Dependable systems and competent people

Essentials for safety

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Throughout its existence, Lloyd's Register has been inextricably linked with the safety of ships, in particular the assurance that the condition of the ship and its equipment meets the requirements that are set out in the rules relating to classification. It is interesting to note that in the earliest existing register books the entries include information on the ship, its equipment and the master, the inference being that the underwriters, who benefited from the register, considered the human element as being an important factor when determining the risk, and thereby the premium.

Although classification has become principally a regime for the development and implementation of standards for the hull, propulsion and steering machinery and essential mechanical and electrical engineering systems, Lloyd's Register continues to take a close interest in the human element, carrying out research projects and seeking ways to improve marine safety. The underlying assumption is that the majority of marine incidents result from some form of human error, although this may not be the proximate cause, and the route to improving the safety performance is dependent on achieving both dependable systems and competent people.

Against the backdrop of recent safety performance, this article considers the management of risks as technology changes, alongside the influence of people, as part of complex maritime transport systems. I shall outline responses to address some of the issues.

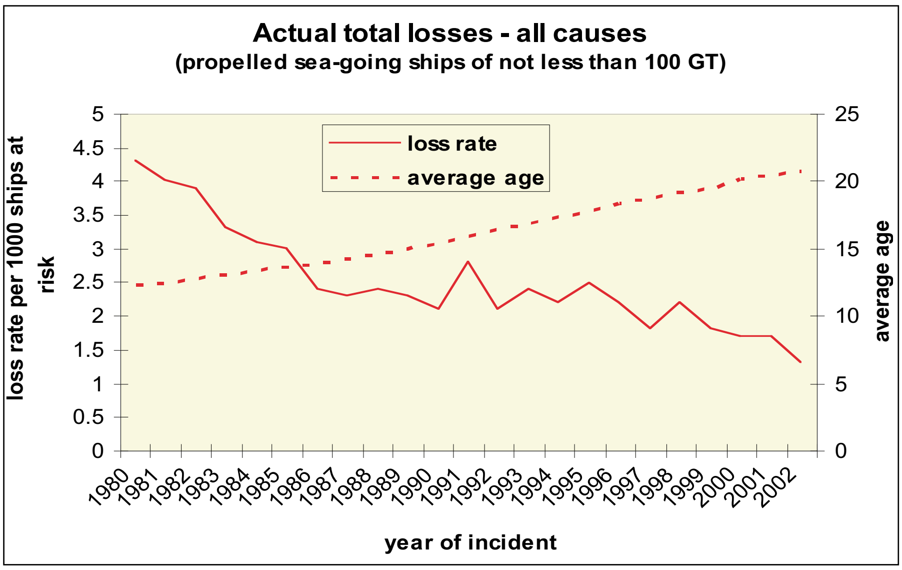
Perceptions of risk

A number of high-profile casualties continue to keep marine risks on the political agenda. However the industry has worked very hard to improve its performance and the outcome is illustrated in Figure 1, below, which clearly shows the reduction of total losses over the period from 1980. This has been achieved against a background of a progressively ageing fleet and is somewhat counterintuitive to the general perception of a direct link between casualties and old ships. One thing is quite certain – the perception at a political level and among the general public is that shipping is still not as safe as it should be.

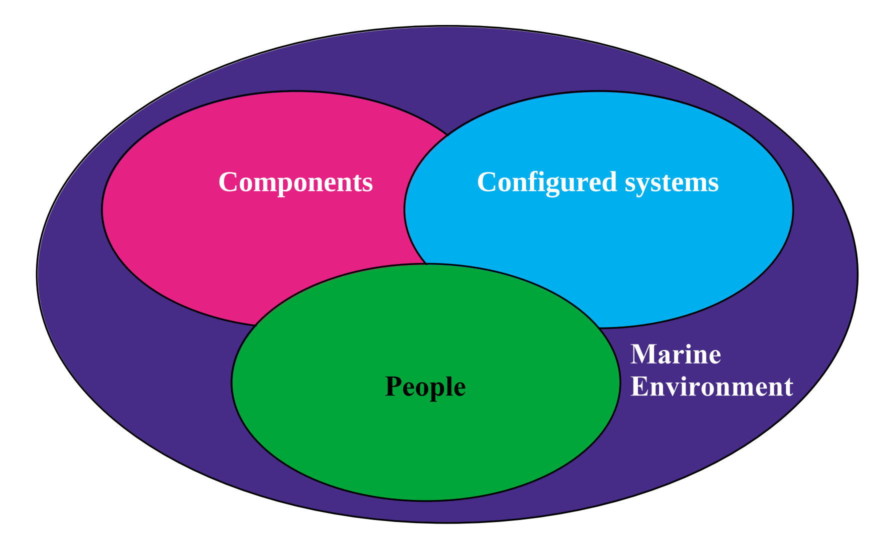
The relationship between perception of risk and the factual evidence present complex issues and frequently result in misunderstandings. It is interesting that some recent studies of the age of sail suggest that the perceived risks from working aloft on sailing warships did not appear to reflect the evidence from the surgeon's records. Injuries and deaths from falling from the rigging were less significant than those from falls from the deck, down ladders and openings and other more routine tasks. So perhaps nothing changes and a large part of the personal injury count has always been due to slips and falls, and not the generally perceived high-risk activities.

Within the marine industry there is also increased concern over business risks, with underwriters indicating high losses associated with cargo loss and damage, machinery breakdown and personal injury. The cost of claims does not replicate the overall improvement in performance indicated in Figure 1.

So although the marine industry has progressively adopted a more formal approach to risk assessment, exemplified by the adoption by IMO of formal safety assessment as the structured way to consider future development of effective and appropriate international marine regulation, and the requirement for risk assessment in the ISM Code, it remains the perceptions of risk that are the dominant drivers of legislation and change. One of the principal perceptions is that the major cause of marine casualties, major and minor, is the human element and the evidence from the investigations of marine casualties supports this perception.



▲ Figure 1: Casualties and fleet age profile 1980-2003



▲ Figure 2: Constituent elements of the total marine system

It is worth noting that a more detailed analysis of the basic factual information from several competent accident investigation reports has shown categorically that further drilling down indicates that opportunities existed for avoiding such incidents during, for instance, design, equipment selection, maintenance and repair. It is concluded that a high proportion of those accidents ascribed to failure of the hardware, not the human element, actually result from the failings of people – but not those who were actually operating the ship at the time. Even so, errors by the crew, pilots and shore staff continue to contribute directly to the majority of accidents in the marine industry.

Total system

However, in this article the principal theme I shall be developing is that in seeking to reduce all sources of human error, consideration has to be given to the total maritime transport system, including the interaction of all of its elements. As illustrated in Figure 2, above, the maritime transport system can be considered to be:

- The ship, made up of individual component parts (and in this context it is not necessary to debate when a component becomes a sub-system or a system) and configured systems;
- People, which includes the crew and the people involved in design, construction, surveillance, survey, management, chartering, loading and unloading and so on;
- The marine environment, which of course includes the sea itself but also other elements that impact on the operation, such as traffic management systems, ports and fairways, other traffic and so on; some of which also include people.

It has to be recognised that the ship at delivery is not the complete system; the people are an essential part of the system. Once complete and working as a system, the effects of the marine environment come into play. To gain further improvements in marine safety and reduce losses requires systems thinking and an integrated approach to risk management.

Regulation and risk control

The UK government has set down some useful principles that constitute good practice in developing legislation for business. With some minor adjustment, these distil down to the following:

- Don't make rules unless the benefits justify the imposed costs.
- Don't make rules unless the smallest company will be able to cope.
- Don't make detailed prescriptive rules when a goal can be defined and industry can decide how to achieve it.

When looking at the classification rules and the international and national regulations that apply to the marine industry, the value of these tenets is clear. In principle, the IMO has taken cognisance of the first element in establishing within the formal safety assessment procedures a cost-benefit trade off, although there remains a need to determine a generally acceptable view of the cost-benefit determinant for such an international and diverse industry. The second tenet has to be given very serious consideration, simply because there are a large number of relatively small companies in the marine industry, suppliers of equipment as well as operators. In small companies there are real problems in maintaining the appropriate specialist skills at the right level across the whole business.

The marine industry is beginning to take greater interest in goal setting, defining what should be achieved and not how it is to be achieved. When considering human factors, the goal setting regime works very effectively provided that there is a clear framework against which assessment can be made to demonstrate compliance.

It is well known that the most effective ways of controlling risks are either to remove, minimise or limit the effect of the hazard itself or to design the system to 'engineer out the risk'. To provide effective risk control measures shipboard systems make extensive use of control systems, which can provide risk mitigation without human action, and alarm systems, which do not provide risk mitigation without human action.

The least effective ways of controlling risks are to rely on administrative controls, such as warning notices. For instance, the marine industry relies on notices advising of barred speed ranges on propulsion systems where an automatic arrangement to prevent operation within a particular speed range could be fitted. The former is cheaper, but can be ignored with disastrous consequences, and the latter certainly restricts operating flexibility in emergencies. Overrides of control functions can, of course, be provided but the proper use of these facilities, as intended by the designer, is often not fully understood. Reliance is also placed on the use of personal protective equipment (PPE) to augment human capabilities, where risks cannot be dealt with by other means. There are still too many incidents where loss of life results from improper use or lack of use of PPE.

Systems and complexity

There has been a notable trend over recent years towards increasingly complex shipboard systems. Modern vessels now rely on a high degree of automation and supervisory control that adds considerably to the complexity of the total installation. The major driver for change has been to achieve greater competitiveness through the potential for reduction in through-life costs. The advance in automation technology and increased use of digital systems in place of traditional hard-wired or pneumatic controls provides an opportunity to reduce both the first cost and operational costs.

The options available to the systems designer have expanded, as the capability of electronic systems has increased, remarkably. This explosion in potential has been quite extraordinary and is evident in terms of a very definite increase in the number of possible solutions. Furthermore, things can now be done that would have been impossible without this technology, such as building an engine that does not require a camshaft, or enhancing overall fuel efficiency on a continuous basis, through a sophisticated power management system.

The possibility of increasing the level of functionality encourages the design and construction of more complex systems that offer the purchaser more options when using the ship. And with the progressive reduction in the cost of programmable devices this increase in capability can be achieved cost-effectively.

The downside of this trend is that the owner is left with a system that may possess unnecessary properties, and the result may well be beyond the understanding of the average, well-trained seafarer. The situation is made more complex by the interconnection of systems, so that the possible interactions and dependencies are no longer as obvious as with older simple systems.

It is a well-established practice that marine systems are designed to tolerate a single failure without presenting a major hazard. In many cases it is possible to configure systems so that failure by the user is reasonably unlikely and can be tolerated in the same way as a mechanical failure – it should not lead immediately to a hazardous condition. Essentially the designer is providing the user with a system that can be used in a manner that will allow more time to react in the event of a failure and therefore improve the probability of correct action being taken. This requires the designer to look at wider definitions of systems rather than the traditional breakdown used in marine engineering. In practice, little consideration is given in this regard and seafarers simply make use of what is provided.

Sea-staff-friendly

It may seem obvious that systems must be useable by seagoing staff of average competence – but this demands more than the systematic conformance of the working environment to ergonomic principles. Unfortunately, there are plentiful examples of modern ships where the background noise, vibration and lighting levels do not provide an ideal working environment for the crew. It is also possible for the basic ergonomic requirements of the installation to be addressed but for the system to become unusable under certain circumstances, notably during abnormal operations and emergencies.

The design of bridges and control rooms should reflect the operating procedures, both routine and emergency, and suit the characteristics, capabilities, experience and training of the crew. As it is, errors can often be traced to a misunderstanding of the information supplied by the machine interface or to an overload of information information or unachievable expectations of crew performance. In short, a badly designed interface or ill-considered allocation of function encourages mistakes that no amount of training or management intervention can completely mitigate.

Ideally, design should include active participation by the people who will actually operate the system (user-centred design) but different crews will inevitably operate the ship during its service lifetime. Nevertheless, user input is extremely valuable and should be sought at appropriate times. It should also influence any standards, codes of practice and rules that are referenced by the designer.

It is, of course, much more straightforward to write a standard for a single, discrete item, defining dimensions, characteristics, materials and interfaces. ‘Systems engineering’ provides an approach that permits the designer to select the best solution while ensuring that the key requirements are satisfied. The more open approach to definition of requirements and explicit trade-offs between design parameters can make it easier to incorporate the human element aspects since it inevitably means taking a non-prescriptive, goal-setting approach.

Improvements in the reliability of equipment and extended intervals between routine overhaul have resulted in a significant change in the demand for ships’ staff. The decrease in maintenance and repair work is consistent with the reduction in crew numbers but it also significantly reduces the exposure of seagoing engineers to the learning experience that is associated with these tasks. In effect, the lack of opportunity to learn from ‘precursor’ events may reduce effectiveness when dealing with a hazard.

The environment that provided the experience for dealing competently with all manner of abnormal situations has been changed by the advances in technology that have increased reliability and reduced maintenance. Familiarity with items of equipment has been reduced by the reduction in routine intervention.

At the same time, the operator is faced with an increased dependence on marine electronics. The electronic systems for automatic control, even of complicated operational patterns, some of which would simply not be possible to achieve using traditional manual controls, and the safety monitoring systems that provide shut downs and alarms are all inherently highly reliable. Despite the warnings of the potential for software errors leading to major disasters, there is very little evidence of these being considered in a rational manner.

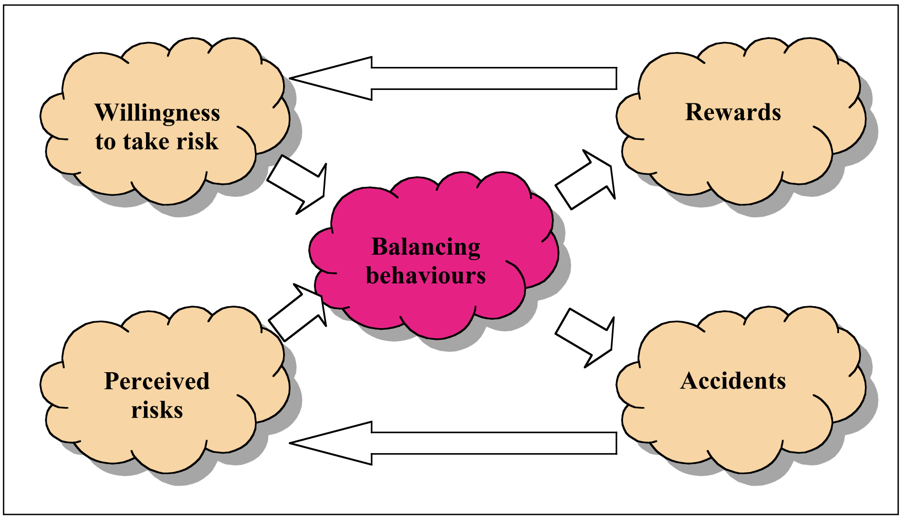
The scale of application of software based systems and the scope of their application became very evident during the ‘millennium bug period’. That made ship operators aware of how many programmable devices were actually present on a modern ship. Although no significant failures were reported, the associated investigation programmes did result in operators questioning the need for many of the less essential software-based systems and using the opportunity to rationalise the inventory. Software system failures generally arise from poor specification, inadequate consideration of the intended use of a system or poor development and testing procedures.

Examples of failures resulting from these errors include software problems with electronic charts and failure of the Panama Canal VTS.

Relying on the systems

Given the reliability of machinery and the commonly held, but perhaps questionable, presumption that the alarm and control systems are, essentially, fault-free, it is not unreasonable that the human operator should be comfortable relying on the systems. To some degree, the roles of the automation and safety systems and the human operator have been reversed. The operation is now controlled automatically with human supervision rather than the control and alarm system assisting the human operator to identify malfunctions at an early stage.

This reliance on the system, with the human relegated to monitoring the progress of the ship can encourage a suspension of the traditional seafaring skills of the crew. Dulling of the response to visual signals, such as observing weather changes from the bridge, or to smells and sounds in an engine room because the user is focused on monitoring information presented to him, represents a danger to safety that is often overlooked.



▲ Figure 3: The risk thermostat

Certainly the improved functionality of all manner of support systems, including navigation, communication, control of main and auxiliary machinery and general monitoring and alarm, has been essential in the reduction of crew numbers. This reduction in numbers of available people has more complex consequences, including crew fatigue. Some maintenance tasks, such as repairing machinery after failure, simply cannot be handled by the number of people available, thereby presenting an additional potential hazard to the ship.

In designing the total ship system it is therefore imperative that the corresponding workloads are considered, including the availability of people to deal with reasonably foreseeable incidents. The ISM Code requires that mitigation measures be put in place for all identified hazards.

As the level of complexity increases, so the human element becomes more deeply embedded among the physical elements. As machinery and equipment are left to operate unattended, the monitoring systems detect warning signals and prod the control systems to take immediate action. The crew member who eventually gets called in to deal with any resulting major problem enters a situation part-way through. Without time to gear up, it is all too easy to misjudge the situation in the confusion and to initiate actions that exacerbate the situation.

Human behaviour

Human behaviour when reacting to risks may be illustrated by the balancing mechanism shown in Figure 3, above. People, and this same argument can be extended to organisations at progressively higher levels, react to their perception of the balance between the risk exposure and the potential reward. In essence, if the reward is greater, there is an increased willingness to take risks.

The awareness of the possible outcome of risks, possibly by knowledge of accidents or by reference to hazard assessments, tempers the willingness to take risks because people develop an understanding of the risk environment, and so build up a perception of the risks involved. The outcome is that people naturally balance the response to risk, and of course there are various controlling influences which include awareness of possible consequences of following a particular approach to a task, the personal value of the potential reward, cultural attitudes and peer pressures.

Awareness and research

Although the human element has featured high on the agenda for many years it is evident that there is little common understanding of what is involved and how the effects can be managed. It has become clear from the research activities of Lloyd's Register that the marine industry would benefit from increased awareness and a shared understanding of human factors considerations. Furthermore, there remains a lack of systematically collected research data to support the perceptions of the impact of people on marine safety.

Lloyd's Register provides funding for a programme of support for education, training and research across the full range of industry sectors that it works in. This is in addition to an extensive programme of activity that directly supports the operations of the Lloyd's Register Group. As part of this programme of funding, Lloyd's Register has committed to provide support to two major initiatives.

First, as all *Seaways* readers know, an international awareness campaign is being carried out by The Nautical Institute. This centres on the publication of the *Alert!* bulletin on a quarterly basis for a three-year period, with an associated website. The campaign, which has the active support of international professional institutions, aims to place topical issues related to the human element before a large number of marine professionals in a format that is aimed at raising the general awareness level across the marine industry. We were all very pleased that the campaign was recognised earlier this year by being selected as winner of the 2004 Seatrade Awards in the category of Innovation in Ship Operations.

Second, Lloyd's Register has funded a research unit within the internationally acclaimed Seafarers' International Research Centre at Cardiff University, initially for a period of five years. The unit will undertake an independent programme which will include investigation of the perception of marine risks and the impact of training and new technology. Their work is expected to inform the marine industry about attitudes towards risks and the effectiveness of risk control measures.

By making available funds in excess of £900,000 to these two initiatives, Lloyd's Register anticipates that the industry will benefit from a better understanding of human element issues through an effective awareness campaign and a programme of thorough social science research.

In conclusion...

Perhaps the title of this paper is a little ambitious. Marine safety depends on many contributory factors. The hardware, the ship and its systems, must be reliable and dependable. Without that safe operation is not possible. Additionally, competent people must be available to operate the ship and that competence extends to the availability of the complete range of skills that are necessary, at the appropriate level and with sufficient capacity. It is no longer possible, if indeed it ever was, to treat systems and the human element as independent facets of ship safety.

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