Interferry, Dubai. October 2012

Goal / Risk Based Design – Benefits and Challenges

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Summary

The term goal or risk based design is increasingly being used within the Marine industry. Such an approach has been used in other industries for many years. The Marine industry's regulation, be it Classification, Statutory, national or industry body has been almost wholly prescriptive, which works well in many regards. There are some draw backs with a wholly prescriptive approach however, for instance, it does not enable innovation and the size of safety margin are typically not fully understood. As the Marine industry is driven by further regulation and efficiency, designs have to be maximised, which typically means moving from a wholly prescriptive approach as more complex technology and modelling is used. As with any other approach there are many potential benefits to goal or risk based design. There are, of course, also many challenges in realising these benefits and some pitfalls to be aware of. This paper looks at what goal / risk based design is, the benefits of such an approach, the challenges that the industry will have to manage in achieving these benefits, and the pitfalls of such an approach.

1. Background

The Marine industry has developed a global regulatory system which is relatively easy to apply and is cost effective. The global nature of the industry has, by necessity, driven the relative simplicity of application. The desire for cost effectiveness and the ease of contracting against standards for build has also helped develop a robust system of prescriptive rules. For vessels which are standard and where there is high confidence that the prescriptive regime achieves a good level of safety, there is little reason to change from a wholly prescriptive approach.

The marine industry is now entering a period with increasing regulatory demands, particularly for increased environmental performance, and the desire to increase the cost effectiveness of ship operation. Ten years ago the majority of the international regulatory regime was prescriptive. Having only a prescriptive regime does not, however, facilitate design innovation. The concept of Alternative Design and Arrangements (AD&A) was introduced into SOLAS chp II.2 some time ago. More recently AD&A was broadened to include Chp II.1 & III. The fundamental requirement of AD&A is to demonstrate equivalence with the objectives of the chapter. This gives scope for innovation in design. More recently Goal Based rules are appearing within the IMO, and are the subject of much discussion. IMO's goal based rules are described as 'Rules for Rules' (ref 1). The application of Goal based rules within the IMO is changing, having started out with the objective of ensuring that the Classification Societies where achieving certain goals, or standards. The application to day is moving to mirror the objective of Goal based standards in other industries.

There is a clear need within the Marine industry to day to allow design innovation, whilst at the same time also providing for a fully prescriptive route of rule compliance. This applies to all those involved in regulation, be it Statutory regulation from Flag States, Classification Societies or other industry bodies.

A question often asked of prescriptive rules, be they statutory or Classification Rules is 'what are the objectives and limitations of the rules'? It is very good question. In developing a response to this question and, an understanding of the goal / risk based concept, Ship Classification Rules will be wholly considered.

2. The Evolution of Classification Rules

Lloyd's Registers rules started out 252 years ago, when the marine industry and industrial society was in quite a different position to that of today. Designs were relatively simple, and ships were essentially hand built from wood. There was no detailed understanding of the loading that a ship's structure might experience, the ship was simply built 'stronger' until a standard appeared that historically ensured the vessel withstood the loading it was exposed to. This is how class rules were developed at the time, from experience and what worked. The benefit of course was the maintenance and development of such rules by an independent 3rd party (the Class Society), and their involvement in ensuring the ship maintained, through life, the as built structural strength. Originally Classification Rules also recognised how important the Masters seamanship capabilities were to the safe operation of the ship. A lot has changed over 252 years. Rules were typically driven by the

- Need for something relatively simple and straight forward to follow.
- Engineers being typically cautious by nature, with limited ability to model the stresses that a vessel actually experiences.
- The experience available at the time.

This approach has resulted in considerable safety margin or 'fat', appearing in prescriptive Class Rules. Statutory rules, such as SOLAS and MARPOL were wholly driven by incidents, the loss of the Titanic being the instigator of the SOLAS convention, for instance. The majority of statutory requirements have been and still are, prescriptive.

3. The Challenges of Today

Increased statutory regulation continues to flow down from the IMO, through Flag States. An example of this is Safe Return to Port (SRtP). Currently the weight of new statutory regulation is driven by environmental concerns, Ballast Water Management, and Energy Efficiency Design Index (EEDI) being two examples. The SRtP regulation is in response to the concern over the increase in size of ships carrying passengers, and the ability to effectively evacuate thousands of people. The fundamental requirement of SRtP is to ensure that the ship can act as its own life boat, up to certain casualty states. SRtP is a form of goal based regulation, in as much as it has a very clearly stated objective, which is the fundamental requirement which has to be met. The objective of EEDI is to reduce environmental pollution, with CO2 being the principal focus. EEDI will create a focus in a number of areas, including making structures lighter and more streamline.

Cost reduction is another clear focus the industry has today. The current economic down turn and escalating operational costs is forcing companies to optimise design and embrace new, novel and complex technologies.

There is then a growing need within the industry to facilitate innovation within the regulatory structure, as well as provide a purely prescriptive regulatory regime.

4. What is a Goal / Risk Based Standard?

This question is a frequently asked. An example of each is given below. An example prescriptive standard is:

All motor vehicle exhausts are to be fitted with a filtration unit of 120 mesh size or less

The prescriptive standard specifies the technical measure to be used, the requirement is very clear. Behind this requirement is concern over the environmental or safety impacts as a result of particulate release. Compliance with this standard is easily checked, is the filter unit fitted or not? However there is nothing within this standard to ensure that the filter is actually effective in what it was developed to achieve, hence it may not be task or cost effective.

There clearly may be many other ways of achieving the objective which is reducing the environmental or safety impact of particulates. The problem is that the objective, or goal is not defined, and hence there is no scope for innovation, people simply have to fit the cloth filtration unit. There is also no ownership of the problem by the car manufacturer, since he simply has to comply by fitting the filtration unit required.

An example goal based standard is:

The level of particulates emitted from a motor vehicle engine should not exceed 1 ppm

The goal based standard defines what the goal is that has to be achieved. This is the fundamental requirement which must be achieved. A manufacturer may use any solution in achieving the goal, it provides maximum scope for innovation. Compliance with the goal is easily achieved by air sampling. There is however a very different responsibility placed on the manufacturer. The manufacturer has to understand and 'own' the goal, and just as importantly, demonstration is required to the regulator that the goal has been achieved.

It can be seen from the above two examples that a purely prescriptive route promotes and re-enforces a compliance culture. A goal based route requires engagement with the objective, and an active demonstration that the goal has been met. Figure 1 illustrates the required shift in culture when moving from a purely prescriptive approach to that of goal based regulation.

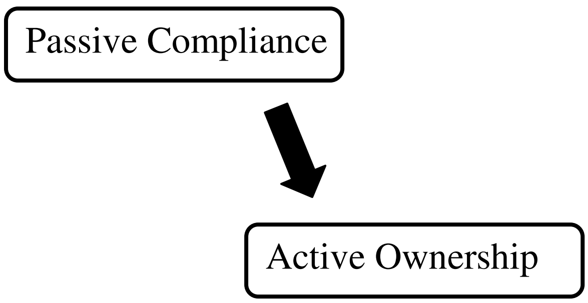

Figure 1. Change of culture required

A further question that is also often asked, or assumed, is that the style of regulatory regime has to be either prescriptive or goal based. The actual answer is surprising to many people, a goal based regime builds on a prescriptive regime. A simple example is that of over pressure protection. Long ago industrial society realised that it was very sensible to provide over pressure protection against pressure vessels incidents. Today a typical prescriptive standard requires the provision of two pressure relief devices, set at somewhere between 105 – 120% over pressure. A goal based regime would build on, rather than replace this fundamental experience gained from many pressure vessel explosions.

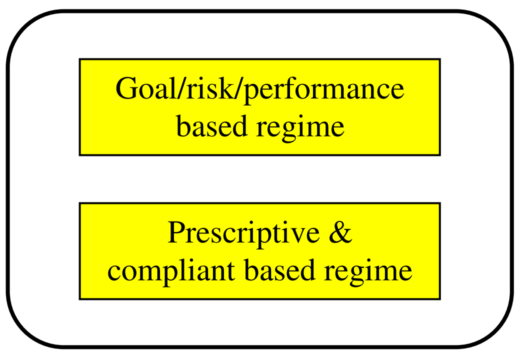

Figure 2. Complimentary prescriptive & goal based regime

5. Classification Rules and Standards

At this point it is very useful to understand what prescriptive Classification Rules and standards actually manage. Let us develop the theme of pressure relief devices further. Pressure relief devices mitigate the likelihood of an over pressure excursion. However, there are some assumptions or facts about which we need to remind ourselves. The relief valves could still fail, but the probability of a pressure vessel failing has been reduced considerably by the use of pressure relief valves.

Now, imagine two factory sites involving an identical chemical process, with very hazardous pressurized liquids passing through three large pressure vessels.

The first site has been in the same place for many decades, and a town has grown up around it. The three large pressure vessels are sited against the factory boundary wall. The factory wall is adjacent to a main street in the town, with a bus stop outside the factory wall. There is a school not far from the factory, and many tens of children use this bus stop each day to get to and from school.

The second site is a new site which has been built out of town. It has the same process plant with the same three pressure vessels placed adjacent to the factory boundary wall. There is a field of wheat next to the factory boundary wall.

Failure of the over protection system and the resulting energy release of the boiler exploding, while having the same incident initiators, will have a totally different final consequence – damage to a field of wheat in one case, but potential multiple fatalities in the other.

Typically prescriptive rules and standards manage ***known hazards***, not consequences, or unknown hazards. This is often misunderstood, but is fundamental in understanding the limitations of prescriptive rules in design optimization.

As has been said before, prescription is highly valued in the marine industry and provides a simple, cost effective and safe approach to vessel build where the ship is standard and well understood.

6. Meeting the Challenges of Today

Today's challenges of increased performance are driven by regulation or operational effectiveness. Design optimisation is how these challenges are being met, this may also involve new, novel or complex technology. When optimising a design, generally the optimisation involves the identification and removal of excessive safety margin, or 'fat'. To achieve optimisation effectively it is hence fundamental that the goal that you are trying to achieve is understood, and is expressed in a clear way, which will need to include clear goals for safety and the environment. These currently do not exist in prescriptive rules, as illustrated in section 4.

Typically optimised designs, particularly those that involve new, novel or complex technologies, will have higher capital asset values than the non optimised equivalent. As asset values increase, so clearly do stakeholder expectations, in terms of reaping the performance rewards of the optimised investment, but also ensuring the safety and environmental performance of such assets. Meeting these expectations will only be achieved by a culture that takes active ownership in managing the risks involved in design and operation of the asset, which is very different to a culture of passive compliance.

7. Level and Style of Goals.

The objectives or goals of regulation can be specified in a number of ways. The goals can be specified in the style of performance standards. The industry is use to performance standards, for instance maintaining a certain speed, or turning circle. Goals could also be specified in strict risk terms, which are typically expressed as a fatality frequency per year. There are in fact many ways a goal could be set. There are also many levels at which a goal could be set, in this regard there are no rules, simply what works.

If we develop the example of section 4, the car exhaust further. The goal based standard of 15ppm particulates emitted from the vehicle, could be considered to be set at the 1st system level, the engine. Discussion could be had around whether the limit of 15ppm is the engine exhaust or all emissions from the car. So tyre wear, clutch plate loss and so on could be considered within this 15ppm. It is evident from this that whilst the examples given appear simple, and were meant to be, goal based regulation soon becomes quite complex, and requires a great deal of development in establishing clear goals. Developing this simple example further to the next level may involve looking at several systems. The goal could be set to consider all emissions from the car, that is particulates, gasses, fluids, heat, noise etc. There are a number of ways such a goal could be specified, from a performance perspective, noise should not be beyond 90db, particulates 15 ppm and so on. However such performance criterion does not address overtly the implied objective of the concern which is impact on human health and the environment. If we then think of the total potential impact of the car on human health and the environment, not only from emissions, but all interactions, such as collisions, we might specify the goal in strict risk terms, such as a probability of death or injury.

We then have a tiered approach to managing safety. This might start with a prescriptive standard, the cloth filtration unit. Goal based standards are then set at increasingly higher system levels within the car, ultimately specifying the cars safety and environmental performance in risk terms.

The 1st level goal illustrated of 15ppm is relatively easily understood, and from a regulators perspective it is quite easy for the car manufacturer to demonstrate that the standard is being met. As the level of goal increases, ultimately to the car level, demonstrating that the goal has been achieved can be a fairly tough challenge. Such a demonstration will include assumptions, modelling, data and so on. Ultimately the regulator needs to be convinced that the goals have been achieved. In this regard ***confidence*** is the key item, since the regulator needs to have sufficient confidence that the work undertaken and presented, demonstrates that the goal has been achieved. Confidence that prescriptive regulation has been met is generally without question, since it is very easy to check. Whether the prescriptive regulations have really delivered what is required, is, as we have seen, a different issue.

If this is thought of from a ship perspective, there are many challenging aspects to a goal or risk based approach. Consider a passenger ship. The SRtP requirements have been introduced, to reflect the concern over the ability to effectively evacuate a large passenger ship, up to certain casualty states. When moving beyond such a casualty state, when the ship has to be abandoned, evacuation modelling software might be used to optimise the vessel layout and demonstrate that a goal has been achieved. Some fundamental questions that need to be asked are:

- What confidence is there in the data – has the software be validated?
- What modelling assumptions have been made? Is there confidence in the data being used, e.g. do humans actually behave as the model assumes?
- Will the vessel motion be as assumed in the model?

One view expressed is that modelling is much better than using a prescriptive standard which is based on vessel sizes / passenger numbers very different to those being built today. This is a valid view, however, when optimising the design we have to remember that we are generally removing excess safety margin. The fundamental questions that must be asked are

- What is the actual safety goal that is to be achieved, and
- Is there sufficient confidence in the modelling which demonstrates the goal has been met?

It can be seen that there is considerable potential benefit in optimising designs by the use of goal or risk based regulation. There is a significant amount of effort required to realise the benefits of such an approach. Companies pursuing this route have to invest the time and money up front to realise the through life benefits. Not investing the time and effort will only result in increased expenditure without realising the benefits. Occasionally the technologies may be inherently more hazardous, for instance LNG as a marine fuel. There is very good experience with the safe handling of bulk LNG in the marine industry. Whilst there is a clear environmental benefit to LNG, the cryogenic and gas hazards of LNG are quite different to heavy fuel oil or marine diesel oil. If the up front work is not put in to realising the benefits of LNG, the implications of getting the design wrong could be quite disastrous for both safety and business.

8. Challenges and Pitfalls of Goal / Risk Based Regulation.

To recap the benefits of goal / risk based regulation are the ability to develop an optimised design, with through life regulatory and performance benefits.

The Challenges of realising the benefits however are numerous and include:

1. Setting the goals at the right levels. The higher the level the more complex it is to effectively demonstrate they have been achieved.

2. Providing confidence to the regulators is a much more onerous task than using prescriptive regulation.

3. There is significant cost and effort involved in realising the through life benefits. Giving the regulators the required level of confidence involves cost and effort expended during the design, ahead of realising any through life benefits.

4. The organisation has to move from one that is operating in passive compliance in meeting prescriptive rules, to one that is embracing active ownership in demonstrating that the goals are being met.

So far the subject of attention within this paper has been design. In realising the benefits of optimisation using goal or risk based design, there are a number of further pitfalls that the reader needs to be aware of. Modelling validation and the data used has already been mentioned. In industries such as the nuclear industry there is significant investment in validating modelling software. The unwanted consequences of getting the design wrong cannot be tolerated. As vessel size, complexity and design optimisation increase, the asset value also increases. When passenger vessels are considered, there is only one scale effect which is happening in the industry, which is the ships are getting larger and hence carry more people. The marine industry is not use to the degree of modelling validation that is undertaken in other industries, and yet the potential safety and business implications of increasingly larger and more expensive vessels is huge. The largest cruise ships today have a capacity of approximately 7,500 people. The robustness of modelling validation, data used and so on needs to reflect the potential scale of consequences.

There are then two aspects related to the real life proving of the design, often referred to as the commissioning process. The design optimisation process has developed a system design that should have certain functionality. This functionality has to be proved through commissioning. That is actual testing of the systems, to ensure operation is as expected in both normal and abnormal modes. This provides further confirmation to all involved that the design process has evolved the anticipated system functionality. Just as importantly, is that commissioning proves that the as built condition is the same as the designed condition. It would not be the first time a vessel has not been built in accordance with the plans!

The final pitfall is maintaining the vessel, through life, as it was designed and built. Ensuring the hardware is maintained in the same state through life should be relatively straight forward, and is when prescriptive rules have been used. However, there is a high degree of rigour required in managing design changes, to ensure the original optimised design intent is not lost or misunderstood. The challenge comes from having sufficient understanding of the rational used when optimising the design, a number of years after it has been in service, or for instance, after it has been sold. Documentation in such cases, along with the required safety culture, is the key. A more subtly issue is the change in any assumed human interactions. For instance a certain level of crew competence or capability, or manning level may be assumed. If that assumed level of competence or manning changes, the implications for the design, before the change takes place, have to be recognised and actions taken accordingly. This is notoriously difficult in industries, which are typically regulated on a national level, where one regulator has responsibility for all aspects of an industrial activity. The marine industry has several additional challenges, the regulation of a global industry, and the division of various aspects of responsibility to different organisations.

9. Future Classification Rule Developments

Historically Lloyd's Register has always addressed novelty of design on a case by case basis. It has been recognised that the volume of new, novel & complex design and the desire for design optimisation, (which typically involves the removal of excess safety margin, 'fat'), has changed significantly over the last 20 or so years. The degree of rigor and structure required to support the level of optimisation through the use of new, novel and complex technologies today has to be quite different to that of 20 years ago.

What gives ***confidence*** to enable Lloyd's Register to independently classify a vessel is that the objectives of the rules are met. This means that:

- The goals of Classification Rules need to be specified
- Rule structure needs to be developed, currently only the detail of the rule is specified.

A fundamental question was placed before both of Lloyd's Registers Technical Committees (TC) in 2011. [Lloyd's Register have 2 Technical Committees, one for the merchant marine, the full TC and one for navys, the Naval TC. Both TC's are made up from operators, builders, equipment suppliers, academia and regulators. The role of TC members is to independently question and endorse proposed rule amendments or new rule proposals and generally to provide independent direction to the Classification Rules of Lloyd's Register.] The question posed was, should Lloyd's Register allow a more consistent approach to new, novel and complex design, allowing design innovation and optimisation. The response from both committees was very clear:

- New and revised rules need to allow for new, novel and complex technologies and to facilitate innovation and design optimisation in a consistent manner.
- The rules however must also allow for an approach which also incorporates prescriptive rules, where this is appropriate.

Figure 3 outlines the structure that is now being used within Lloyd's Register when new rules are being developed.

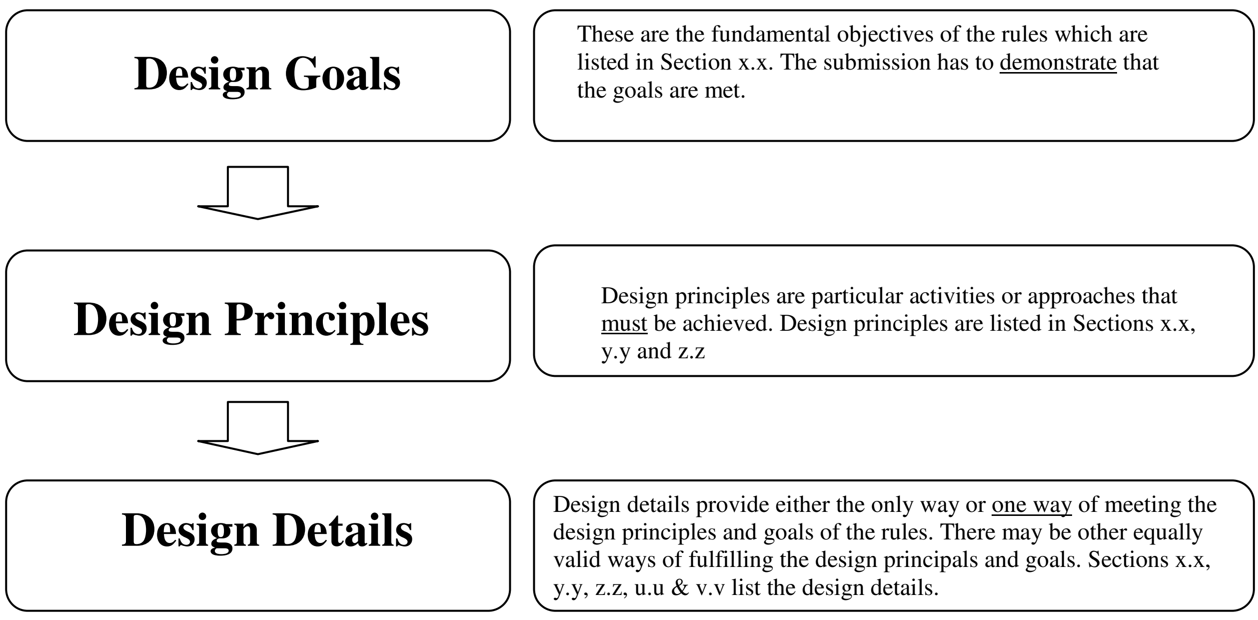

Figure 3. Outline Structure of New Rule Development

The approach outlined in Figure 3 meets several objectives. To allow for innovation and clarity of what Classification Rules must achieve, the Design Goal is specified at the appropriate levels. In meeting that goal there may well be some fundamental activities or requirements that have to be met, these are referred to as Design Principles. The Design Goals and Principles are the fundamental requirements that have to be met. The Design Details are traditional prescriptive Classification Rules, which automatically ensure the Design Goals and Principles are met. The Design Details are *one* way of ensuring that the Design Goals and Principles are met, they are not the *only* way the Design Goals and Principles can be met.

If a design is straight forward, and involves no innovation or optimisation, then the Design Details can be used in isolation. This ensures the most cost effective and straight forward solution for designers and builders using Classification Rules. If a design is to be optimised, or innovation used in the design then what is important for the designer to understand is what are the design goals and principles that must be satisfied. Without this clarity of the fundamental requirements of Classification Rules there is little confidence that design optimisation and innovation will ensure the appropriate level of safety.

Hence new Classification Rules will facilitate both innovation and optimisation, in addition to allowing for a cost effective and simple solution to a standard design.

Figure 3 mirrors several developments in the marine industry:

- IMO goal based standards, ref 2
- The Naval Ship Code, ref 3

The structure at Figure 3 is also very similar to the approach and structure used in high hazard industries, such as the International Atomic Energy Agency (IAEA) guidance ref 4

10. Summary

The need to innovate and optimise ship design is being driven by new regulation and the pursuit of efficiency. Current prescriptive rules are compliance documents and do not facilitate innovation and optimisation. To allow safe and effective design optimisation, the safety goals of regulation must be clearly specified, to ensure an adequate level of safety is maintained. A goal / risk based regime can support both those pursing a purely prescriptive approach to standard vessel design, and those pursuing design optimisation.

There are several ways a goal can be specified, be it in the form of a performance standard, or in strict risk terms. Goals can also be set at different levels. There is considerable rigour required in demonstrating that the goals have been met. As goals are set at a higher level, greater rigour is typically required.

In realising the benefits of design optimisation there are a number of challenges and pitfalls that need to be managed.

The use of a goal / risk based regime can be very powerful in maximising design. It has to be realised that the investment in time and effort, and the culture that needs to exist is very different from that required when using purely prescriptive rules.

11. References

Ref 1 IMO MSC.1/Circ 1394 Annex. 14 June 2011
Ref 2 IMO MSC78/6/2
Ref 3 Naval ship code ANEP 77 (Edition 3) 27th September 2011. NATO Standardization Agency (NSA)
Ref 4 International Atomic Energy Agency. Vienna, Austria. Safety Standards.

12. Authors Biography

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Vince Jenkins is the Global Marine Risk Advisor attached to the Technical Directorate of Lloyd's Register. He describes himself as a pragmatic problem solver. His earlier years were spent as a seagoing engineer with Cunard, before graduating in Mechanical Engineering. He spent 11 years in the nuclear industry which introduced him to nuclear submarine technology and its challenges. He subsequently spent 10 + years at DNV, typically involved in delivering Marine consultancy and developing DNV's capabilities in that area. During this time he personally undertook considerable risk based work in the Cruise industry, looking at major project risk. Vince joined Lloyd's Register in January 2008.