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The Impact of Safety Requirements on Shipbuilding

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Abstract

The paper begin by examining shipbuilding in the context of competitiveness, specification and cost-effectiveness before considering the impact of safety requirements in the its operations. The basis of the safety case approach is then given, and its application to shipbuilding is illustrated by an example based on the use of staging in ship construction. The key conclusion is that the safety case approach provides the management with a technique for treating potential hazards in shipbuilding so that their risks can be kept within an acceptable level.

1 Introduction

It is often forgotten that approximately two-thirds of the earth's surface is covered by water and shipping plays a very important role in the global transportation system. Indeed, for most countries marine transportation offers the only economic mode of transporting bulk goods from one location to another. In the UK, for example, goods transported by ship represent 95% by volume and 80% by value of imports and exports. Shipping is an international business and success in a given operation depends on a number of factors, including the level of world trade, government, policies, the cost of energy or price of oil, technological developments, the degree of competition faced and possible special circumstances[Kuo, 1922].

Shipbuilders are suppliers to the shipping industry and their performance is directly affected by the current state of shipping. It would therefore be useful to start by identifying the shipbuilder's goal. Possible goals may range from "having the capability to design and build technically advanced ships" to "being profitable in supplying ships to owners". The commercial goal of an effective shipbuilder should be as follows.

To be competitive in meeting the ship operator's specification with solutions that are cost-effective at an acceptable level of safety.

This paper begins with an examination of competitiveness, specification and cost-effectiveness in shipbuilding before considering the impact of safety requirements on how the goal is to be satisfied.

2 Meeting the Shipbuilder's Goal

To understand the goal of shipbuilders and to contribute to ways of meeting it, requires an appreciation of the terms "competitive", "specification","cost-effective" and "acceptable level of safety".

It would therefore be useful to give brief consideration to the first three features, while the fourth one forms the central theme of this paper.

2.1 Competitive

It is the client, i.e. the shipowner or operator, who defines this term. Competitiveness must be related to the needs being met by his operations, e.g.,generating the desired level of profit and meeting the quality requirement. Competitiveness depends on timing and is the shipbuilder's response to the presence of other suppliers with alternative ship design. However, competition for the ship operator can also take on non-marine forms. Ro-Ro passenger ferry operations across the English Channel, for example, are now facing competition from both airlines and the Channel Tunnel. The competitive shipbuilder is therefore one who knows the marine market, is efficient in the management of the various shipbuilding functions and has the necessary financial and human resources. It must be recognized that all four of these factors have to be developed in a balanced manner.

2.2 Specification

The owner or operator will require a given ship to do a specific task and the specification provides information on the type of to be built, the methods to be adopted, the quality standards to be met and the materials to be used. The ship production process is based on this and has to adhere closely to the work programme to ensure all the requirements and deadlines are met. Typical items in a specification include the following: cargo to be transported, speed, price and principal dimensions.

2.3 Cost-effective

The requirement for cost-effectiveness is primarily concerned with value for money and embraces both capital and operational cost. It must also incorporate the customer's expectation which can be difficult to define scientifically and assurately, forcing the shipbuilder to rely extensively on his own experience, Time-value of money also needs to be given attention as the future value of the sum involved needs to be balanced against alternative ways of generating the return.

3 Acceptable Level of Safety

Safety is a term which has a very wide range of interpretations. They vary from "freedom from danger"[Concise Oxford Dictionary, 1982 ed.], to the financier's definition of "not losing money". Practising engineers tend to regard safety as most closely associated with adherence to rules and regulations, while those responsible for any type of operation tend to relate safety to operational procedures. Researchers and academics are likely to consider safety in the context of reliability and risk analysis studies aimed at obtaining estimates of the probability of accidents occurring. All these features are part of safety, and a comprehensive definition is given as follows[Kuo, 1990]:

> *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 the environment.*

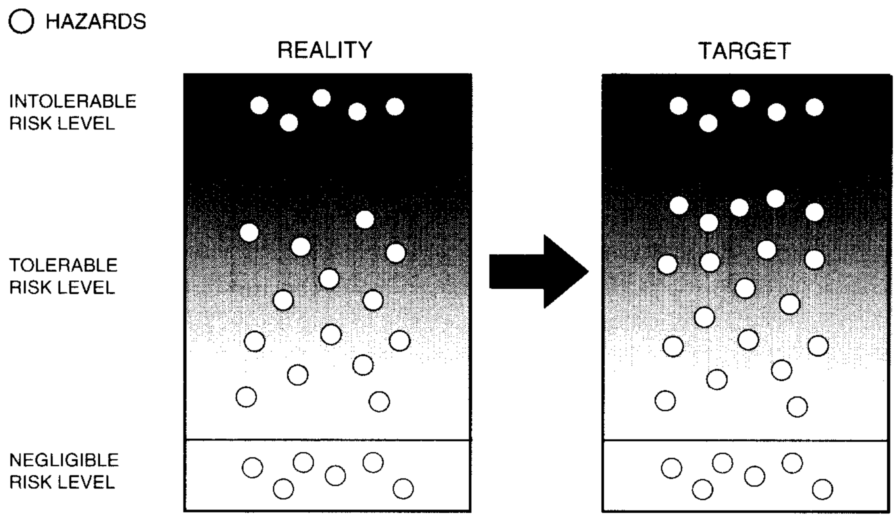

Figure 1.

There are two importment points to note here. Firstly, safety is governed by three factors each of which makes a different contribution in different circumstances. Secondly, it would be impractical to seek to achieve absolute safety in performing a task or activity, and shipbuilding is no exception here. There will always be potential hazards in shipbuilding and those responsible for engineering functions, management and practical operation have to ensure that these hazards are not intolerable but in one of the acceptable regions where the risk levels are either tolerable or negligible, see Figure 1. The precise location of a given hazard will be determined by assessing whether it is cost-effective to reduce the risk level,using the ALARP principle(As Low As Reasonably Practicable), see[4]. A good illustration of this is the selection of the "best" staging method for the outfitting phase of a ship from a list of alternatives, based on individual cost considerations alongside whether the risk level involved in its use is suitably located in the tolerable or negligible region.

4 Safety in Shipbuilding

Traditionally, safety in shipbuilding has been based on the philosophy that safety requirements are met by applying the statutory rules and regulations devised by the appropriate authorities of the country concerned. For example, organizations in the UK refer to the Health and Safety Work Acts for the minimum safety standards required in manufacturing processes. This method is often referred to as the "prescriptive approach". It can be applied, with appropriate rules, to every phase of the shipbuilding process as highlighted here.

Concept generation phase : The ideas and concepts for a new ship are generated, taking relevant safety regulations into consideration, e.g., the stability rules applicable to the design.

Preliminary Design phase : The preferred concept(s) will be further developed using more accurate calculation methods and additional data, and safety regulations governing the design will be adopted from the one of the statutory authorities and/or classification societies.

Detailed design phase : Once the go-ahead is given with the signing of the contract, a detailed design will be produced with safety regulations being closely followed. For example, the design of a high speed craft would be based on the Safety Code for High Speed Craft, [IMO, 1994].

Procurement phase : Materials and equipment are ordered after the detailed design is completed, and although safety is not explicitly mentioned here all the quality standards adopted will take safety features into account.

Construction phase : In recent years the introduction of safety regulations into the construction phase has focused attention on safety requirements. These cover every aspect from the wearing of safety helmets and protective clothing through welding fume levels to how assembled units are lifted from building halls to docks and berths.

Commissioning phase : In this phase a full check is made to ensure that contractual conditions have been met before the ship is handed over to the ship owner or operator. One further phase, the ship repair phase, can be added to the above process where a shipyard has facilities for doing repairs.

The advantages of the prescriptive method are that it provides a reference standard, is a straightforward concept and experience is incorporated in the regulations. Its main drawbacks are that responsibility for safety is not devolved to the shipyard, only minimum standards need to be met; regulations are strongly influenced by previous accidents, are slow to catch up with new developments and tend to inhibit innovative solutions.

It is believed that the regulatory approach can cope with the majority of circumstances in shipbuilding and ship repair, but there is scope for the ship builder to consider an additional approach to examining safety when seeking alternative or novel solutions. As can be seen, to ensure a high standard of safety and be cost-effective it is essential to introduce safety features at the early stages of the shipbuilding life-cycle.

5 Basic of the Safety Case Approach

The safety case approach is based on the belief that the safety of a system should be the responsibility of those directly controlling it, and it is they who have to demonstrate to the appropriate authorities that the activities of a project are entirely satisfactory.

The approach was initially developed for application to onshore installations in the UK after a major accident at a chemical installation in 1974. It was introduced to UK offshore operations in 1993 on the recommendation of the Cullen Report[6] on the Paper Alpha disaster in 1988 which had cost 167 lives. Essentially, the operator of an offshore installation has to prepare a safety case which provides, for example, a description of the installation, the operating environment, the potential hazards and how they will be managed. The attractiveness of the approach is that the principles can be used for examining the safety of any activity.

The key elements of the approach are :

(a) Hazard identification : Appropriate techniques are used to identify the main potential hazards in an activity or project, e.g., the shipbuilding process.

(b) Risk assessment and reduction : The risk level of the identificated hazards will be assessed so as to place each in the appropriate risk region and in the case of these with intolerable risk levels, methods need to be adopted to reduce their risk levels.

(c) Emergency preparedness : Even the most carefully considered solution may not guarantee total success and so methods of escape, evacuation and rescue from disaster areas must also be provided.

(d) Safety Management System(SMS) : In practice the above three elements can only be successfully implemented with the aid of an SMS, which should be similar to the organization's management system but with the goal of improving safety.

The connections between the various elements are best illustrated in Figure 2, which also shows the five components of the Safety Management System. The key merits of the safety case approach in relation to shipbuilding can summarized as follows:

- Since safety involves not only engineering issues but also management and operations, it is the shipbuilder who must set safety goals for the shipbuilding process.
- The shipbuilder has a strong incentive to deal positively with safety so as to help achieve improved performance and cost effectiveness.

It has to be recognized that the functioning of a shipyard is quite different from the operation of a ship. However , the principles of the safety case approach will assist the shipbuilder to tackle certain problems by novel methods which can both be cost-effective and have good safety features.

6 An Illustrative Practical Example

This example, selected to illustrate the use of the safety case in shipbuilding, is concerned with staging. The driving force is the demand for improved efficiency in ship production, which in turn calls for assessment of every aspect of the ship construction process. Staging is identified as having a critical role in achieving cost-effective production. It is obvious, however, that providing for the safety of the work force plays a balancing role in this cost equation. Hence the choice of staging as the illustrative example, and the following aspects of the safety case concept are now considered.

6.1 Hazard Identification

Using technique such as "What If?" and "HAZOP", see for example [Kletz, 1992], and one's practical experience of shipbuilding it is possible to identify a number of potential hazards in the use of staging which could lead to injuries to personnel, some of which could even be fatal.

The principal hazards include:

H1 : Failure of a structural member in the staging arrangement.

H2 : Excessive movement of staging due to strong wind-loads.

H3 : Wet supporting planks which are liable to be slippery underfoot.

H4 : Failure of a component at a joint between structural members.

H5 : Dropping of materials from work being carried out from the staging.

H6 : The base of the staging is unstable.

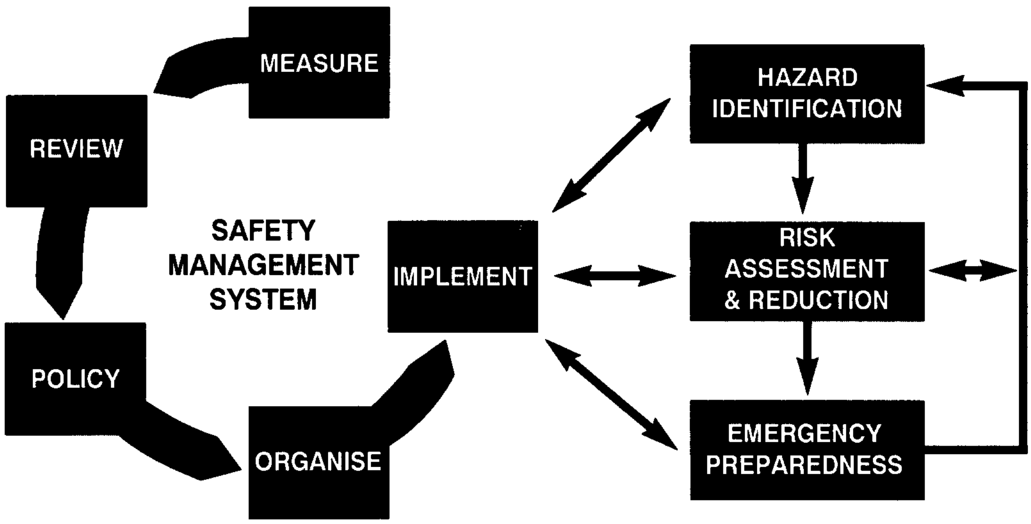

Figure 2.

H7 : Impact between staging and moving vehicles.

H8 : Units accidentally falling on the staging.

6.2 Risk Assessment and Reduction

The risk(R) of each potential hazard can be determined by estimating the probability of occurance(P) and the consequence(C), i.e., R = P x C. Probability can be estimated from a combination of published data, Fault Tree Analysis techniques, see for example [Aldwinkle et al., 1984], and practical experience. The consequence of a potential hazard can be assigned in the first instance by using a severity index. Its risk level can then be found in one of the three regions shown in Figure 1. Table 1 summarizes the output of this example.

It will be noted that risk reduction can be achieved by means of management action as well as by engineering and operational decisions. Since hazards H3 and H5 have been classed as "intolerable" the following combined actions can be applied to reduce their risk levels:

H3(Slippery Surface Underfoot) : Management sets limiting conditions for working on staging; use of high-friction material for the supporting planks; workers to wear special shoes with low-slip factor; workers to use some form of safety harness while on the job.

H5 (Materials Being Dropped) : Use of nets to catch the dropped materials (and, of course, anyone failing); adopting a policy of reducing the number of people working under staging when hazardous work is being carried out above; removal of flammable material from the dropping area when burning work is being done overhead; anchoring all working equipment being used on staging; ensuring the safe handing and speedy removal of redundant materials and equipment from platforms.

The suggested modes of action in each case would make it possible to reduce the probability of occurrence of 0.4 for H3 and 0.25 for H5 to lower and more acceptable values.

Table 1.

Hazard Ref.	Brief Description	P (Prob.)	C (Conseq.)	R (Risk)	Risk Level
H1	Structural member fails	0.01	0.4	0.004	T
H2	Excessive movement	0.10	0.1	0.010	T
H3	Slippery underfoot	0.40	0.2	0.080	In
H4	Joint fails	0.01	0.4	0.004	T
H5	Materials being dropped	0.25	0.2	0.050	In
H6	Base unstable	0.07	0.4	0.028	T
H7	Impact with vehicle	0.05	0.4	0.002	N
H8	Falling units	0.02	0.3	0.006	N

Severity Index :	0.0-0.1	Minor	0.5-0.7	Very Serious	**Risk Level:**	In(Intolerable)
	0.1-0.2	Important	0.7-0.9	Unacceptable		T(Tolerable)
	0.2-0.5	Serious				N(Negligible)

6.3 Emergency Preparedness

In the event of an accident occurring, an agreed plan of action has to be implemented. This will vary from shipyard to shipyard but will include, for example, the presence of rescue services, information on the location of the nearest hospital, routes to be followed, and communication methods.

6.4 Safety Management System(SMS)

The previous three stages will not be implemented in a systematic way unless the management puts in place a Safety Management System. The features of an SMS are summarized as follows:

- Policy : The organization has to set up policies to guide the performance of the staff, and goals for safety in ship construction should be embedded in these policies, because the management is responsible for safety. The policies should incorporate generating a culture that enables all personnel to have a strong commitment to their work and the control of risk levels; creating an atmosphere that encourages discussion of safety issues; supporting positive initiatives.

- Organize : Allocating responsibility for safety matters to staff-members, e.g., for staging; ensuring that individual works recognize accountability for their own aspect of safety responsibility; devising effective communication mechanisms; allocating adequate resources for safety training; giving attention to industrial standards. Parallel systems for monitoring safety.

- Implement : Ensuring that hazards associated with staging are identified, risks assessed and reduced as appropriate and that emergency plans are in place, i.e., that the previous three elements have been properly implemented.

- Measure : Devising criteria to measure performance standards; monitoring high-risk tasks, such as work on staging; recording near-misses; having a system for reporting incidents and accidents.
- Review : Performing audits; examining all aspects of SMS activities; reviewing performance to identify and take appropriate action to remedy deficiencies; developing "benchmarks" for comparison with other companies; in the present case, taking appropriate action on the staging.

It has to be recognized that many of the aspects considered are related to what are known as human factors, which deal with the interface between human capabilities and characteristics with various features of the system, e.g., hardware and software. Generally it is human error which receives attention, and examples include slips, loss of concentration and poor judgment. A matter of greater concern, however, is the violation of rules for safe working practice, and a typical example of this would be the use of inadequate protective clothing when regulations demand such safeguards. The latter problem can only be overcome by changing attitudes and developing a positive safety culture.

7 Discussion

On the basis of the issues examined it would be useful to consider the following four aspects:

7.1 Contributing to the Shipbuilder's Competitiveness

The safety case approach can contribute to competitiveness in two ways. Firstly, it can help management to focus on potential hazards in a positive way, and not on technological hazards alone, but also on such activities as the introduction of high-cost new equipment. Secondly, applying this approach to a given situation may lead to improvements in the present regulations for dealing with it and thereby to greater over-all cost-effectiveness.

7.2 Human Factors and Safety Culture

It has been found that 60% of ship accidents leading to insurance claims are caused directly by human actions[P&I Club, 1992] and the majority have been attributed to human error. However, it is important to recognize that many accidents are also caused by violations of rules for safe working practice. A typical marine example would be a worker's entering a hold to do a welding job without checking for the presence of toxic gas. Reduction in such violations can only be achieved by changing organizational attitudes and culture. The development of a safety culture within a shipyard is an extremely important factor in raising the standard of safety. For further discussion on the role human factors in marine safety, see [Kuo, 1993], [Reason, 1994].

7.3 Change in Attitude

With the prescriptive approach, shipbuilders tend to accept regulations as being both correct and unalterable. There are, however, occasions when safety regulations can adversely affect production times without necessarily achieving better safety standards and in such cases it would be helpful for the shipbuilder to query the regulations of interest and propose alternative and better solutions. Developing such an attitude has, of course, educational implications and resources need to be made available for educating staff accordingly.

7.4 Cost of Safety

There is a belief that increased safety will *always* mean higher cost. This incorrect and there is a need quantify more imaginatively the benefits derived from improved safety. For example, one shipyard has been able to reduce staging costs by 50% through giving attention to the safety of working practices and cutting down on human errors and violations.

8 Conclusions

The main conclusions derived from this study are:

1. The adoption of the safety case concept can help management to concentrate its safety effort and resources on critical shipyard activities with potential hazards having intolerable risk levels.
2. Selective application of the safety case concept in conjunction with prescriptive rules and regulations will help the shipbuilder to meet his goal.
3. The demand for high productivity in shipyards while maintaining high safety standards can be met when management considers safety requirements in the early stages of the shipbuilding "life cycle".

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