Risk Based Design

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Abstract. The shipping industry is going through a period of rapid technological change, and the rate of change is accelerating. This change is making it impossible for traditional prescriptive class and statutory requirements to keep pace with engineering advances. LR have developed a new ShipRight Procedure Risk Based Designs which is intended to provide a consistent and transparent process to assist both clients and surveyors when working on projects for which prescriptive rules does not exist or where these rules are not in themselves suitable and sufficient. This process is not intended to replace traditional rules, but rather to manage the process of implementing technology. This will allow Class societies and other bodies of the industry to achieve the knowledge/experience necessary for the development of prescriptive rules. Whilst the final objective is to develop prescriptive rules for emerging technologies a process to manage deviations and the application of risk based principles will be needed even after such prescriptive rules are published. Paper will provide background on why the RBD process has been developed along with its basic principles. Typical field of applicability is any innovative field as for instance Low flash fuel systems (LNG, methanol, hydrogen, etc) and IGF code.

Keywords. Risk based design, Ship Right Procedure .

1. Introduction

Compliance with rules and regulations is essential to the design of a 'safe' ship. Traditionally, rules and regulations have been largely prescriptive, and this has provided clarity and certainty. It has also served the industry reasonably well. However, there is an increasing move towards goal-based rules and regulations. This is because of increased recognition that prescriptive rules and regulations are not always sufficient. That is, they cannot be easily and rapidly revised to keep pace with technological advances and innovation needed to improve safety, tackle environmental concerns and help reduce costs.

Of course, for many years there has been the opportunity to deviate from prescription by following Alternative Design & Arrangement (AD&A) guidelines, seeking class support and gaining agreement from the National Administration. Acceptance of alternatives is based on demonstrating equivalence to the prescriptive requirements being replaced. This approach has proven particularly useful in dealing with relatively small changes within a system. However, goal-based rules and

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regulations set broad and high-level goals that impact the system as a whole, and require demonstration that these goals have been met. This is a fundamental change compared to complying with detailed prescriptive requirements, and requires a more holistic approach to demonstration. This is recognised and goal-based rules and regulations often require risk assessment as a part of the demonstration. In this field LR might support the Client with design development consultancy.

Demonstrating that goals have been met can be time consuming and it can create uncertainty on the required level of detail to satisfy class and the National Administration. In this regard, LR has developed a simple four stage procedure to help designers, owners and yards prepare appropriate demonstrations for submission to LR that involve the use of risk assessment. This procedure is known as 'Risk Based Designs' (RBD) and has been successfully used for a number of years.

RBD is summarised below and the process illustrated in Figure 1. Detailed guidance is available from LR in the form of a ShipRight document [4].

2. RBD-1: Design and Safety Statement

This stage is essentially setting the scene and scope of the assessment, and identifying those organisations with a stake in its outcome. It involves identifying all stakeholders who can influence the design, their roles, responsibilities, qualifications and experience. Stakeholders typically include shipowners/operators, shipyards, equipment suppliers, designers, system integrators and the appropriate National Administrations. It can also include port authorities and other government or non-governmental organisations. Importantly, this stage also references relevant goal-based and prescriptive rules, regulations and guidance.

In addition to the above, LR's experience has found that this stage can benefit from screening the design against key requirements. For example, for ships designed to meet the International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code), LR has developed a design screening exercise that benchmarks the proposed design against key requirements of the Code. This identifies potential 'showstoppers' early in design, thereby avoiding unnecessary changes and delays at a later stage. To help with the above, LR has developed easy to use forms to capture and present the information required of RBD-1.

3. RBD-2: Risk Assessment

Stage 2 is the preparation, undertaking and reporting of the risk assessment. This includes under-taking four tasks by answering four simple questions, summarised as follows:

3.1. What can go wrong?

This is the task of identifying the hazards associated with the design and how they might be realised. For example, identifying how equipment might fail resulting in a spill of fuel. The task is commonly referred to as Hazard Identification and is fundamental to the risk assessment; if a hazard (and how it might occur) is not identified then it cannot be assessed and the first time we will be aware of it is when an accident has occurred!

3.2. How bad will it be?

This is the task of determining the consequences of something going wrong. That is, who or what might be harmed and the severity of that harm. For example, injury or fatality, ship damage or ship loss. This task is commonly referred to as Consequence Analysis.

3.3. How often?

This is the task of estimating the likelihood that it will go wrong, where the likelihood is expressed as a frequency, probability or descriptive term. For example, a frequency of 0.1 per year, a probability of 0.01 or a description of ‘unlikely’. This task is commonly referred to as Frequency Analysis,

3.4. So what?

This is the task of determining the level of the risk by combining the consequence and likelihood information to provide a risk ‘score’. This score can be compared against criteria to determine if the design can be justified or whether additional or alternative safeguards are required to ensure justification. That is, the risk can be accepted by class and the National Administration. An example of risk criteria illustrating consequences and likelihood is illustrated in Figure 2.
In reporting this stage it is important to demonstrate the competency of the risk assessment team specific to the design and its operation, and with respects to the assessment techniques chosen. Furthermore, it is important to agree the criteria with all stakeholders, in particular class and the National Administration.

4. RBD-3: Revision and Supporting Studies

In certain cases it may be necessary to revise the risk assessment conducted at Stage 2 to address uncertainties with input and assumptions. For example, the risk results and hence, the conclusions drawn, may be sensitive to changes in the assumed reliability of safeguards or assumptions made on actions taken by the crew. Sometimes further studies are also required to support the risk assessment.

5. RBD-4: Final Design Assessment

Stage 4 is essentially a final check of the design, and the depth of the check will depend upon the complexity of the design and the potential ‘seriousness’ of design failure. For example, a ‘gas as fuel design’ (IGF) for a cruise ship will require extensive engineering review to finalise safeguards compared to say treatment of a waste stream with a non-hazardous chemical. Stage 4 for a ‘gas as fuel design’ is likely to require

Hazard & Operability Study (HAZOP) of the operational and safety controls, and possibly Failure Modes & Effects Analysis (FMEA) of equipment identified as safety critical in the risk assessment (Stage 2).

6. RBD-1 to RBD-4: Reporting

Responsibility for conducting the studies for each of the stages lies with the organisation seeking approval from LR. Each stage is concluded by a report which should be appraised by LR (and generally the National Administration) before commencing the next stage. It should be appreciated that the appraisal process aims to ensure that all reasonably foreseeable hazards associated with a particular design are adequately controlled, irrespective of whether they may eventually fall within the scope of Classification approval or within the scope of Statutory approval.
Where a design submitted to LR is based on a design previously appraised using a risk based approach then reference can be made to these previous risk studies. This minimises assessment effort and allows the focus of the studies to concentrate on design, use and arrangement differences.
A checklist of items to be considered and documents to be submitted at each stage is given in Figure 3.

7. Conclusions

Risk assessment is increasingly required as part of the move towards goal-based rules and regulations. To ensure that such studies are undertaken consistently, with an appropriate degree of rigour and in a manner consistent with applicable classification and statutory requirements, LR has developed a ‘Risk Based Designs’ (RBD) procedure. This has provided clarity on stakeholder involvement and responsibilities, streamlined submission, and proved successful over a number of years.

References

[1] MSC Circ.1002. Guidelines on Alternative Design and Arrangements for Fire.
[2] MSC Circ.1212. Guidelines on Alternative Design and Arrangements for SOLAS Chapters II-1 and III.
[3] IMO Circ.1455. Guidelines for the Approval of Alternative and Equivalents as Provided for in Various IMO Instruments
[4] Risk Based Designs (RBD). ShipRight Design and Construction, Additional Design Procedures. Lloyd’s Register.

Figure 1: Risk Based Designs (RBD) Process Diagram [4]

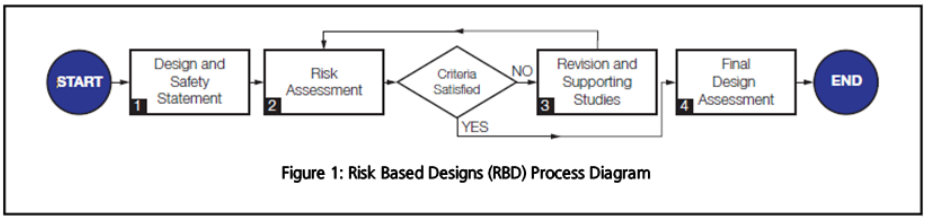
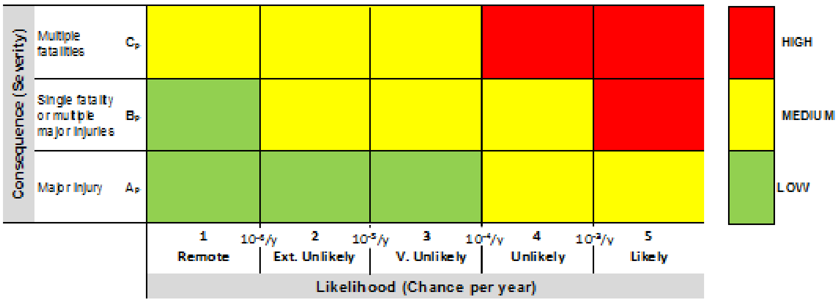


Figure 1: Risk Based Designs (RBD) Process Diagram

Figure 2: Risk Matrix **Example** – persons on board [5]



Consequence Category Examples

A_P Major injury - *long-term disability / health effect*
B_P Single fatality or multiple major injuries - *one death or multiple individuals suffering long-term disability / health effects*
C_P Multiple fatalities - *two or more deaths*

Likelihood Category Examples

1. Remote - *1 in a million or less per year*
2. Extremely Unlikely - *between 1 in a million and 1 in 100,000 per year*
3. Very Unlikely - *between 1 in 100,000 and 1 in 10,000 per year*
4. Unlikely - *between 1 in 10,000 and 1 in 1,000 per year*
5. Likely - *between 1 in 1,000 and 1 in 100 per year*

The likelihood categories can be related to a ship life. For example, assuming a ship lifetime is 25 years, then for a scenario with an annual likelihood of 1 in a million (i.e. rating 1 Remote) the probability of occurrence in the ship's lifetime is 1 in 40,000 (i.e. $1/(10^{-6} \times 25)$).

Risk Rating and Risk Criteria Examples

Low Risk – A_P1, A_P2, A_P3 & B_P1
The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective it is good practice to implement mitigation measures that would further reduce the risk.

Medium Risk – A_P4, A_P5, B_P2, B_P3, B_P4, C_P1, C_P2 & C_P3
The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.

High Risk – B_P5, C_P4 & C_P5
The risk is unacceptable and is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.

Figure 3: RBD Checklist

Stage 1 Appraisal, Design and Safety Statement

Stage 1 – Design and Safety Statement	1	2	3
Propose Development Team (see *Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.2*)	✓	✓	
Define novel or alternative design (see *Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.3*)	✓		
Define scope of novel or alternative design (see *Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.4*	✓		
Identify Classification and Statutory requirements not complied with (see *Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.5*)	✓		✓
Determine safety objectives of Classification and Statutory requirements (see *Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.6*)	✓		✓
Determine functional requirements to satisfy safety objectives (see *Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.7*)	✓		✓
Determine integration requirements to meet safety objectives and functional requirements (see *Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.6* and *Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.7*; see also *Ch 1, 8 System Integration*)	✓		✓
Describe extent of deviation from Classification and Statutory requirements (see *Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.8*	✓		✓
Prepare Stage1 Appraisal Report (see *Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.9*)	✓	✓	✓

Note 1. Client responsibility for development and submission to LR for Classification purposes.

Note 2. Documents that LR Classification need to see on completion.

Note 3. Areas where LR might support the Client with design development consultancy.

RBD – Stage 2 Appraisal, Risk Assessment

Stage 2 – Risk Assessment	1	2	3
Propose assessment team (*see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.2*)	✓		✓
Propose assessment method (*see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.3*)	✓		✓
Propose acceptance criteria (*see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.4*)	✓		✓
Identify hazards (*see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.5*)	✓		✓
Identify how hazards can occur (*see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.6*)	✓		✓
Determine consequences (accident/casualty scenarios) (*see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.7*)	✓		✓
Estimate likelihood (accidental/casualty scenarios) (*see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.8*)	✓		✓
Categorise risk (accidental/casualty scenarios) (*see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.9*)	✓		✓
Determine if acceptance criteria are satisfied (*see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.10*)	✓		✓
Identify additional measures to satisfy acceptance criteria (*see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.11*)	✓		✓
Justify appropriate safety or need for further assessment (*see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.12*)	✓		✓
Prepare Stage 2 Appraisal Report (*see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.13*)	✓	✓	✓

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RBD – Stage 3 Appraisal, Revision and Supporting Studies

Stage 3 – Revision and Supporting Studies	1	2	3
Define objective and scope of assessment(s) (*see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.2*)	✓		✓
Identify acceptance criteria (*see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.3*)	✓		✓
Propose assessment team(s), method(s) and technique(s) (*see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.4*)	✓		✓
Undertake assessment(s) (*see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.5*)	✓		✓
Justify appropriate safety (*see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.6*)	✓		✓
Prepare Stage 3 Appraisal Report (*see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.7*)	✓	✓	✓
Revise Stage 2 Appraisal Report or Provide Addendum/Supplement (*see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.8*)	✓	✓	✓
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RBD – Stage 4 Appraisal, Final Design AssessmentFig 3

Stage 4 – Final Design Assessment	1	2	3
Define objective and scope (*see Ch 1, 4.5 RBD – Stage 4 Appraisal, Final Design Assessment 4.5.2*)	✓		✓
Propose assessment team(s), method(s) and technique(s) (*see Ch 1, 4.5 RBD – Stage 4 Appraisal, Final Design Assessment 4.5.3*)	✓		✓
Undertake assessment (*see Ch 1, 4.5 RBD – Stage 4 Appraisal, Final Design Assessment 4.5.4*)	✓		✓
Prepare Stage 4 Appraisal Report (*see Ch 1, 4.5 RBD – Stage 4 Appraisal, Final Design Assessment 4.5.5*)	✓	✓	✓
Note 1. Client responsibility for development and submission to LR for Classification purposes. Note 2. Documents that LR Classification need to see on completion. Note 3. Areas where LR might support the Client with design development consultancy.			