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18th INTERNATIONAL SHIP AND
OFFSHORE STRUCTURES CONGRESS

09-13 SEPTEMBER 2012
ROSTOCK, GERMANY

VOLUME 3

COMMITTEE IV.1

DESIGN PRINCIPLES AND CRITERIA

COMMITTEE MANDATE

Concern for the quantification of general economic, safety and sustainability criteria (as there are reliability, availability, maintainability, dependability) for marine structures and for the development of appropriate principles for rational life-cycle design using these criteria. Special attention shall be given to the issue of Goal-Based Standards as presently proposed by IMO in respect of their objectives and requirements and plans for the implementation, and to their potential for success in achieving their aims taking account of possible differences with the safety and sustainability standards in ISO and similar standards developed for the offshore and other maritime industries and of the current regulatory framework for ship structures. The IMO-related work shall be performed at a time scale consistent with that necessary for submission of documents to the relevant IMO committees.

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1 DISCUSSION

1.1 Official Discussion by Rolf Skjong

1.1.1 Introduction

The committee mandate is quite broad and general, and the topics described in the mandate are not closely related. It is therefore hard to identify a clear objective of the report. In this discussion document is it assumed that the main focus may be referred to as 'design for sustainability'?

ISSC does not have a consultative status as NGO at IMO and cannot submit documents to IMO. It is therefore unclear why the ISSC work shall be performed at a time scale consistent with that necessary for submission of documents to the relevant IMO committees.

The focus on the IMO Goal Based Construction Standards for bulk and tank (GBCS/BT), and the more general risk based approach to GBS (GBS/Safety Level Approach, GBS/SLA) is largely presented by referring to the ongoing process at IMO. The report is raising few questions as to the purpose and usefulness of the approach, and how this is linked to the design for sustainability approach.

The report is supposed to cover both ship and offshore structures. In regulatory aspects this is problematic, as the regulatory regimes are very different, and a 'design for sustainability' approach would require different adaptations. The report would need to consider that the ship regulations are largely international, whilst the offshore regime is regulated by the coastal state and therefore varying between states. The report also does not discuss the interesting development of a common EU regulation for the offshore sector in Europe (EU, 2011a), and other impacts of the Macondo accident.

The ISO sustainability standards mentioned in the mandate are not presented nor discussed. This seems logical as the relationship between these standards and the regulatory development at IMO or to 'design for sustainability' seems remote.

The report also contains quite a few pages about noise impact and ice loads on offshore wind turbines. Whilst the information might be useful, it is not at all clear why these topics are included, as this is not required by the mandate and not closely linked to 'design for sustainability'.

This review report is therefore largely limited to commenting on terminology, design for sustainability and GB(C)S.

1.1.2 Terminology

Systemic and Random Losses

There are some terminologies in the report that are found non-traditional. In particular this comment relates to the use of the terms 'systemic' and 'random losses'. The normal terminology is regular releases and accidental losses, which is understandable to most readers without any need for definition of terminology.

In a risk context, which is an important topic of the document, the term systemic is used in a different context and meaning. The term 'systemic risk' is much used in the finance sector. Systemic risk is the risk of collapse of an entire financial system or an entire market, as opposed to risk associated with any one individual entity, group or component of a system. It refers to the risks imposed by interlinkages and interdependencies in a system or market, where the failure of a single entity or cluster

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of entities can cause a cascading failure, which could potentially bring down the entire system or market. The word itself, simple refers to 'system' effects. The term is used a lot in the OECD book 'Emerging risk in the 21^{st} century' (OECD, 2003), which actually had the working title 'Emerging Systemic Risk' during its development, a title ending up as the title of Chapter 1 of the book. If the term 'systemic' is used about structures, it should be used in a systems reliability context.

Full Cost Accounting

Full cost accounting (FCA) generally refers to the process of collecting and presenting information about environmental, social, and economic costs and benefits/advantages (sometimes also referred to as the "triple bottom line") - for each proposed alternative when a decision is necessary. A synonym, true cost accounting (TCA) is also often used. Both terms may be problematic as definitions of "true" and "full" are very often subjective and subject to different valuation.

A large number of standards now exist in this area including Ecological Footprint, eco-labels, and the United Nations International Council for Local Environmental Initiatives approach to triple bottom line using the ecoBudget metric. The International Organization for Standardization (ISO) has several standards useful in FCA or TCA including for greenhouse gases.

However, the real subject in a regulatory context, which seems to be the scope of the report, is the classical concepts of internalization of the costs. Internalization is a policy instrument to correct market imperfections and the resulting inefficient allocation of resources that can occur when costs are not borne by those who incur them. Internalization of external costs such as those related to air pollution, noise and accidents should also reduce the environmental costs by providing incentives to reduce demand, which would be the effect if all external costs were born by the users and included in the evaluations done by the relevant decision-makers and/or regulators.

Net Present Value (NPV)

The concept of NPV is discussed in section 3.2.1. 'The conventional ship value assessment adopts the Net Present Value (NPV) ... approach, which only measures the tangible aspects of the ship, including ship's features and functions, discounted through time. NPV therefore fails to capture the importance of partnership and cooperation between the stakeholders of the shipbuilding industry'.

Net Present Value is mainly used to evaluate investment projects. It simply evaluates if an investment should be made or not, by depreciating the costs and economic benefits to present value using the corporate rate of return as the rate of depreciation. The corporate rate of return may be based on many considerations like return of alternative investments, risk premium of the project etc. (Skjong and Lereim, 1988). There is no problem including effects of sustainability considerations into this calculation if e.g. this is internalized in the calculations for example as a tax. The point is that NPV is a simple tool to be used by the investor, and any effect from sustainability considerations, taxes, future risks etc. can be taken into the consideration. Whilst the mathematical formula of depreciation is the same, the depreciation rate will be different in evaluating e.g. safety measures in a regulatory context or sustainability considerations where the aspects of the well-being of future generations are included. In any case it is not the NPV concept as such that fail to capture the importance of partnership and cooperation, it is the analyst that has not included it.

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Performance Based and Prescriptive Rules

In Chapter 2 it is stated 'A performance-based set of Rules implies a 'calibration' of lower level targets to targets at a higher level (and ultimately to the final target: sustainability). If this calibration is not performed, the term 'prescriptive Rules' applies, as the requirement is introduced in an 'axiomatic' way (i.e. without a proper justification in terms of achievement of the final target).'

A performance based rule specifies the performance, without prescribing a technical solution. The sentence about calibration seems more relevant for risk based rules. Prescriptive rules may also be risk based and calibrated. In summary, the paragraph quoted above is rather misleading and confusing.

The statement that 'Goal Based Standards' can be seen as a synonymous of 'Performance Based Rules' may be correct, but this is not clear yet and would only apply to GBS/SLA. For GBCS/BT only few of the functional requirements contain description of performance, and some 'functional requirements' are specifying design conditions and not functions. For example, functional requirement II.2 Environmental condition: 'Ships shall be designed in accordance with North Atlantic environmental conditions and relevant long-term sea state scatter diagrams'.

1.1.3 Sustainability

The Pure Rate of Social Time Preference

The ISSC report choose the following definition of sustainability: 'An activity is sustainable if it is proved that it adds value to the society, i.e. it improves the quality of life of the members and does not prevent future generations to achieve similar improvements.'

This is generally an adequate definition. However, in implementing the sustainability principle in any type of analysis to make the principle operational and useful in decision-making, the report should discuss how this may be achieved. In particular, when discussion relates to greenhouse gas abatements investments, where decisions now also affect future generations the pure rate of social time preference is an extremely important parameter. It is therefore a serious weakness of the report that this is not discussed.

Debates about discounting have a long history in economics and public policy. Discounting involves many related and often confused concepts. One is the idea of a discount rate on goods, which measures the relative price of goods at different points of time. Another is called the real return on capital, the real interest rate, the opportunity cost of capital, or the real return. The real return measures the yield on investments corrected by the change in the overall price level. In principle, this is observable in the marketplace. The Intergovernmental Panel on Climate Change's (IPCC) second assessment report discussed actual returns and reported real returns on investment ranging from 5 to 26 percent per year.

Yet another important discount concept involves the relative weight of the economic welfare of different generations over time. This is usually referred to as the pure rate of social time preference. It is calculated in per-cent per unit time, like an interest rate, but refers to the discount in future welfare, not future goods or dollars. A zero time discount rate means that, for *decisions now*, future generations into the indefinite future are treated symmetrically with present generations; a positive time discount rate means that the welfare of future generations is reduced or "discounted" compared to nearer generations.

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In the climate change debate there is a well-known case where differences in assumptions had drastic consequences.

The British government in November 2006 presented a comprehensive new study, the Stern Review on the Economics of Climate Change. Prime Minister Blair presented a dire picture for the future "It is not in doubt that if the science is right, the consequences for our planet are literally disastrous. Without radical international measures to reduce carbon emissions within the next 10 to 15 years, there is compelling evidence to suggest we might lose the chance to control temperature rises" (Blair, 2006).

This result of the Stern (2006) review was to a large extent the result of applying a pure rate of social time preference of 0.01%. As demonstrated by Nordhaus (2007) such assumptions would result in decision-making that are utterly irresponsible, since small consequences in distant future with small probabilities of occurrence could have direct consequences on resource allocation today. A number of illustrative cases are given in Nordhaus (2007, 2008).

For example Nordhaus (2007) in one example demonstrates that the modelling assumptions in the Stern (2006) review result in reducing per capita consumption for one year today from $ 10 000 to $ 4 400 in order to prevent a reduction of consumption from $ 130 000 to $ 129 870 starting two centuries from now and continuing at that rate till eternity.

Nordhaus (2007) calculates the optimal climate change policy using the in DICE-2007 model. The Dynamic Integrated model of Climate and the Economy has been continuously developed since the early nineties. In one run the model calculates the optimal trajectory of climate change policies.

The optimal carbon price in 2015 was calculated to be $ 35 per ton C, rising over time to $ 85 in 2050 and to $ 206 in 2100 (all data are in 2005 U.S. dollars). It is claimed that this optimised path leads to a projected global temperature increase from 1900 to 2100 of around $2.3° C$.

The discussion between Nordhaus and Stern illustrates the importance of analysing modelling assumptions in detail. The fundamental idea is that such decision rules should follow the principle of generality 'A decision rule should be applicable to anyone anytime'.

In any case the IPCC (2007) report give a decision rule applicable today, for greenhouse gas abatement decisions, see below.

Safety Criteria in IMO (FSA)

At IMO the most important decision criteria for safety has been established since 2000 by a submission by Norway (2000) and based on cost effectiveness criteria: Net and Gross Cost of Averting a fatality (NCAF/GCAF), and also the Quality Adjusted Life Years (QALY) criterion for evaluating health and injury effects. This is now described in the FSA Guidelines (IMO, 2007). The implication is that internalizing costs to safety, injuries and ill health is made easy in any decision model.

The criterion used for recommendations based on NCAF and GCAF can be found in the consolidated version of the FSA Guidelines (IMO, 2007, page 54). The criterion that has been used for all FSAs submitted to IMO so far has been at $ 3million, see Table 2, page 54 of IMO (2007). However, it is stated in the FSA Guidelines that the proposed values for NCAF and GCAF have been derived by considering societal indicators (refer to document Norway 2000). They are provided for illustrative

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purposes only. The specific values selected as appropriate and used in an FSA study should be explicitly defined. These criteria are not static, but should be updated every year according to the average risk free rate of return (approximately 5%) or by use of the formula based on the Life Quality Index (LQI), Skjong and Ronold (1998, 2002).

It is noted that the $ 3million is in reality derived from 1998 statistics for OECD member countries. If adjusted for US inflation rates until 2010, this figure should be updated to $ 4.14 million (2010). If adjusted for a 5% risk free rate of return the figure should be $ 5.39million (2010), and if a full update based on LQI for OECD member countries is carried out the result is $ 7.45million.

The main changes are due to the following: The number of OECD countries has increased, Gross Domestic Product per Capita has increased, life expectancy at birth has increased and we spend less time in economic activity. In addition the US$ has decreased its value against most other currencies.

The ISSC report chapter 3.3.1 is discussing this topic without mentioning the background documents and the concepts used at IMO, and is introducing the concept CSX for the well-established Cost of Averting a Fatality (CAF) criteria at IMO. Furthermore the concept is confused by referring to the large variability in actual decisions. 'The problem with this approach is that the resulting CSX values differ widely. The values reported in literature, ... ranges from $ 1 000 for investments in sport and recreation to $ 100 000 000 for investments in the nuclear industry'. By such statements the ISSC report is just confusing the reader. The point with cost benefit assessment is that resources reallocation could save many more lives. For example it was demonstrated in Tengs *et al.* (1995) that 40 000 lives could be saved in the US by reallocation of resources.

For health effects and injuries the IMO FSA Guidelines advocates the use of the QALY (Quality Adjusted Life Year) concept, which is promoted by the World Health Organization (WHO). For converting a CAF criterion to a QALY criterion it is simply assumed that a fatality correspond to $e/2$ QALY (where e is the life expectancy). It is worth noting that WHO maintain an evaluation of the QALY for various reduced health states.

The Cost of Averting a Ton of CO_2 Heating Effect (CATCH)

As pointed out in Skjong (2009) a similar approach may be used in prioritising reduction in greenhouse gas emissions. Actually, most of the high level analysis that is needed was carried out by Intergovernmental Panel on Climate Change (IPCC), and is reported in the Fourth Assessment Report, Contributions from Working Group III (IPCC, 2007). The report contains estimates of the risk reduction at different carbon price levels, both based on top-down and bottom-up studies and for two different scenarios. This is given in IPCC (2007), Table SPM.1 and 2. Reproduced here as Table 1 and Table 2.

The economic potential for emission reduction estimates is surprisingly consistent at all carbon price levels. The two scenarios are defined as follows:

The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions

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Table 1: Global economic mitigation potential in 2030 estimated from bottom-up studies

Carbon Price (US$/tCO$_2$–eq)	Economic Potential (GtCO$_2$ –eq/yr)	Reduction Relative to SPES A1 B (68 GtCO$_2$ –eq/yr) (%)	Reduction Relative to SPES B2 (49 GtCO$_2$ –eq/yr) (%)
0	5-7	7-10	10-14
20	9-17	14-25	19-35
50	13-26	20-38	27-52
100	16-31	23-46	32-63

Table 2: Global economic mitigation potential in 2030 estimated from top-down studies

Carbon Price (US$/tCO$_2$–eq)	Economic Potential (GtCO$_2$ –eq/yr)	Reduction Relative to SPES A1 B (68 GtCO$_2$ –eq/yr) (%)	Reduction Relative to SPES B2 (49 GtCO$_2$ –eq/yr) (%)
20	9-18	13-27	18-37
50	14-23	21-34	29-47
100	17-26	24-38	35-53

of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Assuming that the politically expressed wish to reduce the emission by 80%, compared to the current level B2 scenario at 2030, and ignoring the uncertainties, this indicates that all measures that can avert a tonne of CO_2 – eq. emission for less than or about $ 50 should be implemented now or in the near future. This is higher than the current price ine.g. the EU market and demonstrates that the current market based instrument fail to internalize the societal costs.At IMO this way of deciding to implement RCOs would be consistent with current decision making processes and FSA, e.g.

Cost of Averting a Tonne CO_2– eq. Heating effect (CATCH) = $ 50

It may obviously also be argued that due to the uncertainty in the estimates, and the long term irreversible effect of climate change, a safety factor should be introduced too. For EU and others, a reference to the precautionary approach would be of relevance, as this is also representing an agreed policy.

The CATCH concept has been applied in Longva *et al.* (2010) for setting the target Energy Efficiency Design Index (EEDI), but could be used in various ways, including introducing a fuel levy. The approach quantifies the cost of averting greenhouse

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gas emission, which indicate the costs that needs to be internalized in the decision processes, by regulators and individuals to achieve sustainability.

Economics of Marine Accidents

The section with this title in the ISSC report is really about the cost of averting oil spills. There are obviously other costs relating to marine accidents, like the loss of life and property.

In section 3.2.3 it is stated that 'The circumstances surrounding a spill incident are complex and unique. Predicting the per-unit costs of a spill response is a highly imprecise science since the factors impacting cost are as complex as the factors impacting the degree of damage the spilled oil will cause. Clearly, one universal per-unit cost is meaningless in the face of these complex factors...'

This is correct, but fails to address the real issue about ship 'design for sustainability'. Most ships are certified for global trade. The implication is that the implicit willingness to pay for averting e.g. oil spill in ship design and operation is not depending on circumstances surrounding a specific spill.

In any case, the ISSC report fail to cover the issue as debated over years at IMO, which focused on identifying a criterion for the cost of averting oil spill in FSA.At MEPC 62 this was largely concluded by preparing an annex to the IMO FSA Guidelines.

It was noted that the most appropriate conversion formula to use will depend on the specific scope of each FSA to be performed; a general approach to be followed was outlined.

The consolidated oil spill database is based on:

- IOPCF data;
- US Data;
- Norwegian data;

Figure 1 shows the data of the consolidated oil spill database in terms of specific costs pertonne spilled (Figure 5 of document Germany *et al.* (2011)). It should be acknowledged that the consolidated oil spill database has limitations and possible deficiencies.

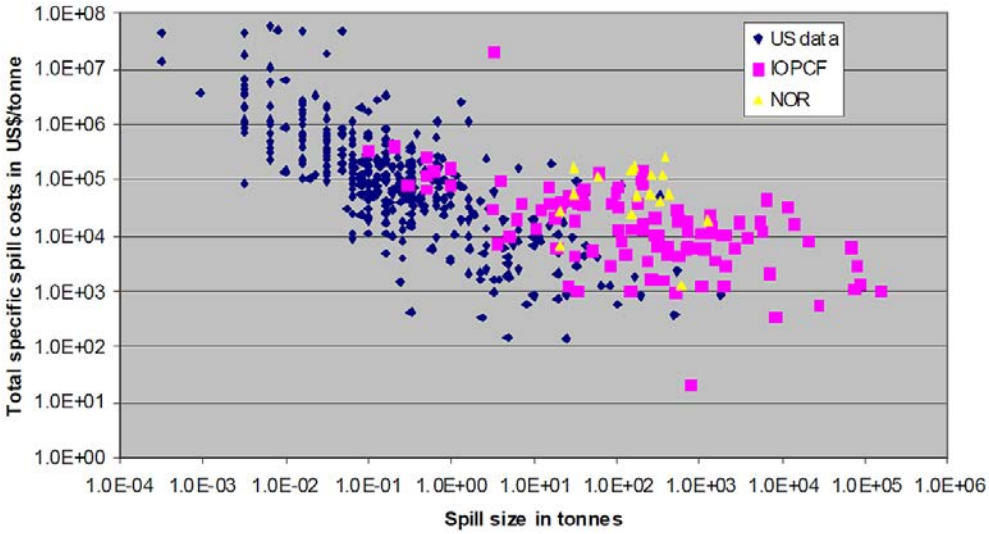

Figure 1: Oil spill costs as a function of spill size.

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Table 3

Dataset	f(V)=Total Spill Cost (TSC) (2009 US dollars)	Reference
All spills	$67{,}275\ V^{0.5893}$	MEPC 62/INF.24
V>0.1 tonnes	$42{,}301\ V^{0.7233}$	MEPC 62/18[6]

These are described in Germany *et al.* (2011) and may also involve incomplete or missing data on costs or other information.

The submitter of the FSA can amend this database with new oil spill data; however, this amendment should be properly documented.

Some regression formulae derived from the consolidated oil spill database are summarized in Table 3, in which V is spill size in tonnes.

The FSA analysts are free to use other conversion formulae, so long as these are well documented by the data. For example, if an FSA is considering only small spills, the submitter may filter the data and perform his or her own regression analysis.

It is recommended that the FSA analyst use the following formula to estimate the societal oil spill costs (SC) used in the analysis:

$$SC_{threshold} = F_{Assurance} \cdot F_{Uncertainty} \cdot f(V)$$

The assurance factor ($F_{Assurance}$): allowing for society's willingness to pay to averting accidents; Uncertainty factor ($F_{Uncertainty}$): allowing for uncertainties in the cost information from occurred spill accidents; and Volume-dependent total cost function $f(V)$: representing the fact that the cost per unit oil spilled decreases with the spill size in US$ per tonne oil spilled.

The values of both assurance and uncertainty factors should be well documented.

In order to consider the large scatter, the FSA analyst may perform a regression to determine a function $f(V)$ that covers a percentile different than 50% and document it in the report.

It is still unclear if the present formulations will be corresponding to the willingness to pay for averting oil pollution accidents that are implicit in the present MARPOL. This will presumably be analysed up to MSC91, and maybe $F_{Assurance}$ will be given a value in the FSA Guidelines reflecting the current willingness to pay for averting accidents that are now implicit in e.g. MARPOL. In any case, IMO is in a process of agreeing on how to internalize the societal cost of oil spill in the regulatory process, an approach that would be helpful for the 'design for sustainability approach'. This may be compared to the decision processes in EU on offshore regulations. The EU Impact Assessment (EU, 2011b) is largely a worst case scenario analysis estimating a return period for a Macondo type accident in Europe.

Other Criteria for Internalizing Costs in Decision Models

In general there is currently a large literature available on factors to be used in internalizing societal costs in decision models, and attempts to link this to sustainability concepts. Based on a review such costs are identified for NO_x, VOC, SO_x, Particular Matter, etc in Vanem *et al.* (2011). In general, there is a large literature available to support a 'design for sustainability' approach, and given the mandate of the ISSC committee it would be expected that such literature was reviewed.

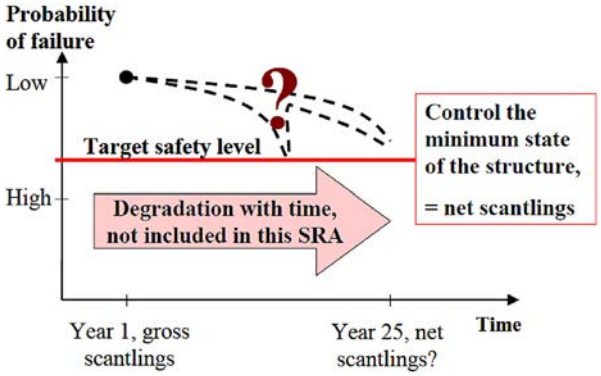

Figure 2: Safety Level as a function of ship age

1.1.4 Goal Based Standards

Goal Based Construction Standards for Bulk Carriers and Tankers (GBCS/BT)

The presentation of GBS development at IMO and the corresponding activities in IACS in the ISSC report is generally correct. However, there are few statements that represent a technical evaluation of the activity. For example the role of the regulator in the process may be questioned. This is reflected in the choice of the high level goals. As an illustration of this, the GBCS/BT is specifying a 25 years design life.

Figure 2 is an illustration of the questionable approach in defining goals in the GBCS/BT. The design life is specified to 25 years. However, the GBCS/BT does not indicate how safe the ship should be during the life. Given the role of the ship owner and the regulator, it would make more sense that the design life should be be a commercial decision by the owner, whilst the role of the regulator is to implement controls that the safety is acceptable during that design life. In structural reliability analysis this is traditionally done by specifying the target safety level, which may be derived from 'design for sustainability' approaches, using the criteria already defined by IMO.

This simple illustration may also serve to explain the current focus on the GBS/SLA or the risk based approach to goal based standards. The difference between GBCS/BT and GBS/SLA can be illustrated very well in Figure 2. In GBCS/BT the goal is represented by a *vertical* line indicating the design life, in GBS/SLA the goal is represented by the *horizontal* line specifying the safety level.

Potential Success of Goal Based Standards (for Bulk and Tank)

This is briefly discussed in section 5.3 focusing on the procedural consequences of having to go through an IMO audit process for the classification rules. It is worth noting that these issues were discussed, without being answered at the early development phase of GBS. This goes back to MSC78 (May 2003). In a society where decision processes are expected to be evidence based it is clearly of relevance for researchers to revisit these critical question from back in 2003 once this process has concluded and the first ship is built to the GBS standard in 2016.

In section 4.2.1 it is stated that 'It is the intention that the goals prescribed by IMO may be achieved by alternative designs that offer an equivalent level of safety, while promoting new technology and greater innovation within the shipping industry.'

This statement is a reasonably interpretation in general of GBS, but is not part of

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GBCS/BT at IMO. However, the IACS common structural rules for BT contain an equivalence paragraph.

Questions still remain. Are there going to be benefits from GBCS/BT? Could the result be a permanent end to innovation for these hip types? Are there any reasons class societies should improve the rules when they have finally been approved? Will classification societies have any incentives to carry out R&D activities on rule developments for bulk carriers and tankers? IACS (2003) voiced the following opinion early in the debate about GBS 'Proposals made for this Committee to consider the introduction of far reaching changes should be based on facts from sound investigation and should, at least, include a proper cost/benefit analysis as part of a Formal Safety Assessment (FSA)'. Such a cost/benefit analysis was never carried out.

Naval Ship Code

Given that the mandate of the committee was to look into GBS, it is somewhat surprising that the report does not consider the Naval ship code.

The vision of the International Naval Safety Association (INSA) is that the Naval Ship Code becomes established as a cost-effective goal based standard for naval ship safety benchmarked against statute, and accepted by the global naval community and intergovernmental bodies.

What are the benefits of a Goal Based Standard? According to INSA(2012) 'A "goal-based" standard, rather than relying on the existing rules, considers what the ultimate safety objective of the designer might be, and will consider a range of alternative design approaches that will reach this desired goal. Thus, whereas in the past the rules would have been specific over every detail, now, the over-arching objectives will be specified, giving the designer choice, and the freedom to innovate.'

It is worth noting that this is more in agreement with the GBS/SLA, and not in agreement with the GBCS/BT. The experience with the work with the Naval Ship Code was also communicated to IMO in order to influence IMO to develop GBS in a similar direction (Netherlands, 2007, 2008). Netherlands (2007) relates to Life Saving Appliances (LSA), where IMO now has started work on GBS on revising SOLAS, Chapter III on LSA (Denmark *et al.*, 2011).

Risk Based Approach to Goal Based Standards

Risk Based Approach and Goal Based regulations or standards are about two different issues. The risk based approach relates to justification of regulations, like described e.g. in the FSA Guidelines (IMO, 2007). As explained above, this may well be extended to include sustainability considerations.

Goal based relates to the style of writing and structuring the regulations. When risk based is combined with goal based the implication is that the goals related to safety and environmental protection is referring the acceptable risk levels, or the ALARP principle. At IMO (and elsewhere) the ALARP principle is gaining popularity and as described in the FSA Guidelines this result in decision making based on cost-benefit evaluations. As explained above, this can be linked to internalizing the societal costs in the decision process and to 'design for sustainability'.

The link between Goal Based and Risk Based was made already back in 2003, see for example Denmark *et al.* (2004), and the following years saw a number of submissions supporting what was later referred to as GBS/SLA. However, all focus until 2011 was on developing the GBCS/BT(for bulk carriers and tankers > 150 meters).

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The first working group at IMO that discussed the GBS/SLA was established at MSC90 (May 2012), and it is not at all clear which direction this development is leading.

The main proposal for MSC90 was the document submitted by Germany (2012), since this document again points to the fact that GBS standards will involve a restructuring of the IMO instruments. In principle it could be foreseen that in the long term the IMO instruments (SOLAS, MARPOL, Load Line Convention etc) are replaced by one instrument only containing the goals and the functional requirements. Tier IV of the regulatory system would consist of IMO Codes and Classification Rules. This is very different result compared to GBCS/BT, where SOLAS is amended by including some definitions and the entry into force dates, whilst the goals and functional requirements are included in a MSC Resolution 'International Goal-Based Ship Construction standards for Bulk Carriers and Oil Tankers'. The Guidelines for Verification of conformity with the international Goal-Based Ship Construction Standards for Bulk Carriers and Oil Tankers are yet another document (Tier III of GBCS/BT).

The working group at MSC90 agreed that SLA is an application of risk-based concepts in order to determine the safety level of the regulations, with a view to developing or changing international regulations, within or outside the GBS approach. With this in mind, the group developed the definition of SLA 'Safety-level approach is the structured application of risk-based methodologies for the IMO rule-making process.'

This agreement is somewhat difficult to interpret, because the SLA definition is in practice the same as the definition of FSA. For example in IMO(2007) FSA is defined as follows 'Formal Safety Assessment (FSA) is a structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property, by using risk analysis and cost benefit assessment' and it is meant to be used in the IMO rule making process etc.

It seems that SLA is the same as FSA. It would probably be better to say that GBS/SLA is the risk based approach to goal based standards, and that FSA is that risk based methodology. FSA is also the methodology to determine the safety level in current regulations. As a matter of fact, this is the outcome of FSA Step 2: Risk analysis.

IMO (2012) includes Figure 3, which clearly indicates that the goals relates to safety level. A Tier 0 is also included with the IMO mission statement.

In any case, the work programme for GBS/SLA approach that was agreed at MSC90 (IMO, 2012) is:

1. conduct relevant SLA exercises, as examples for further consideration, taking note of the experience gained within the DE Sub-Committee in restructuring SOLAS chapter III and other relevant experience within other organs, using a goal-based/risk-based approach; and
2. initially assess the current safety levels, taking into account the various FSA studies submitted to IMO, including:
   (a) developing risk models for SLA to assess the current regulations;
   (b) applying risk models to assess the current regulations; and
   (c) identifying the need, procedures, if necessary, and sources for collecting/improving data, taking into account the work of the FSI Sub-Committee and the GISIS database

Since the restructuring of SOLAS chapter III is an on-going work in the DE Sub-Committee, the group did not specify any time frame for the above issues, however,

envisaged at least two to three years to develop interim guidelines for the safety level approach.

1.1.5 Some specific comments

Accidental Limit State

The topic discussed in Section 5.2, is also addressed in Hørte *et al.* (2007) using structural reliability analysis with the following clear conclusion:

'The cost benefit analyses show that the scantlings at the cost optimum target safety level for the damaged case are lower than those for the intact case. There is therefore not a need for a structural criterion for the damaged condition based on the case study reported here, the intact criterion is dimensioning.'

This is an important observation. A criterion may be excluded from a rule because the criterion is not dimensioning. Exclusion should therefore not be construed to mean 'not considered'.

Double counting

In section 3.2 'These figures indicate the efficiency of shipping. The ratio between the total freight rates and goods transported leads shows (sic) that on average less than 10% of the value of goods transported is required undertake (sic) that transportation using the shipping of the world. Even if the annual investment in newbuilding is add to this, in the order of 100 billion USD (SAJ, 2010), the overall system is still very lean.'

Presumably the annual investments are paid for by the freight rates, or shipping would not even be economically sustainable. To add investments would represent double counting.

Insufficient understanding

In section 3.2.1 'Wang (2008), building on this, found that currently there is insufficient understanding of the value of a ship by the ship owner and shipyard.'

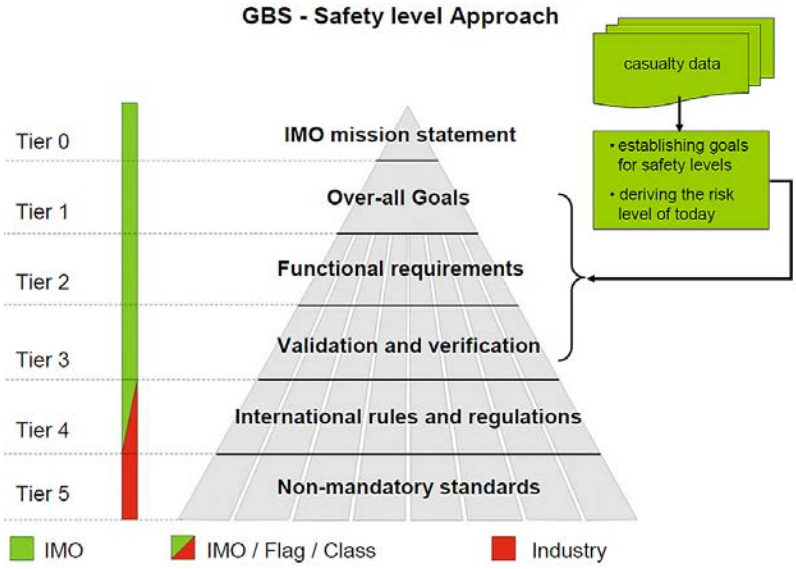

Figure 3: Structure of GBS/SLA (Denmark *et al.*, 2006)

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The statement and reasoning following the sentence is unclear. The shipyard will find out the value of the ship every time a contract with an owner is signed, and the owner will know the value when he tries to sell the ship in the market. Presumably Wang (2008) was concluding something else.

Learning from Aviation Industry

Chapter 6.2 of the report contains a very brief explanation of the design principles used in the aviation industry. The safe-life/fail-safe philosophy seems to be dealing with similar considerations as the GBCS/BT relating to functional requirement II.7 Structural redundancy (a 'systemic' effect) 'Ships shall be of redundant design and construction so that localized damage (such as local permanent deformation, cracking or weld failure) of any stiffening structural member will not lead to immediate consequential collapse of the complete stiffened panel.'

The purpose of Chapter 6.2 is rather unclear, and there would be added value to the report if there was a discussion and comparison of the ship and aviation approaches. Table (6) of the ISSC report also indicate that the aviation industry use a safety level approach. A discussion on how this is implemented and relevance to maritime would therefore be interesting.

Relating to fatigue, the main difference relates to the reliance on testing. Full scale testing is not feasible for ships, whilst this is the main approach within aviation. For an application of structural reliability analysis of aircraft fatigue see Sigurdsson *et al.* (1992).

References in the ISSC Committee report

The way of writing IMO references is confusing. At IMO, there are essential two types of documents: Submissions and resulting regulations, guidelines, circulars etc. Only the output from IMO should be referenced as IMO (yyyy). The submissions should be referenced by the organization submitting them (as done in the reference list in this discussion document).

Furthermore, the references (IMO, 2009f) and (IMO, 2010d) are wrong references (About Noise, not GBS.)

There is also a reference to an OECD report, said to be Endresen (2008), whilst the reference list only contain a reference to Endresen *et al.* (2008), which seems not to be an OECD report.

1.1.6 Concluding Remarks

The ISSC report on 'Design Principles and Criteria' seems to wish to describe a basic design philosophy referred to as 'Design for Sustainability'. This is a very good idea, and probably a better terminology than 'risk based design', which consists of many of the same elements (holistic, from design to scrapping etc.). However, although all ideas to promote the idea of 'design for sustainability' are available in the literature the report fail to describe the philosophy consistently, and rather fundamental issues related to sustainability, like the 'pure rate of social time preference' are not even mentioned.

The description of the regulatory systems with commonalities and differences are missing. If the 'design for sustainability' philosophy was adequately described it would be much easier to describe how this could be implemented in ship regulations through IMO and the Classification Societies. Likewise, implementation in the various offshore regimes would be possible, both in the prescriptive regimes and the goal based or

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safety case based regimes. Obviously, in the goal based or safety case based regimes implementation would be in principle strait forward, as long as the regulators would be prepared to define how externalities should be implemented in the decision processes of the operators. The Norwegian offshore regulatory regime is in this respect an exception, as also e.g. safety targets are specified by the operators.

The mandate of the committee is probably partly to blame for the lack of structure in the report. For example, there is a lack of fundamental principles to follow in the GBCS/BT, and it is hard to detect any useful information as relating to design principles and criteria in the ISO sustainability standards. The mandate is therefore not practical.

There are generally too many parts of the report that serves no purpose. What is the purpose of just quoting the result of the expert group on Formal Safety Assessment, without any discussion or conclusion? What is the relation between FSA and GBS/SLA? The heading under which FSA is mentioned is the SLA, and there have been many IMO submissions explaining the relation. Similarly, there is a chapter on design criteria for ice action on offshore wind turbines that seems unrelated to the topic of the report and to the mandate. Already in the introduction there is a statement that port authorities extend the international legal requirements for shipping. This is not followed up anywhere in the report. The issues described in Chapter 4.1.2 does not relate to international regulations, but to the fact that ports are regulated by national regulations and the municipal authorities. This is not a new development.

In any case the idea of developing an approach under the heading 'design for sustainability' is generally supported, and hopefully this discussion documents hints to the direction this goal should be pursued.

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1.2 Floor and Written Discussions

1.2.1 Paul James

Can a goal based standard cover only one system? Should it be more comprehensive and cover all ship systems? The NATO naval ship code tries to do this, has the committee considered this code?

1.2.2 Richard Birmingham

The Official Discusser correctly noted that the report of Committee IV.1 focused on "design for sustainability", however the wording of the mandate necessitated that much of the discussion was framed by goal based standards (GBS). This is unfortunate as the GBS debate is highly politicised and distorted by particular interest groups. The ISSC reports should make every effort to avoid participating in such political debate.

The discusser asserted that most of the specific issues of concern in design for sustainability had been dealt with, and had been considered since the 17^{th} century. This assertion misses the point. Sustainability is all about a holistic approach, where economic, societal, and environmental concerns are considered simultaneously. The fact that the tools for multi-criterion decision making have been developed many years ago does not mean that they have been successfully applied to the problem of addressing sustainability in design.

The issue of sustainability has only been recognized for a few decades, and methods to identify the most sustainable solutions are still being sought. Even this will only be the first step towards effective "design for sustainability", which, when achieved, will be very different from responding piecemeal to the codes that address specific issues in isolation which is the current procedure. I hope the Official Discusser recognizes that there is much work still to be done.

1.2.3 Berend Bohlmann

I wonder how it could happen that under the flag of Goal Based Standards we see sailing just another set of prescriptive rules. Can you comment on this?

2 REPLY BY COMMITTEE

2.1 Reply to Official Discusser

The committee members thank the official discusser for his contribution and critical remarks to the committee report. With his general comments regarding the broadness of the mandate and how the report has covered the task the discusser sheds light on the general difficulties that can occur in the ISSC committee work. Regularly the committees consist of experts from various fields of expertise that might not always match the mandate perfectly. As a consequence the members of the committee approach the mandate from their perspectives which can be different from the perspective of the discusser. Further the distribution of expertise among the committee members rules the focus of the report. Having in mind that no expertise from the offshore industry was available and no expertise regarding the activities at ISO it is self-explanatory why the report shows deficits in these fields as they were mentioned by the discusser.

The discusser's statement that ISSC does not have a consultative status as NGO at IMO is correct. In the past there have been opportunities for ISSC committees to present comments via RINA to IMO committees as the previous committee IV.1 has done. With this tradition in mind the mandate requested that the committee work

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should be done in line with the IMO schedules but finally the committee did not use this opportunity.

The basic assumption of the discusser is correct. The report wants to generally describe the efforts done in the maritime industry to increase sustainability, be it the local regulations to reduce emissions or any measures to avoid negative impact to society or be it the rules and regulations to build more robust ships which are assumed to cause less accidents with negative consequences for the environment.

The discusser expresses his concerns about the terminology that was used in the report. It was like a red line in the committee work from the very beginning, that the committee members discussed questions of terminology. From the committee members' point of view there was a broad variety in terminology in the literature reviewed which was discussed by the committee. Consequently the committee found it appropriate to propose a set of definitions which were coherent within the committee.

With regard to the definition of losses the discusser does not agree with the use of "systemic" and "random". It is the understanding of the committee that the word "loss" is overarching and describes any negative contribution to sustainability. According to the committee's understanding losses are divided into two categories systemic and random. In this context any kind of a regular release of e.g. exhaust gases or noise to the environment are defined as systemic. Accidental losses e.g. a release of oil to the environment as a consequence of a structural failure of a ship is defined as random.

With regard to the definition of full cost accounting the discusser mentions that "true" and "full" costs are very often subjective and subject to different valuation. This statement is not in contradiction to the definition of the committee. It may be that someone uses the term differently but in the context of the report full cost accounting is seen as an overarching concept related the economic evaluation of measures to achieve sustainability. However, in most of the studies reviewed by the committee the quantifications were dealing with partial costs only. Not all possible costs were included in the studies. Further it is agreed that the redistribution of costs by policy instruments is a possible measure to correct market developments that occur when the costs of the consequences of an action are not directly borne by those who are responsible for the action (e.g. costs of consequences of increased CO_2 emissions). It might be worth to describe the various instruments that exist in detail and their effects. However, the committee found this to be outside of the scope of the report and put focus on the criteria for design and to define the costs the society suffers from shipping activities.

Regarding the discusser's remark on the usage of the term "calibration" in context with performance based rules the committee respects the opinion of the discusser but disagrees. It is the understanding of the committee that in case of performance based rules there is a need to enforce coherence between the different levels by calibration, which by the way was set in quotation marks in the report. If a performance is introduced at a lower level (e.g. Tier 2) without showing that it comes from a more general requirement on a higher level (e.g. Tier 1) it becomes a prescriptive rule. Let's take an example. In case of GBS Tier 1 we have the general requirement that a ship has to be capable of operating under specified operating conditions. On Tier 2 we have the specific requirement that the North Atlantic spectrum has to be taken for the dimensioning of the scantlings. If the North Atlantic requirement would stand alone without the more general requirement of Tier 1one could say it is a prescriptive requirement. From the committee's point of view the term calibration is not limited

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to risk analysis where it has a specific meaning. If we talk about calibration in context of calibrating instruments we again have a very specific meaning. However, both cases are included in a more general definition of the term as used by the committee.

Further the committee does not see a problem in the fact that the present formulation of the GBS for some functional requirements contains reference conditions for performances and not performances in the strict sense. As long as one doesn't know better the reference condition North Atlantic can be seen as reasonable. The key point is that the performances and their reference conditions as described in GBS at Tier 2 should be consistent with those at Tier 1.

The discusser's remarks on the pure rate of social time preference are well appreciated by the committee and demonstrate the expertise of the discusser in this field. Together with the references introduced the remarks are a good supplement to the committee's work.

The section of the committee report dealing with the methodology of FSA and the safety criteria in IMO is a continuation of the previous report. In the previous report the committee presented the risk evaluation criteria related to safety of human life (GCAF/NCAF) and the cost effectiveness criterion related to accidental oil spills of tankers (CATS) in detail. Further the discussion and the methods to escalate the costs accepted by the society based on the different societal indicators have been presented in the previous report. In the present report the committee focused on the new criterion for the reduction of greenhouse gas emissions (Cost of averting a ton of CO_2 heating effect CATCH) as it was proposed by Eide *et al.* (2009). The decision parameter for emission reduction "CATCH" has been established using the same approach as adopted in the development of the decision parameter NCAF/GCAF as already included in the FSA guidelines and the similar parameter for assessing measures to reduce oil spills "CATS". These decision criteria (related to human life, oil spills and greenhouse gas emissions) indicate the costs that need to be "internalized" in the decision processes by regulators and individuals to achieve sustainability.

Regarding the discusser's comment that the report failed to address the recent discussion at IMO on costs related to oil spills the committee members admit that that there was no review done of MEPC documents published during this period. However, the previous report discusses the CATS issue in detail. The committee appreciates and welcomes the supplementing information on costs for cleaning up of accidental oil spills which come from recent publications.

With the comments on the section about goal based standards (GBS) the discusser expresses his concerns about the present development at IMO. The discusser uses the abbreviation GBCS as he has used it the first time in 2005 during a presentation at MSC (`http://research.dnv.com/skj/PRESENT/DNV-MSC80.pdf`) which was intended to support the paper MSC 80/6/6 submitted by Denmark and Norway. Presumably the author wants to differentiate between the now existing approach of GBS for oil tankers and bulk carriers and the GBS safety level approach which is still under development at IMO. However, in the meantime the abbreviation GBS is commonly used and the usage of the abbreviation GBCS in turn caused confusion among the readers of the discussion.

The committee members agree with the discusser, that there is a significant difference between the first expectations when the GBS discussion at IMO started and the final outcome.

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One group at IMO expected that reliability methods or risk analyses would be introduced into rule development and that IMO would focus on their core activity of formulating acceptable limits of risk. On the next lower tier classification societies or other regulatory bodies would then formulate the rules for structures or systems in such a way that the systems would not expose humans or environment to a risk higher than that allowed by IMO.

However, the opposite group prevailed driven by commercial interests. Today it can be said that the driving factor for the GBS discussion was to get a single set of prescriptive structural rules which lead to ships with higher steel weight. Evidence can be seen in the lengthy discussions about the corrosion allowances that were lead in the various working group meetings at IMO or the discussion lead during presentations of the Common Structural Rules about scantlings and their increase compared to the former classification rules. The discusser in this context highlights the GBS requirement that a ship is to be designed for a specific design life of 25 years what can be seen as a pure commercial issue. At least it should be to the owners/investors discretion for what period of time he wants to spend an investment and to calculate the related return of investment.

The committee appreciates that during the floor discussion it was clearly expressed that the intention of the initiators of the GBS discussion at IMO was not to introduce risk analysis techniques into rule development but to just use a euphonic expression.

With regard to the future of the Common Structural Rules it is questionable if investments will be spent in further development. Presently the rules have to be submitted to IMO for validation and verification as described in the Resolution MSC 296(87). The classification societies have to pay a fee of $ 50 000. The verification will be done by means of an audit of the self-assessment that has been done by the classification societies prior to the submission and which is part of the submitted documentation. However the auditors are free to go further into details. Future changes of the rules will be subject to a continuous "re-verification" for which the classification societies have to pay again. Having in mind the required lead time for the verification procedure it is expected that significant improvements during the rule development will be delayed until they will be available for the market.

With this new procedure of approval the classification rules have become part of SOLAS and thus have a character of statutory rules. Consequently the latitude of judgement of the societies is rather limited. As soon as a society interprets a specific rule in a wider sense than a competing society the society is at risk of having approved a non SOLAS compliant design. As a further consequence unconventional or innovative designs might lead to an increased involvement of the flag state administrations during the early design phase. It can be expected that the acceptance of direct strength analyses as a support for unconventional or innovative designs might be limited.

However, the next committee should further follow and discuss the development of the safety level approach SLA at IMO and how this approach will influence the future development of IMO regulations.

The committee agrees that the report does not refer to the Naval Ship Code of INSA. This is due to the lack of expertise on this field among the committee members.

With regard to the section on aviation industry, on the one hand the committee utilised the expertise of one committee member coming from the aviation industry to describe their design principles, on the other hand the committee agrees with the discusser that there is a comparison of the approaches missing.

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With regard to the concluding remarks of the discusser it can be confirmed that the main focus of this committee was to discuss two important issues:

1. The concept of "design to sustainability"
2. How sustainability can be implemented in the various regulations

The committee agrees with the discusser that the mandate was formulated for a wider range of topics. However, with respect to the composition of the committee and the available expertise there were made limitations in the scope of the report. It is suggested that the mandate for the succeeding committee should be narrowed down.

2.2 Reply to Floor and Written Discussions

2.2.1 Paul James

To answer the first question one can simply say yes, the answer to the second question is also yes. With regard to the GBS for tankers and bulk carriers it was mentioned during the floor discussion the initiative to develop the so called goal based standard was driven by one interest group that was mainly interested to force the classification societies to develop rules for two distinguished ship types with the objective to build more robust hulls. A proof for this statement can be seen in the general allegations against the classification societies that were published in the past. As an example refer to Gratsos and Zachariadis (2005). A further example that GBS can be developed for only one system is the recent development of the goal based guidelines on framework of requirements for ships' life-saving appliances at IMO. However, assuming that the discusser would prefer a more general approach the committee would agree that the goal based standards should cover more than only structures but also other operational systems aboard which is in line with the recent new developments at IMO.

With regard to the NATO naval ship code the committee admits that it did not review the respective development.

2.2.2 Richard Birmingham

The committee welcomes the supplementing remark.

2.2.3 Berend Bohlmann

It can be said that the development of the Common Structural Rules for Bulk Carriers and Oil Tankers was the easiest approach to fulfil the requirements of GBS. Even though a few individuals at that time thought about the development of risk based rules and the Safety Level Approach it has been the understanding of the classification societies from the very beginning that GBS would result in a common set of requirements for ship structures which only could be covered by a common approach of structural rules. The later progress of the discussion at IMO affirmed this early assumption.

2.2.4 References

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