

# CHALLENGES IN THE APPLICATION OF RISK IN CLASSIFICATION

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## **Abstract**

Classification Societies are responsible for “classing” marine vessels and structures in regard to their soundness of design and construction for the service for which they are intended (fit for purpose). This function is performed through verification of compliance with a set of rules, guides, standards and other criteria that Classification Societies develop for the design and construction of marine vessels and structures.

The rules and guides on which classification is predicated have been historically established from principles of naval architecture, marine engineering and other scientific principles that have proven satisfactory by service experience and systematic analysis. The objective of these rules has always been to ensure that the probabilities of accidents with the potential for adversely affecting life, property, and the natural environment are low. However this assurance was not explicit, as rules and regulations were developed without the benefit of quantitative estimates of risk. Furthermore, the rules are strictly only applicable to systems and structures similar to those upon which the rules are based. They are less successful when applied to novel systems for which there is limited, or no, historical experience.

While risk-based methods have successfully been employed in certain industries, notably the nuclear industry, their introduction to the marine industry has been slow. This paper discusses risk principles, how they can be applied to the classification business, the challenges faced by those responsible for introducing these methods, and an assessment of the future of risk assessment in the marine industry.

## **Introduction**

Classification Societies are independent organizations that promote the security of life, property and the environment of ships and offshore structures. This is done through a procedure known as classification, by the establishment and administration of standards, known as rules, for the design, construction, and operational maintenance of marine vessels and structures. Classification involves three distinct activities:

- Rule Development, which is the essence of the classification business,
- Class Assignment, which is the engineering review of design drawings and calculations to determine compliance to the corresponding classification rules, including surveys during construction, installation and commissioning, and
- Maintenance of Class, which involves periodic surveys over the life cycle of the vessel or installation.

The rules and guides on which classification is predicated are of a prescriptive nature, and have been historically established from principles of naval architecture, marine engineering and other scientific principles. The International Maritime Organization and flag administrations have also traditionally applied this approach in the development of statutory regulations. Without a doubt, this approach has been successful, as demonstrated by the generally decreasing trend of accidents over the years. However, rules and regulations developed in this manner have some deficiencies, which can result in:

- Slow and cumbersome regulatory process, often compromised by the competing interests of the parties involved
- Resources may be spent on issues to mitigate small risks, when they may be more effectively devoted to issues involving a larger risk
- Rules and regulations are often driven by recent accidents, therefore being reactive rather than proactive. This may result in over-reaction leading to decisions that are not entirely comprehensive in certain instances, and overly burdensome in others.
- Delays are frequently experienced in the regulatory endorsement of new technologies, due to the lack of previous historical experience.

In addition to the above, in recent years there has been a surge in the introduction of new and novel concepts and applications in the maritime and offshore industry. Such new concepts introduce new challenges to the industry. Is it possible to achieve reliable and safe designs without the benefit of proven historical experience? How can these novel designs be safely operated? How should they be regulated and classified in the absence of directly applicable requirements?

Fortunately, risk assessment techniques have evolved to a point where they can certainly help with this challenge. These techniques have proven to be very useful for other industries facing similar challenges: new technologies pushing the envelop of existing developments. Risk assessment is not a new concept in the marine industry. In fact, classification societies originally started more than a hundred years ago by “classing” vessels into levels of risk. This classification was done using technical expertise, mainly through an “informal” risk assessment where risk was considered implicitly. What is new is the application of risk assessment in a formalized way, using consistent methodologies, gathering data to feed into relevant models, and documenting the results so that others can review them, comment or use them for similar applications. With this innovative approach, it is possible to:

- analyze complex designs,
- identify hazards,
- estimate likelihood and consequences of failure (in an integrated fashion),
- identify risk control options,
- perform cost benefit analyses, and
- make decisions on design features to achieve a safe design.

As a consequence, some Classification Societies have started to set up the infrastructure necessary to reassess and modernize the traditional classification scheme with the incorporation and integration of risk assessment.

### **Essentials of Risk**

Risk is a measure of the likelihood that an undesirable scenario will occur together with a measure of the resulting consequences. Mathematically, this is the product of frequency and consequence of undesirable events. If the event involves the unsuccessful performance (i.e. failure) of parts of the design, then one of the contributors to the “frequency” of the event is the unreliability of such “parts”. These “parts” may be:

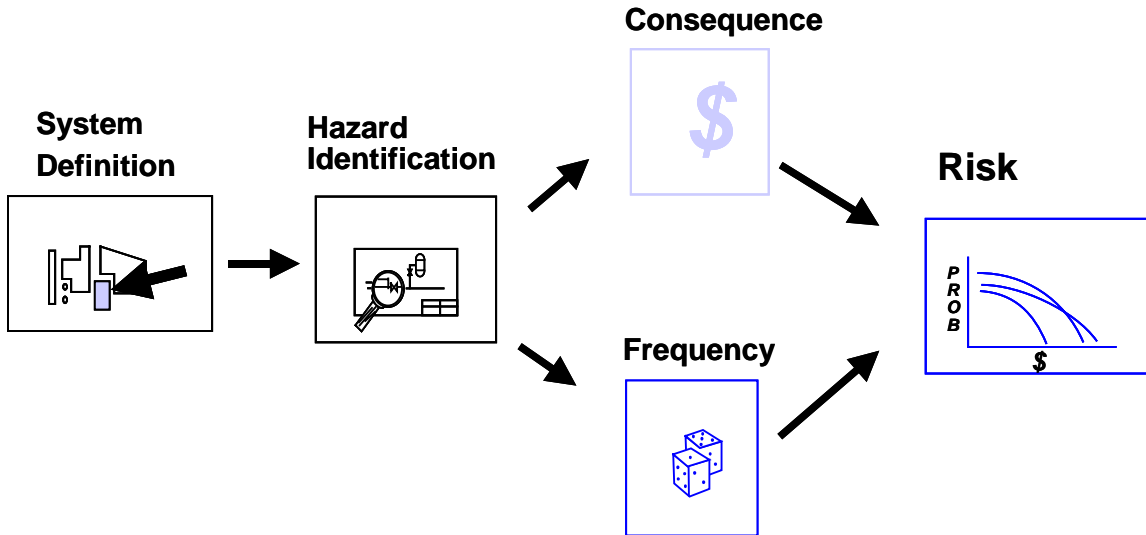
- Machinery or systems (mechanical reliability)
- Structures (structural reliability), and/or
- People (human reliability)

Risk assessment is an analytical technique that can successfully integrate diverse aspects of design and operation in order to assess risk. Risk assessment tools comprise an integrated array of techniques, including reliability, availability and maintainability engineering, statistics, decision theory, systems engineering and human behavior.

In simple terms, risk assessment involves three key questions (see Figure 1):

1. What can go wrong (hazard identification)?
2. How likely is it (frequency)?
3. What are the consequences?

The specific methodology to use in finding the answers to these questions will vary depending on the objectives of the study. Risk assessment techniques are categorized in two main groups: qualitative and quantitative. While a qualitative analysis may suffice for certain cases, a more detailed quantitative analysis may be necessary for others. There are different analysis techniques and models that can be used. ABS has published the *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries* [Ref. 1] with the objective of providing an overview of the risk assessment field for managers and technical professionals in the industry. This guidance document provides an introduction to some of the analysis methods available and suggests risk analysis approaches to support different types of decision-making within the maritime and offshore industries.



**Figure 1: The risk estimation process**

### **Role of Risk and Reliability in Classification**

Risk assessment can bring many benefits to the classification business, if properly implemented. Risk assessment should be used as a complementary tool to the existing classification framework, which has been proven successful for many years. The objective is to mesh the current classification requirements with an overall risk management approach.

This paper will discuss the application of risk and reliability methods to the following four key classification activities:

- a) Rationalization and improvement of classification rules
- b) Designs using alternatives to classification rules
- c) Novel concepts outside the scope of rules
- d) Surveys incorporating risk-based inspection methods.

#### **a) Rationalization and improvement of classification rules**

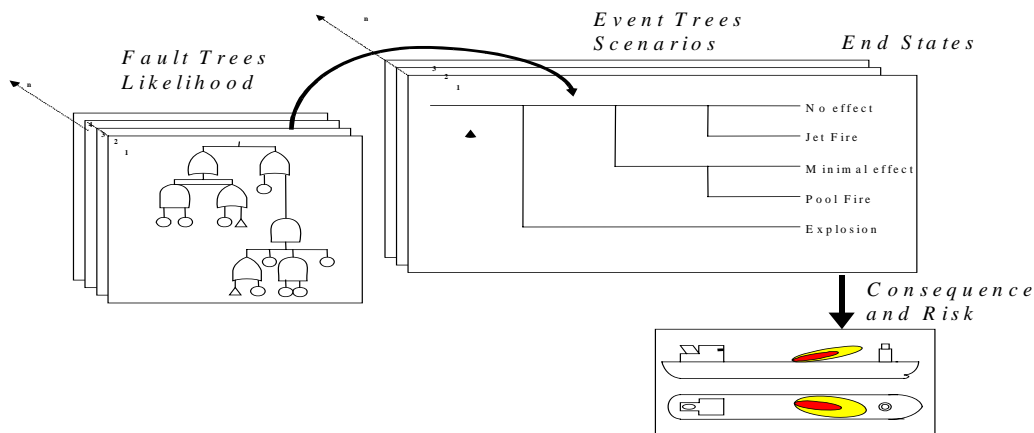
When considering the introduction of a new classification rule, or the modification, or even elimination, of an existing rule, risk assessment tools can be used if considered applicable. Alternative rule proposals are compared via risk assessment, and the risk reduction benefits for each option are evaluated. Rules developed in this manner are referred to as “risk-based” rules. Note that risk-based rules can still be prescriptive, but the relationship to risk is explicitly considered and assessed in the development of the rule.

There are three distinct objectives for the use of risk assessment tools in the development of class rules:

- to identify current prescriptive requirements which can positively be shown not to have any impact on risk (potential for rule elimination or relaxation),
- to identify potential new requirements using risk tools that can decrease risks not currently addressed by the rules (potential rule addition), and
- to identify current rules that only affect risk under certain specific conditions, rather than for all conditions within the type (potential for rule modification).

Another trend is the gradual introduction to the marine industry of performance-based or goal-based classification rules and regulations. The philosophy is that rather than prescribe how to design a specific system, prescribe a set of measurable or calculable targets that should be met to demonstrate compliance. In other words, measurable or calculable outcomes are to be met, but without prescribing how to meet those outcomes. This process would give a lot of flexibility to designers, while still assuring that the end product complies with the safety objectives imposed by classification. Development of performance-based rules often involve the use of risk parameters, although not necessarily.

The risk assessment tools necessary for use in rule development can be both qualitative and quantitative. In developing quantitative tools, ABS has built detailed risk models for an Oil Carrier and a Floating Production, Storage and Offloading (FPSO) facility. These models employ Quantitative Risk Assessment (QRA) methodologies, using event tree and fault tree techniques (Figure 2). Quantitative models take longer to develop, but once built they can be easily modified in order to analyze and compare numerically the impact on risk due to changes in system design. This is very useful for example to compare the risk reduction benefit that potential rule requirements under consideration can have on the final design.



**Figure 2: Quantitative Model for Oil Carrier**

## **b) Designs using alternatives to classification rules**

ABS requirements are being updated by expanding the statement on "alternative arrangements". Alternative ways of complying with ABS prescriptive rules are acceptable as long as it can be demonstrated that the alternative arrangement design is as safe as (or "equivalent") to the prescriptively compliant design. This demonstration should be based on sound engineering principles, including risk assessments. For a design to be considered equivalent, it must provide compliance with the overall criteria for safety and suitability for intended service established in the applicable ABS Rules and Guides. In practical terms, it must provide at least the same level of safety as ABS class rules and/or safety objectives.

An equivalency demonstration can be relatively simple in some cases, but it can be very complicated in others, depending on the degree of innovation of the proposed design, on the number of prescriptive requirements affected, and on the nature of the objectives of those requirements.

ABS developed the *Guide for Risk Evaluations for the Classification of Marine-Related Facilities* [Ref. 2] in order to create a formalized process using risk measures to demonstrate equivalency. This alternative offers many advantages to owners, designers and ABS, for example:

- Increased ability to suggest novel or alternative designs that are technically superior and more cost effective
- Increased confidence that the proposed designs will provide the same (or better) level of safety
- Better understanding of hazards, mitigation measures and risk posed by the proposed designs

The Guide describes three steps to complete an alternative arrangement analysis:

1. Define objectives of the evaluation
2. Perform a basic risk analysis
3. Complement with a detailed risk analysis for specific/critical issues as identified in the previous step, if necessary.

## **c) Novel concepts outside the scope of classification rules**

In common with other industries, the marine and offshore industries face ever-increasing demands and new challenges. Commercial pressures have led, for example, to larger faster container ships and the changing security environment has increased interest in relatively light and large high-speed craft. Similarly, the search for offshore oil has led to exploration and production in deeper waters, and the expansion of transport of natural gas have led to new designs. To meet these challenges novel designs have been developed, the novelty varying from the application of improved materials, tools and technologies through new systems up to entirely new configurations for the entire facility. Deviation from conventional engineering practice is always accompanied by greater uncertainties, and hence greater risk.

In the early phases of novel technology development, there are a) known hazards, b) hazards whose effects are not totally understood, and c) hazards that have not been recognized. Hazards that are unknown or not fully understood cannot be managed or mitigated appropriately, potentially resulting in major accidents. Risk-based methods provide a proactive systematic approach to help identify unknown risks and use that information as a tool in decision-making.

In history there have been several well-known novel systems that failed in a mode not normally considered part of design practice at the time. These, and other similar less well-known cases, illustrate the problem of designing systems for which there is limited, or no historical experience. The temptation is to apply to the design of novel systems existing methods, or adapted versions, developed for conventional systems, which are closest to the novel system in question. As discussed below risk-based methods offer several advantages over this approach. Key among these are methods for identifying the hazards that the system will be exposed to, and also methods for systematically accounting for the uncertainties associated with design, construction and operation of any engineering system.

Risk-based methods offer several advantages over conventional methods in dealing with novel systems. The key advantages are:

- Systematic approach to identifying hazards and failure modes. A feature of many novel systems is the existence of a failure mode absent in conventional systems.
- Thorough method to qualitatively, or quantitatively, evaluate the likelihood of hazard being realized and its associated consequence
- Rigorous treatment of uncertainties associated with each relevant design parameter and design model

Various organizations, including ABS, have developed methodologies that embody risk-based principles. In this regard ABS has developed the *Guidance Notes on Review and Approval of Novel Concepts* (Ref. 3), which lays out a methodology for obtaining Classification of a novel design. The process draws upon engineering, testing and risk assessment to determine if the concept provides acceptable levels of safety consistent with current offshore and marine industry practice.

Clearly in the evolution of a concept design that is novel, or has significant novel features, the impact of the novel aspects should be considered starting early in the design process and should be a continuing consideration in the design. Depending on the design stage various qualitative or quantitative methods can be usefully applied.

The process is illustrated in Figure 3. The figure summarizes the design stages and the risk methods that can potentially be applied. As the design progresses the level of uncertainty decreases as the results from various design analyses and risk assessments become available and are absorbed in the design process. The role of ABS, as a classification society, in this process is summarized in the right hand column. During the concept design stage various analyses may be required by ABS to establish the soundness of the concept. Once this phase is completed an “Approval-In-Principle” (AIP) is awarded. One result of the work performed during this phase is the identification additional studies and risk analyses that will required to support the detail design stage. As the design progresses beyond the AIP phase the process resembles more and more the Classification process associated with conventional systems.

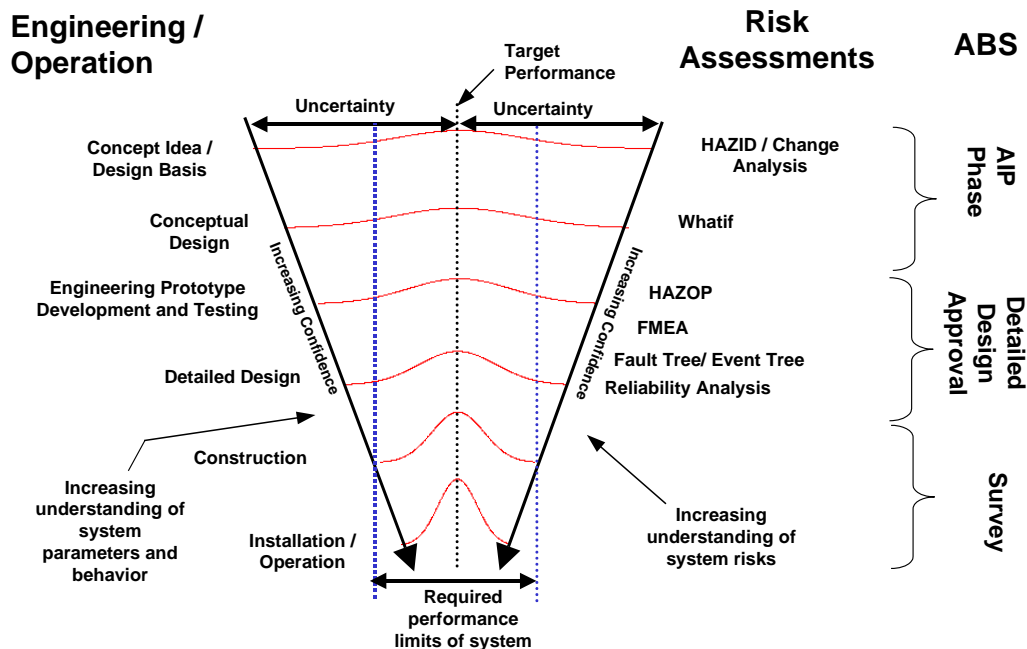


Figure 3 The Design Evolution of Novel Systems

#### d) Surveys incorporating risk-based inspection (RBI) methods

Another example of the application of risk-based methods is to inspection. In many ways this is an ideal application. Ships and offshore structures, and their associated systems often operate in harsh and demanding marine environments. Consequences of this are that structures and systems often suffer high degradation rates. The main degradation types relevant to marine structures and systems are corrosion and fatigue cracking. The former is a result of exposure to seawater and air, and the latter derives from cyclic loading induced to by waves or by operating cycles.

Ships that are important in international trade such as containerships, and offshore structures used for energy exploration and production tend to be large, high value assets. They also tend to be complex. These features combine to make the survey process difficult. A consequence of size is that it is, in general, only feasible to periodically inspect a small proportion of the structure or system. Furthermore, certain parts of the structure or system may be inaccessible. The challenge, therefore, is to ensure that the available inspection resources are applied most efficiently, and risk methods are useful for accomplishing this goal.

Traditional maintenance philosophy for ship and offshore structures and systems is prescriptive. While prescriptive methods in engineering have the virtue of simplicity, they lack flexibility in application, their effectiveness cannot be easily measured, and they cannot easily take advantage of improvements in inspection technology. Hence there has been in many aspects of engineering a trend away from prescriptive methods towards performance-based methods. Performance-based methods generally require the application of first-principles methods. As such they are better at taking advantage of improvements in all aspects of engineering design, construction and maintenance.

RBI methods are perhaps most widely applied in the process industry. In this industry the reduction of cost is the primary motivation to adopt RBI methods over traditional prescriptive methods, which are generally based on predetermined inspections undertaken at fixed frequencies. Traditional inspection methods are often accused of causing excessive downtime leading to reduction in operating revenue. Furthermore, it is difficult to demonstrate that traditional methods are capable of assigning maintenance resources in a cost effective manner such that the most maintenance resources are applied to the highest risk systems and components. The same broad characteristics also apply to other industries in which RBI methods are applied, most notably the nuclear power industry.

Risk-based inspection (RBI) addresses the following questions:

- What type of damage to inspect?
- Where to inspect?
- When to inspect?
- How to inspect?

As described early in this paper, risk methods, including RBI, rely on the rational assessment of risk in which the probability of occurrence of a hazard and its consequences are calculated, or qualitatively estimated. The product of probability of occurrence and consequence yields risk. The risk of each structural component and detail is ranked by risk. This information is used to develop an inspection plan in which, in general, the most inspection resources are applied to the elements that have the highest risk. The other important aspect is the increase in risk with time as each element degrades. The explicit consideration of time allows rational judgments to be made regarding inspection intervals.

Another useful feature of the risk framework is the ability to consider the impact on safety of applying alternative inspection practices to be estimated explicitly. A number of possible benefits result in relation to traditional inspection methods including greater flexibility in planning inspections and making maintenance more cost effective.

In the marine environment RBI methods are increasingly being applied to offshore facilities, both the hull and the process plant. Most applications have been to the latter where it has been a relatively simple matter to adapt existing applications for land process plant to marine process plant. The application to ships structures and systems has been slower, at least partly due to the current regulatory and statutory regime that applies to trading ships. However, the desire for greater flexibility and the drive to reduce costs will likely result in greater use of RBI in the survey of ships. There are aspects of ships that are unique in the context of RBI, and methods applied to offshore structures cannot necessarily be applied without some modification.

In common with other applications of risk to classification the American Bureau of Shipping (ABS), along with other Classification Societies, have been responding to clients who wish to employ risk methods in the inspection process. In order to meet this challenge ABS has developed *A Guide for Surveys Using Risk-based Inspection for the Offshore Industry* (Ref. 4). The guide specifies requirements in terms of scope, methodology and documentation to ensure that RBI is applied in a sufficiently rigorous and uniform way.

### **Challenges in Implementation**

The following challenges in the implementation of risk assessment in classification will be discussed:

- a) Shortage of data
- b) Acceptance criteria
- c) Cultural Challenges
- d) Variable quality of risk assessments.

#### **a) Shortage of data**

The availability of practical, adequate and applicable reliability data is always a challenge in any industry. The maritime and offshore industries are no exception. In the offshore side, the situation has improved with the establishment of the Offshore Reliability Data (OREDA) handbook project [Ref. 5]. This database is derived from actual operating experience on a number of offshore platforms in the North Sea. For the maritime industry, however, there is not yet such source. Among some of the most relevant activities, starting in 1993, the Ship Operations Cooperative Program (SOCP) sponsored the development of a component reliability data collection system, under the name of RAM/SHIPNET [Ref. 6], and is currently being offered commercially under the name of “Wave Software System”. However the data collected is proprietary of each company, and in any case the amount of data currently collected is probably not yet statistically adequate for use as representative of the maritime industry.

As far as accident level type of data, insurance companies record and provide data for the maritime industry, for example the casualty database maintained by Lloyd's Maritime Information Services (LMIS). However, accident level type of data can only be used for coarse or high-level risk assessment, say for screening purposes. For the type of analysis needed in classification rule development more detailed type of data is needed, e.g. component reliability data. This is because most rules are normally concerned at the component or system level (cause of the accident). Data for similar components from other industries (mainly from the nuclear industry) are available, but considering the uniqueness of the maritime environment (e.g. vibration, humidity, corrosiveness) their validity may be questionable.

The sources of reliability data remain one of the biggest challenges in the maritime industry, and it is very important to keep this in mind when the results obtained are being analyzed and used for regulatory purposes or decision-making. Applicability and accuracy should also be considered.

## **b) Acceptance Criteria**

Qualitative or quantitative risk assessments are performed to support decision-making, for example to select a potential rule requirement, to accept a proposed design or alternative inspection/survey strategy. This decision-making process ultimately requires the use of some acceptance criteria. This is a significant challenge particularly for risk assessments of complex systems as many marine offshore facilities are. Risk assessments can vary in several different ways including scope of the system, scope of the hazards considered, methodology used, etc. The criteria that are appropriate will depend on each of these factors.

ABS has been working on this difficult problem and has evaluated several approaches with the objective of coming up with a suitable approach. Each approach has its advantages and disadvantages. As an example one approach is to consider an upper limit for total risk to people, environment and property as possible acceptance criteria for assignment of class, when the owner or designer voluntarily chooses to be classed with the use of risk assessment, e.g. for designs involving alternative arrangements or novel concepts. While the concept initially appears appealing in theory, a deeper examination of such a philosophy reveals a series of problems that are difficult to overcome. Among these are:

- the contributors to risk, especially to personnel and environment, include elements that are currently outside the scope of class requirements (for example human actions)
- a complete, accurate, and installation specific risk assessment model is necessary to prove compliance
- the uncertainties, inaccuracies and subjectivity of the models and data used in risk assessment
- risk levels typical vary for different types of vessels.

No classification society has yet defined acceptance criteria based on total risk, for classification purposes. Usually, the definition of such criteria is left for the owner to establish. There are currently discussions at the International Maritime Organization about the feasibility of establishing such criteria.

### **c) Cultural Challenges**

While risk methods are firmly established in several industries their introduction has been slower in the marine industry. Although they have been used for some time in the offshore industry the use of risk methods in ships is very limited. This is partly a reflection of the long history of ships. Ship design is dominated by prescriptive methods and the introduction of first-principles methods in the design of ships is relatively new because of the complexities of predicting the wave loading and response of ships. The use of prescriptive methods applies not only to design but also to inspection. Furthermore, the requirements of the statutory and regulatory authorities are also cast in prescriptive terms.

The offshore industry, which is little more than five decades old, has less of a legacy to deal with. First-principles methods in design were introduced early and the industry was quick to adopt risk-based methods especially after a number of bad accidents in the seventies and eighties.

Resistance to change is common to all industries. Change is very rarely introduced without some external impetus. It is suggested that risk-based methods will find greater application as both the marine and offshore industries respond to increased commercial pressures. Responding to these pressures may require novel systems, newer operating methods and generally more flexibility in terms of design and inspection. Risk-methods are well suited to help in meeting these challenges.

### **d) Variable Quality of Risk Assessments**

As in most other industries when starting the use of risk assessments, qualitative techniques are being favored over quantitative ones. This is logical, since qualitative techniques for risk assessments normally do not require intensive labor, and are usually performed in a two to three day brainstorming meeting, depending on the scope of the analysis. The relevant findings at this meeting are followed up by a consolidation of discussions and recommendations for risk reduction measures. Another important point is that there is a wide range of levels for both qualitative and quantitative techniques, such that there is no clear line dividing both approaches. A combination of methods is applied in many cases. Qualitative techniques are very useful as a starting point to evaluate overall risks and identify the potential areas that contribute the most to risk. However, if thorough evaluations of risk reduction measures are being sought, including the amount of expected risk reduction after implementation (very important for cost benefit assessments), then the extra amount of labor required for the use of quantitative techniques may become worthwhile. In all cases, it is important to select the simplest technique that can support the decision to be made, with sufficient confidence. It is

therefore very important to clearly determine beforehand the scope and objectives of any risk analysis, so that a proper selection of an assessment technique can be made and resources are used efficiently.

## **Conclusions**

Class societies have always considered risk in the development and implementation of classification rules, but only in an implicit fashion. Newly developed risk assessment methodologies, together with computing capabilities, can formalize this process by applying scientific rigor to systematically and more accurately identifying risk and their control measures.

The benefits of risk methods to the classification business have been outlined above. Also described are the first steps being made by the classification industry to introduce methodologies based on these methods. The authors believe that this trend will continue, particularly as organizations such as the IMO are encouraging such a movement.

The process of the integration of risk methods in classification will be slow and evolutionary, as it should be. Safety is a paramount concern in the marine and offshore industries and it is important the approaches used to evaluate safety are changed in a gradual manner and with a comprehensive understanding of its impact. It is also important that all those involved in the evaluation of safety support this gradual evolution.

The ABS strategy to develop the use of risk assessment in classification includes three important elements: the development of risk tools, methodologies and training. These elements are integrated to encourage consistent application within the three primary areas of classification activity: Rule development, class assignment and maintenance of class. In providing these services, ABS aims to supplement traditional classification services and improved safety and productivity for marine and offshore structures. As the industry becomes more familiar with risk assessment, and access to data and analytical techniques continues to improve, useful applications will become easier to perform and will consequently grow in number. This evolution should result in a boost of safe designs and safer operations.

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