, risk assessment, auditing, corrections and improvements.

Hazard Classification

There are several means and ways of classifying hazards, depending on the type of industry, environmental conditions, human involvement, technical considerations, etc. Hazards could be classified by type which ranges from “negligible" to “catastrophic" or could be classified by frequency which ranges from “frequent” to “remote”, see Table (1). For each hazard type and category, the technical consequences (system damage/failure) and the consequences to human life should be associated with the likelihood of occurrence.

Table (1). Hazard Classification by Type

		CONSEQUENCES	
Category	Description	Technical Consequences	Health Consequences
I	catastrophic	system loss	Death
II	critical	major system damage	*severe injury *severe occupational illness
III	marginal	minor system damage	*minor injury *minor occupational illness
IV	negligible	less than minor system damage	*less than minor injury or occupational illness

Main types of hazards

Hazards could be broadly classified as follows:

- Natural hazards (catastrophes), such as: earthquakes, flooding, hurricanes, etc.
- Man-induced hazards, such as: fire, explosion, toxification, collapse, structural failure which could be: minor, major or catastrophic,…etc. Sea transport of oil in tankers could induce several types of hazards that may cause serious fatalities, marine pollution and undesirable economic results.

Natural hazards are normally unpredictable and not much can be done to prevent their occurrence. On the other hand, much could be done to prevent, control or reduce the occurrence of some of the consequences of man-induced hazards. This could be achieved by using an effective safety management system.

Main causes of man-induced hazards

Man-induced hazards result mainly from human negligence and errors in design, fabrication, manufacture, operation, inspection, maintenance and repair. These human errors normally result from ignorance, lack of education, lack of information and knowledge, lack of experience, lack of competency, lack of proper training, illness, sickness, tiredness, etc. Carelessness in making a proper and professional electric wire connection could cause a serious fire hazard, which could result in fatalities, large economic losses and pollution.

Hazard Assessment

Hazard assessment is a valuable tool and could be used to improve system design, operation and management. The procedure of hazard assessment is based on identification of the hazard type, assessment of the frequency of the hazard and assessment of the consequences of the hazard. Human health risk assessment consists of four basic elements: hazard identification, dose-response assessment and exposure assessment.

Causes of Accidents

The main causes of accidents are natural catastrophes, human errors, random errors, technical deficiencies, environmental conditions, and “unknown causes". In the maritime industry, the technical deficiencies include: poor design, poor workmanship, poor inspection, poor maintenance, etc. The environmental conditions include: darkness, fog, rain, storm, sudden change of weather, shallow water, etc. Human errors result from several causes associated with the capability and experience of the different categories of personnel involved such as: lack of competency, high stress, tiredness, sickness, family problems, financial problems, psychological problems, over-confidence, improper decisions, miscalculation of situation, misunderstanding of instructions, carelessness, intentional carelessness, improper evaluation of consequences,…etc.

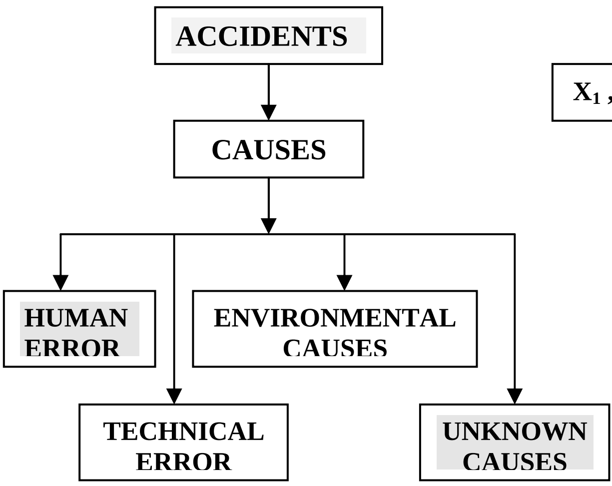

Fig.(2). Main Causes of Accidents

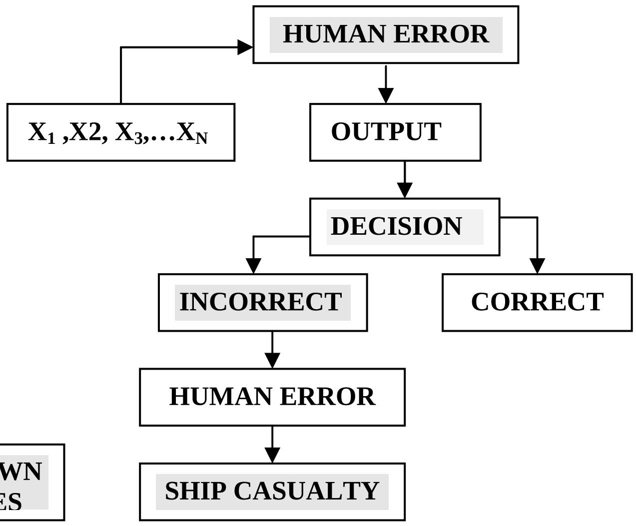

Fig.(3) Role of human Error

The main types of accidents are: collision, capsizing, sinking, grounding, fire, others. Fig. (2) shows the main causes of accidents. Accidents attributed to “unknown causes" results normally from the involvement of more than one cause for the occurrence of the accident. Fig. (3) shows the scenario of the occurrence of ship casualty due to either incorrect decision by the operator or incorrect information provided to the operator. The input data to the operator are x_1, x_2, x_3,. . x_n, which represent either reading from equipment, charts, catalogues,…etc., or from visual observations. The decision taken by the operator is based on personal analysis, views and interpretation of these data. Incorrect data or incorrect interpretation of the data will lead to incorrect decisions that will result in the occurrence of accidents. The main causes of human errors are associated with design, fabrication, operation, maintenance and repair. The consequences of human errors in design, fabrication and material are normally associated with structural failures, buckling, fatigue, cracks, excessive deformations, high stress concentration, etc. Fig. (4) shows the main causes and associated methods of preventive measures to alleviate the occurrence of accidents.

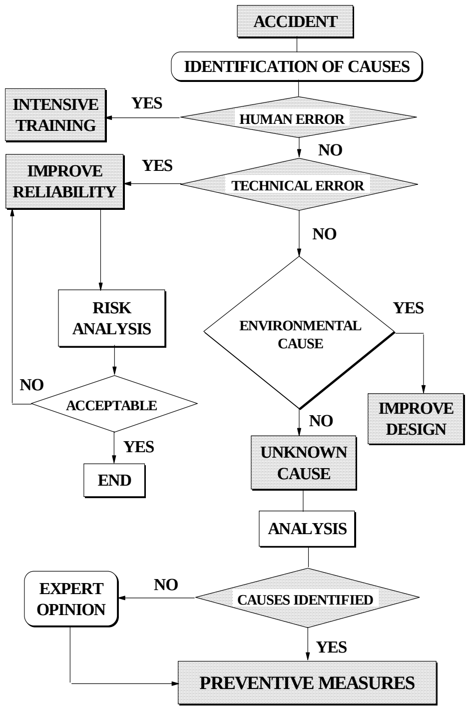

Fig.(4).Accidents: Causes and Preventive Measures

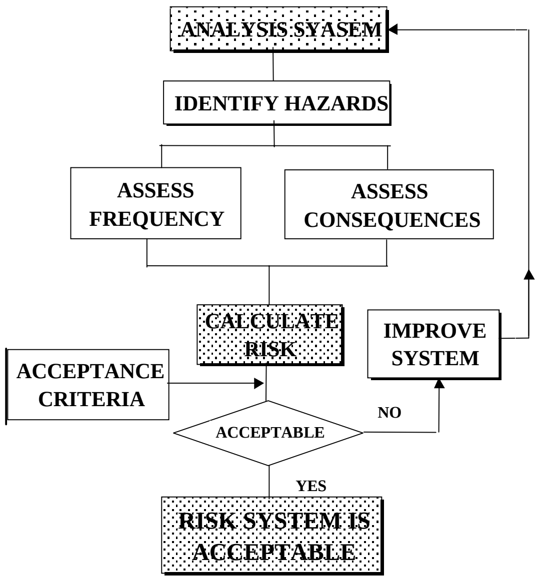

Fig.(5).Risk Analysis Procedure

Risk Analysis

Risk analysis is used for the assessment of the hazard causes, consequences and assessment and can be associated with the following questions:

- What are the types and causes of hazards '?
- What are the possible types, causes and consequences of accidents?
- How often these accidents will occur'?
- How could risk be assessed, calculated and managed?

Fig. (5) shows a flow chart for a procedure for risk analysis that could be used to improve system design. This procedure is based on identification of the hazard type, assessment of the frequency of the hazard, assessment of the consequences of the hazard, computation of the risk and the availability of an acceptable criterion for the type of risk under consideration.

Risk Assessment (RA)

Risk assessment consists of formal scientific techniques that: integrate knowledge about a contemplated action and its possible effects, account for uncertainty associated with that knowledge, express results from a probability standpoint to account for both knowledge and uncertainty.
Risk assessment, therefore, is the process of assigning magnitudes and probabilities to adverse effects of human activities, processes, etc. caused by human errors, technological deficiencies and environmental effects such as an accident, injury to human life, collapse of a bridge, sinking of a ship, explosion of a boiler, fire in a power station, etc. Risk could be defined by the probability of occurrence of an undesirable action or event. Its magnitude ranges from zero (0%) to one (100%). Zero risk means that the undesired event will never occur and a 100% risk means that the undesired

event will certainly occur.
Risk assessment has been recognised as a valuable tool to support decisions about actions that may have undesirable effects. Conceptually, RA applies to the human health, ecology, safety, environment, economy, etc.
Risk assessment is based on the following main items: i) development of accidental scenarios, which could potentially lead to fatalities, economic loss, release of hazardous or toxic material, etc. ii) specification of various pathways (air, water, ground) by which the hazardous material can lead to public exposure and the routes of such exposure (inhalation, skin absorption,…etc.) or could lead to fire, explosion, etc. iii) estimation of consequences such as: fatalities and other human undesirable health effects, environmental contamination, economic loss,…etc. iv) calculation of risk taking into account the likelihood of the scenario and the release of the toxic materials.

Risk Reduction Actions:
The procedure commonly used to reduce risk is based on identification of hazards, location of the hazards and analysis of hazards. Actions that may be taken to reduce risk include actions to eliminate hazards, actions to eliminate or reduce consequences, actions to reduce probabilities to acceptable levels. The methods commonly used to reduce risk include: changes in the design of the physical system, changes in the design of the control systems, changes in the process variables, such as temperature, pressure, stress,…etc., changes in the process/plant materials, changes in the test and inspection procedures of key components, changes in the variability and uncertainties of the system. An appraisal system of hazard and risk for the particular industry or activity under consideration could be developed and used to reduce risk to an acceptable level compatible with economic operation. It should be realised that lack of safety precautions can be very expensive as this will cause, among other things, loss of products, loss of contracts, damage of plant, cost of clean-up,…etc.

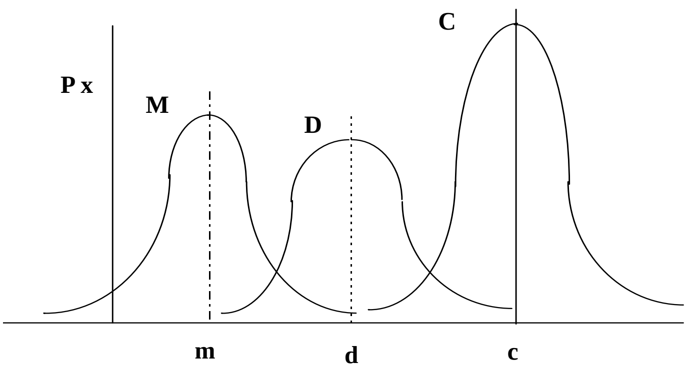

Fig.(6).Demand and Capability Concept

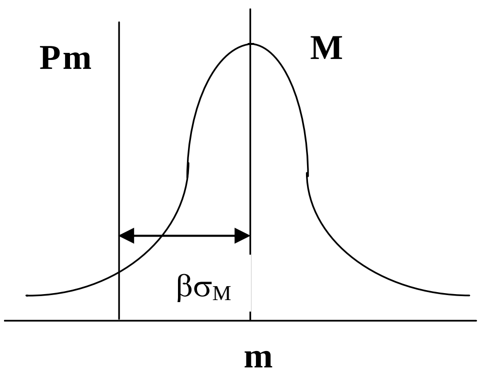

Fig.(7). PDF of Safety Margin

Risk and Safety Assurance
A major requirement for any system is to be reasonably safe, not to have catastrophic failure, nor to cause much trouble in service due to frequent minor failures. Safety in this context, is today concerned not only with the system itself, but also with external damage to the environment and the initiation of health hazards that may result as a consequence of failure or accident.
The fundamental equation for safety assurance is given by:

$C > D$, where: C = Capability of the system, D= Demand on the system
The margin of safety is given by, see Fig. (6): $M = C - D > 0$
The safety factor γ is given by: $\gamma = C / D > 1.0$

Calculation of Risk
Using the demand and capability concept, see Fig.(6), the Risk value could be calculated as

follows: Risk = P_f, Where: P_f = probability of failure of the system, and is given by:

P_f = Prob. (D > C) = $\int p(d).(\int p(c)dc)\, dd$.

If both C and D are both normally distributed and statistically independent, the mean and variance of the margin of safety are given by: $m = c - d$, $\sigma^2_M = \sigma^2_C + \sigma^2_D$,
x = mean value of X, σ^2_X = variance of X, X = C, D
The probability of failure, in this case, is given by:

$P_f = 1 - \phi\{(c - d)/(\sigma^2_C + \sigma^2_D)^{1/2}\}$

Where: $\phi(x)$ = the tabulated cumulative probability of the standard normal variable "x"
The probability of failure could be also given by:

$P_f = \int p(\gamma)\, d\gamma = \int p(m)\, dm = \phi(-\beta)$, where: $\beta = m/\sigma_M$ = the safety index, see Fig. (7):

Methods of Risk Reduction

The procedure commonly used to reduce risk is based on identification of hazard, location of hazard and analysis of hazard. Actions that may be taken to reduce risk include actions to eliminate hazard, actions to eliminate or reduce consequences of hazard, actions to reduce associated probabilities to acceptable levels.

Specific methods of risk reduction include: changes in the design of the physical system, changes in the design of the control systems, changes in the process variables, such as temperature, pressure, stress,…etc., changes in the process / plant materials, changes in the test and inspection procedures of key components.

Using the demand and capability concept, risk could be reduced by: increasing the mean value of capability (very costly), decreasing the mean value of demand (not always feasible), decreasing the variability and uncertainties of demand (not always feasible), decreasing the variability and uncertainties of capability (possible in many cases) and could be achieved by: improving design of the system, using a proper monitoring system, using proper control technology,…etc. Table.(2) shows the variation of risk values R with the factor of safety γ and the coefficients of variation of both capability and demand, v_C and v_D respectively.

Table. (2) Variation of Risk, R with γ, v_C and v_D

	$RX10^3$						
	$\gamma = 1.4$		$\gamma = 1.6$			$\gamma = 2.0$	
	v_D= 0.05	v_D= 0.1	v_D= 0.05	v_D= 0.1	v_D= 0.2	v_D= 0.05	v_D= 0.1
v_C = 0.05	0.0016	0.520	0	0.0013	2.67	0	0
v_C = 0.1	3.50	10.04	0.172	0.736	9.57	0	0.004
v_C = 0.2	79.80	89.25	31.97	36.75	55.92	6.55	7.64

Conclusions:

The main conclusions drawn up from this presentation are:

I. Risk assessment and control require the development of an appropriate *Risk Management System* suitable for the particular industry under consideration.
2. For any particular industry or process, research is needed to clearly identify and control hazards and risk caused by: Human Errors, Technical Deficiencies, Environmental Conditions and Unknown causes.
3 In most types of industries and processes, the Human Factor represents the most serious element creating different types and grades of hazards, accidents and risks

4. Hazards and associated accidents could be significantly reduced by:
- Continuous training and upgrading of workers, operators, engineers,…etc.
- Effective inspection. maintenance and repair work
- Improving the working load and conditions of all operating personnel
- Maintaining machinery and equipment at the highest technical level compatible with economic operation
- Correcting any minor technical deficiency and fault as soon as it is noticed so as to prevent its growth to become a major technical deficiency causing the initiation of hazards and accidents.

5. The risk values increase significantly with reduced safety factors and increased coefficients of variation of either or both capability and demand.

Bibliography

I. Shama, M. A "On the Economics of Safety Assurance", Technical Report, Dept. of Naval Architecture and Ocean Engineering, University of Glasgow, UK. Sept, 1979
3. Shama, M. A., “Energy and Environment in Engineering Education", AEJ, Sept, 1997
4. Shama, M.A., "Ship Casualties; Types, Causes And Environmental Impacts”, MARIND'96, Bulgaria, Varna, June, 1996
5. Sowman, "Emissions Affect Development", The Motor Ship, August, 1996
6. ISSC 79, ISSC ~2, ISSC 94
7. Spencer, "Recording of Data for Marine Accident 1nvestigations”, RINA, Oct l986
8. "Safety Record Of Ships Over twenty-year Period”, ABS, 1991
9. "Comparative Study on Potential Oil Spill in Collision and/or Grounding-Different Tanker Designs", DNV, 1990
10. Casualty Return, 1988
11. "Tanker Spills: Prevention by Design”, Nat. Acad. Press, 1991
12. "The Quest For The Environmental Ship", Intertanko's Safety And Tech. Comm., 19X6
13. "Ship Tech. And Environmental Protection”, GL, 1990
14. "Convention for The Protection of The Mediterranean Sea Against Pollution and its Related Protocols", UN Env. Prog., 1982
15. Don Hinrichsen, “Our Common Seas, Coasts in Crisis”, UN EP, 1990
16. "Enhanced Concerns Over Marine Pollution”, ABS, Feb., 1990
17. Shama, MA. "Impact On Ship Strength of Structural Degradation Due To Corr. AEJ, Oct., 1995
18. DNV, FORUM, No. 1, 1996
19. "The Role of Human Error in Design, Constr. And Reliability of Mar. Structures”, SSC-378,
20. Shama, M.A., "Ship Structural Failures; Types, Causes and Env. Impacts", AEJ, July, 1995
21. Daidola, J.C., "Tanker Structure Behaviour During Collision & Grounding", Mar. Tech., 1995
22. Shama, MA. "Unpublished Work on Strength of Damaged Cargo Ships", 1993
23. Shama, M.A., and others, "Shear Strength of Damaged Coastal Oil Tankers Under Vertical Shear Loading", AEJ, April, 1995
24. Shama. M. A., “Safety Requirements of Nile tourist Vessels”, AEJ, Vol. 28, 1989
25. Shama, M. A., “Mar. Structural safety and Economy”, SNAME, Symp. On MSIMM, USA, 1991
26. Shama, M. A., “Ship Stability: Assessment, Criteria and Risk”, AEJ, July, 1993
27. Shama, M. A., “Appr. of Fishing Vessel Econ. Using Risk Analysis”, USA, ISUMA93, April 1993
28. Shama, M. A., “The Risk of Losing Stability”, Sipp. World and Shipb., UK, Oct., 1975
29. Shama, M. A., “Safety Assurance: Methods of Assess. for Ship Structures”, IMAEM, Italy, 1981