# Improving FSA as a Prerequisite for Risk-Based GBS

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## Abstract Heading

The international shipping industry has begun to move from a reactive to a proactive approach to safety through what is known as "Formal Safety Assessment" (FSA). The recent "Goal Based Standards" (GBS) approach is focused towards being another proactive instrument. Much of the recent debate at IMO is whether the GBS should be "Risk-Based," that is, whether it should use the full arsenal of risk-related methodologies that are already developed which includes FSA. The purpose of this paper is to outline possible improvements in the FSA process so that Risk-Based GBS can proceed smoothly without problems. To that end, a critical review of the FSA methodology is carried out with proposals on ways to improve it. All steps of the FSA approach are studied to identify possible pitfalls and/or other deficiencies. At this point some proposals are made to alleviate such deficiencies, with a view to achieve a clearer and more objective approach.

## Keywords

Maritime Safety; Formal Safety Assessment; Goal Based Standards; Risk-Based GBS; Safety-Level Approach to GBS.

## Introduction

At the IMO and other regulatory fora, much of the recent debate centers on a set of questions that deal with the possible use of the so-called "Safety Level Approach" (SLA) in modern rule-making and design. SLA, also known as the Risk-Based approach, involves the use of probabilistic tools and techniques in the formulation of regulations and in the actual design of ships. Following are examples of questions that are raised within the SLA debate:

- Should the SLA be used within the new Goal Based Standards (GBS) framework?
- Should GBS be Risk- Based?
- Should Formal Safety Assessment (FSA) be used within GBS?
- Should Structural Reliability Analysis (SRA) be used within the GBS? (And so on)

Such questions, if posed in this way, do not address the correct issue. Considering that there is no doubt that modern maritime safety rulemaking should use the concept of risk along with all tools developed to study it, most of the above questions do not really concern "if", but rather, "how" and "when". This paper attempts to shed some light on these issues by clarifying some widely used, although confusing too many, notions such as Risk- Based Rulemaking vs. Risk- Based Design. Also, clarification of the IMO's GBS Traditional Approach vs. Safety Level Approach will be addressed. Furthermore, this paper will review the implications of their use, or misuse, to future ship rulemaking, design and safety.

The paper elaborates on some identified weaknesses of FSA and the Risk-Based approach that must be corrected. It further cautions the over-eagerness of some rule makers and designers to drop all prescriptive rule formulations and haphazardly adopt risk-based formulations borrowed from other industries which may not be appropriate for ships. A reliable risk-based approach involves avoidance to cut corners and thus avoidance on relying on a large number of arbitrary assumptions. To be applied properly, the risk-based approach requires a significant amount of future research in order to reliably link from first principles of the ship risk model with the desired acceptable risk or safety level.

The rest of the paper is structured as follows. The next section provides some background and focuses on proactive regulation and the FSA. The following four sections discuss possible deficiencies within the FSA process. The final section presents the conclusions of the paper.

## Proactive Regulation and FSA

While it is generally accepted that the overall level of maritime safety has improved in recent years, further improvements are still desirable. However, it can be argued that much of the maritime safety policy worldwide has been developed in the aftermath of serious accidents (such as *'Exxon Valdez', 'Estonia', 'Erika'* and *'Prestige'*). Industry circles have questioned the wisdom of such an approach. Why should the maritime industry as well as society in general have to wait for an accident to occur in order to modify existing rules or propose new ones? The safety culture of anticipating hazards rather that waiting for accidents to reveal them has been widely used in other industries such as the nuclear and the aerospace industries. The international shipping industry has begun to move from a reactive to a proactive approach to safety through what is known as 'Formal Safety Assessment' (FSA). The recent 'Goal Based Standards' (GBS) approach aims to be another proactive instrument. Recent discussions have taken place at the IMO on the possible links between the FSA and the GBS (see, for instance, IMO document MSC 81/6/16, among others, and, more recently, document MSC 83/5/3 on the Safety Level Approach to GBS[1]).

GBS started as an attempt of the IMO to better structure its regulatory process by use of a tier system. Here the high level goals are at the top, and the functional requirements necessary to achieve the goals follow. The first development started with the subject of hull design and construction of bulk carriers and oil tankers for two reasons: a) The IMO wanted to have a stronger input into the regulations for the construction of ships, traditionally left to the classification societies. b) Tankers and bulk carriers were chosen first due to their increased structural defects.

Soon a difference of opinion ensued with regards as to how these standards should be developed. Many argued that the standards should follow the risk-based approach for which FSA is suited. It also specifies a safety level to be achieved with the proper methodology to be followed. Within the proponents of the risk approach there are further differences of opinion, such as to whether the method should include specific acceptance criteria or not, and who will develop these; the IMO, or the classification societies which write the rules in detail? The proponents arguing for fewer criteria feel that this system aids design innovation without posing many restrictions. The opponents argue that even unsafe designs can appear to comply when the task of just specifying the methodology without enough specific requirements (criteria) occurs that allows for unlimited latitude.
Those not altogether in favor of the Risk-Based approach argued that in the case of tankers and bulk carriers, the huge accumulated practical experience should be the primary guide, with the standards developed being the direct result of such experience. They also argued that the problems to be fixed on these types of ships are urgent, whereas the risk level approach needs many years to be developed and is more appropriate for "high technology" ships whose design has not solidified over the years. Therefore, they urged the continuation of the "traditional" rulemaking approach that includes a mix of statistical formulations, (formulations from first principles), and empirical prescriptive formulations. Finally, recognizing the urgency to improve the construction standards of tankers and bulk carriers, it was decided that both approaches are developed parallel and independently.

It should be noted, however, that in practice the two approaches are closely related, more so than most people think. The requirements that one group considers necessary "from experience" should also be evident following the Risk-Based approach, provided it is done properly.

In fact, any Risk-Based approach to modern maritime safety regulation must respond to four challenges. It has to be:

- Proactive – as mentioned above, anticipating hazards, rather than waiting for accidents to reveal them which would in any case come at a cost in money and safety (of either human life or property i.e. the ship itself)
- Systematic – using a formal and structured process
- Transparent – being clear and justified of the safety level that is achieved
- Cost-Effective – finding the balance between safety (in terms of risk reduction) and the cost to the stakeholders of the proposed risk control options.
- Where possible calibrated to known experience.

The need for a proactive approach has been argued extensively time and again (among others, see Psaraftis (2002) before *'Prestige'* and Psaraftis (2006) after *'Prestige'* for an analysis of the main issues). FSA has been considered the prime scientific tool for the development of proactive safety regulation.

FSA was introduced by the IMO as *"a rational and systematic process for accessing the risk related to maritime safety and the protection of the marine environment and for evaluating the costs and benefits of IMO's options for reducing these risks"* (see FSA

[1] In this paper we cite IMO documents using the standard code for MSC (MEPC) publications: MSC (MEPC) x/y/z, where x: session; y: agenda item; z: document number of agenda item. MSC's 81st and 82nd sessions (MSC 81 and MSC 82) took place in London and Istanbul in May 2006 and Nov. – Dec. 2006 respectively, and the 83rd session was in London in October 2007. MEPC's 55th and 56th sessions (MEPC 55 and MEPC 56) took place in London in October 2006 and July 2007 respecively. An expanded version of this paper was submitted by Greece to MSC 82 (MSC82/INF.3). IMO documents are available from www.imo.org.

Guidelines in MSC circ. 1023, MEPC circ. 392[2]). In MSC's 81st session (May 2006), an FSA 'drafting group' proposed some amendments to these guidelines (see Annex 1 of document MSC 81/WP.8). These amendments have been approved by the MSC and subsequently were sent on to the MEPC for approval, which happened at its 55th session (October 2006). However, FSA environmental guidelines are still very much open, as will be seen later in the paper.

To achieve the above objectives, the IMO's guidelines on the application of the FSA recommended a five-step approach:

1. Hazard Identification
2. Risk Assessment
3. Risk Control Options
4. Cost-benefit Assessment
5. Recommendations for decision making

Given that the FSA is currently used for proposed new rules and will be eventually used within the Safety Level Approach to GBS, one question arises. Are there potential deficiencies that should be corrected before anything like this is attempted? In the following sections we look at some possible deficiencies in FSA[3].

## HAZID Deficiencies

The objectives of HAZID (Hazard Identification, Step-1 are the following:

a. to identify all potential hazardous scenarios which could lead to significant consequences, and
b. to prioritize them by risk level.

The first objective can be satisfied with a combination of creative and analytical parts that aim to identify all relevant hazards. The creative part (mainly brainstorming) is to ensure that the process is proactive and not solely confined to hazards that have materialized in the past.

It has been noticed that most studies have extensively – if not exclusively- used historical data found in databases. It is understandable that if historical data is available, risk profiles can be drawn without the need to model scenarios. However, this usage has several disadvantages. The most important (and this has been recognized by the IMO) is that the whole philosophy of using historical data is not proactive, and therefore it cannot be used for new designs. It cannot measure the effects of newly implemented risk control options (RCOs), as it needs to wait for accidents to happen so as to have sufficient data.

In some cases, especially in simple FSA studies, historical data can be used. In general, however, probabilistic modeling of failures and the development of scenarios is strongly recommended. It must be acknowledged that such modeling is proposed as an alternative in the IMO FSA guidelines. A variety of formal methods, such as fault trees, event trees, influence diagrams, HRA, HEAP, and possibly others are proposed. However, the use of such methods within the FSA has been limited thus far.

Throughout the IMO guidelines and even in the definition of risk by the IMO, the concept of 'frequency' seems prevalent. Risk is defined as "the combination of the frequency and the severity of consequence," with frequency being defined in terms of accidents (rather than casualties).

If these two definitions look similar, they are not. Frequency is not the same as probability, and the numerical value of the frequency (usually defined as events per unit time) does not necessarily translate into a numerical value for the probability (which is a number between zero and one). Zero collisions in a harbor during a certain year may be due to chance and does not mean that the probability of collision there is zero. Only if the sample of events is large enough, their frequency can be linked to their probability, whereas this is not the case for very infrequent events, or for events for which there is no sufficient data to calculate their frequency. Examples: (a) What is the probability of accidents if tankers implement the Joint Tanker Rules proposed by IACS? (b) What is the probability of collision in the Channel if a new traffic separation scheme is implemented? In these cases calculating the frequency is not possible, since there is no data. Does this means that the relevant probabilities do not exist? Certainly not.

The distinction between probability and frequency and the different views on this issue are well known. See for instance, Kaplan (1981) and Apostolakis (1978, 1990). Most definitions of risk in the literature use the term probability instead of frequency. In decision analysis risk is defined as the combination of probability of occurrence and severity of consequence (Raiffa, 1968). In EU (2000) risk is defined as the probability and severity of an adverse effect/event occurring to man or the environment following exposure, under defined conditions, to a risk source(s). In ISO (2001) risk is defined as the combination of the probability of an event and its consequence. The suggested use of Bayesian approaches was made by some researchers to help in estimating probabilities of events for which little or no data exists in order to compute their frequency. See, for instance, Devanney (1967) for marine equipment failure problems, among others, and Devanney and Stewart (1971) for analysis of oil spill statistics. In the Bayesian approach the probability distribution of an uncertain variable is systematically updated from a prior distribution

[2] Joint MSC and MEPC 'circular' on FSA, adopted on 5 April 2002.

[3] Much of this analysis draws from Kontovas (2005) and Kontovas and Psaraftis (2006a,b), where the reader can find more details. Also, Zachariadis et al (2007) provides additional details on risk analysis on ships and Kontovas et al (2007) provides details on environmental criteria.

(subjective) via observations of the value of that variable (objective). We recommend that Bayesian approaches be very seriously looked at for possible improvements in this step of the FSA. We also recommend that the word 'probability' eventually be used instead of 'frequency' in FSA terminology, with this substitution not only being semantic, but substantive. At least the term 'probability' has to be used as a platform of common understanding and communication among risk analysts.

The second objective of Step 1 is to rank the hazards and to discard scenarios judged to be of minor significance. Ranking is typically undertaken using available data and modeling supported by expert judgment. To that effect, a group of experts is used to rank the risks associated with an accident scenario, where each expert develops a ranked list starting with the most severe.

Notwithstanding our above comments on frequency, the explicit consideration of the frequencies and the consequences of hazards are typically carried out by the so-called risk matrices. This may be used to rank the risk in order of significance. A risk matrix uses a matrix dividing the dimensions of frequency and consequence into categories. Each hazard is allocated to a frequency and consequence category. Then the risk matrix gives a form of evaluation or ranking of the risk that is associated with that hazard. In Tables 1 and 2 the IMO defines the so-called frequency index (FI) and severity index (SI).

**Table 1: Frequency Index (source: MSC Circ. 1023)**

| Frequency Index | | | |
|---|---|---|---|
| FI | FREQUENCY | DEFINITION | F (per ship year) |
| 7 | Frequent | Likely to occur once per month on one ship | 10 |
| 5 | Reasonably probable | Likely to occur once per year in a fleet of 10 ships, i.e. likely to occur a few times during the ship's life | 0.1 |
| 3 | Remote | Likely to occur once per year in a fleet of 1000 ships, i.e. likely to occur in the total life of several similar ships | $10^{-3}$ |
| 1 | Extremely remote | Likely to occur once in the lifetime (20 years) of a world fleet of 5000 ships. | $10^{-5}$ |

| Severity Index | | | | |
|---|---|---|---|---|
| SI | SEVERITY | EFFECTS ON HUMAN SAFETY | EFFECTS ON SHIP | S (Equivalent fatalities) |
| 1 | Minor | Single or minor injuries | Local equipment damage | 0.01 |
| 2 | Significant | Multiple or severe injuries | Non-severe ship damage | 0.1 |
| 3 | Severe | Single fatality or multiple severe injuries | Severe damage | 1 |
| 4 | Catastrophic | Multiple fatalities | Total loss | 10 |

Then a 7 x 4 Risk Matrix is defined, reflecting the greater potential variation for frequencies than that for consequences. In order to facilitate the ranking and validation of ranking, consequence and frequency indices are defined on a logarithmic scale. The so-called "risk index" is established by adding the frequency and consequence indices.

Risk = Probability x Consequence
Log (Risk) = Log (Probability) + Log(Consequence)

The Risk Index is defined as follows:

**R**isk **I**ndex = **F**requency **I**ndex + **S**everity **I**ndex

Then the Risk Matrix can be constructed, for all combinations of the Frequency and Severity Indices, as follows:

**Table 3: Risk Index (source: MSC Circ. 1023)**

| Risk Index (RI) | | | | | |
|---|---|---|---|---|---|
| | | SEVERITY (SI) | | | |
| | | 1 | 2 | 3 | 4 |
| FI | FREQUENCY | Minor | Significant | Severe | Catastrophic |
| 7 | Frequent | **8** | **9** | **10** | **11** |
| 6 | | **7** | **8** | **9** | **10** |
| 5 | Reasonably probable | **6** | **7** | **8** | **9** |
| 4 | | **5** | **6** | **7** | **8** |
| 3 | Remote | **4** | **5** | **6** | **7** |
| 2 | | **3** | **4** | **5** | **6** |
| 1 | Extremely remote | **2** | **3** | **4** | **5** |

Risk matrices are not used for final decision making in the sense that they are not acceptance criteria. However, they obviously have a great deal of influence in the decision making process. They constitute a simple yet most important tool that is provided to the group of experts in the Hazard Identification step so as to accomplish the previously mentioned task of ranking of hazards. The matrices proved to be very simple to be use. However, they do have some weaknesses.

Note the definition of risk as the product of two variables. This definition collapses the two main determinants of an inherently two-dimensional concept such as risk (probability and consequence) into a single number. Doing so loses much of the relevant information and may lead to some nonsensical results. For instance, suppose that once a month (FI=7) there is a risk that leads to a single injury (SI=1). This means that RI=8. Also suppose there is another risk whereupon once a year in a fleet of 10 ships (FI=5) a death occurs (SI=3). Here, RI=8 as well. Are these two scenarios equivalent in terms of risk? One would assume that the latter would be more serious. Also, if within a year in a 1,000–ship fleet an accident occurs that produces more than 10 deaths, then FI=3, SI=4, and RI=7. Why is this scenario less serious than the previous ones?

Note also that the risk matrix as it stands, gives no distinction among hazards that have more than 10 fatalities. According to this scheme, 50 fatalities are equivalent to 100, 500, or more fatalities, even though the IMO acknowledges that this scale can change for passenger ships. Although it is stated in the FSA guidelines that the risk matrix included in the guidelines is just an example, this fact is neither emphasized nor entirely obvious, as this very matrix has been used in many FSA applications so far. As it stands, this particular 'example' matrix over-emphasizes frequent, low-consequence events over extremely rare accidents that are really catastrophic. So even though this step of FSA is not used for the final actual decision-making, a distortion of the relative importance of low-frequency, highly catastrophic events vis-à-vis that of high-frequency, low-consequence events may have negative policy ramifications as regards the priority of measures that might eventually be promulgated in each case. This scenario is a 'political' risk that should be avoided.

Thus we would like to stress the importance to define an appropriate risk matrix for each FSA application at hand, and one that should also lend itself to environmental protection issues. A literature review shows that a higher variation of potentials for both probabilities of occurrence and consequences has to be used. Alternatively, a two-dimensional approach could be adopted, one that retains both dimensions of risk instead of combining them into a single number. Even so, a scheme for the ranking of different (frequency-severity) combinations should be devised, something that would necessitate a more systematic investigation as to whether the decision-maker is risk averse, risk neutral, or risk prone.

## Deficiencies in Cost Benefit Analysis (CBA)

We now move to Step 4, a very important step of an FSA study. Step 4 is also a vulnerable step, in the sense that it involves numerous assumptions on a great number of variables, and as a result runs the risk of wrong conclusions. Its purpose is to identify and compare benefits and costs associated with the implementation of each Risk Control Option (RCO) identified and defined in Step 3. A quantitative approach has to be used in order to estimate and compare the cost effectiveness of each option in terms of the cost per unit risk reduction.

In general, the cost component consists of the one-time (initial) and running costs of an RCO, cumulating over the lifetime of the system. The benefit part is much more intricate. It can be a reduction in fatalities or a benefit to the environment or an economic benefit from preventing a total ship loss. Cost is usually expressed using monetary units. To be able to use a common denominator, a monetary value has to be given for the benefit, too.

After the estimations on cost and benefit, these values have to be combined with the Risk Reduction. There are several indices that express the effectiveness of an RCO, but currently only one is being used extensively in FSA applications. This index is the Cost of Averting a Fatality (CAF) and can be expressed in two forms: Gross and Net.

Gross Cost of Averting a Fatality (GCAF)

$$GCAF = \frac{\Delta C}{\Delta R}$$

Net Cost of Averting a Fatality (NCAF)

$$NCAF = \frac{\Delta C - \Delta B}{\Delta R}$$

where

- ΔC is the cost per ship of the RCO under consideration.
- ΔB is the economic benefit per ship resulting from the implementation of the RCO.
- ΔR is the risk reduction per ship, in terms of the number of fatalities averted, implied by the RCO.

It should be noted here (and this may increase confusion as to the definition of risk) that in this step the reduction in risk (or ΔR) is not measured as before, as the product of frequency and consequence, but just in terms of reduction in the expected number of fatalities once a specific RCO is put in place. This implies a rather narrow perspective, in the sense that, at least for the moment, only consequences that deal with fatalities are considered in this step, although attempts to extend it to environmental consequences are also under way. ΔB can include ship damages prevented and may also include environmental damages averted. We shall comment on the extension of this approach to other consequences (mainly environmental) in Section 5.

An underlying implicit assumption in this approach, which has to be stated, is that there is a reliable way to estimate ΔR, as defined above, for a specific RCO. This may be easier said than done. The expected number of fatalities in a marine accident (and, a fortiori, the expected number of averted fatalities if a specific RCO is implemented) may depend on factors that are difficult or impossible to be quantified or modeled, such as the education of the crew, the health of the crew, the location of the crew on the ship at the time of the accident, and other random factors (such as a slippery deck). So far the favorite method used in the FSA's for the estimation of risk reduction of the RCO is "expert judgment." For example, although the only proper way to estimate the effect of a new design detail is to use first principles, engineering calculations, computer modeling etc., it is easily understood why it is preferable to have a few "experts" provide out of thin air their probable risk reduction values because it is faster, easier, and cheaper. However, it is the most unreliable way and is subject to individual preferences. A small deviation in the value of ΔR can make an RCO acceptable or not. This action was clearly shown in the Greek FSA on the issue of double hull bulk carriers, where the first principles analysis used to estimate the ΔR of a double hull showed totally different values than those estimated by the experts in three independent occasions prior to the FSAs. In spite of all this, we shall continue by assuming that for each RCO under study, the corresponding ΔR can be estimated with some confidence.

### *The $3M criterion*

The dominant yardstick in all of the FSA studies that have been submitted to the IMO thus far is the so-called "$3m criterion", as described in document MSC78/19/2. According to this, in order to recommend the RCO for implementation (covering risk of fatality, injuries and ill health) this must give a CAF value –both NCAF and CGAF- of less than $3 million. If this is not the case, the RCO is rejected.

For a specific RCO, the NCAF formula gives

$$NCAF = \frac{\Delta C - \Delta B}{\Delta R} < \$3m \Rightarrow \Delta C - \Delta B < \$3m \cdot \Delta R$$

This means that for a specific RCO to be adopted, the three variables, namely ΔC, ΔB, and ΔR, have to satisfy the following inequality:

$$\Delta C < \$3m \cdot \Delta R + \Delta B$$

If so, the criterion of $3m will result in the recommendation of the RCO to be introduced, otherwise the RCO in question is rejected.

For the GCAF criterion, the equivalent inequality is simpler:

$$\Delta C < \$3m \cdot \Delta R$$

It can be seen that if ΔB>0 (a reasonable assumption if the RCO in question will result to some positive economic benefit), then if the RCO satisfies the GCAF criterion $(\Delta C < \$3m \cdot \Delta R)$, it will always satisfy the NCAF criterion as well $(\Delta C < \$3m \cdot \Delta R + \Delta B)$. In that sense, the GCAF criterion dominates the NCAF one. The opposite is not necessarily the case.

Perhaps as a result of this property, it has been proposed by many FSA reviewers that first priority should be given to GCAF, as opposed to NCAF. We will come back to this point in the next section.

***Comparing and Ranking of RCOs***

One question is how these criteria apply if there is more than one candidate of the RCOs. The last task in this step is to rank the RCOs using a cost-benefit perspective in order to facilitate the decision-making recommendations. Most often, the CAFs are being used in a way that the ranking is very easy. The lower the CAF of the RCO, the more priority has to been given to its implementation.

Another topic that has to be highlighted is the interaction of the various RCOs. When a specific RCO is implemented, the CAF for the implementation of another RCO changes. The CAFs have to be recalculated in these cases, expect if, in the list of the RCOs, an option of another RCO, which is a combination of them, exists (see also Kontovas (2005) and Kontovas and Psaraftis (2006b)).

For comparing and ranking of the RCOs using this method, we recommend the following:

1. GCAF should have a hierarchically higher priority than NCAF.
2. In cases where negative NCAFs are estimated, GCAF has to be calculated and if the GCAF has an acceptable value then the NCAF should be considered.
3. Interaction of the RCOs needs, in general, recalculation of the CAFs. In general recommendation of two elementary RCOs does not necessarily suggest the recommendation of implementing both of them simultaneously.

Even so, caution is always necessary, and these criteria cannot be applied blindly. The following hypothetical example is relevant:

**Table 4: Hypothetical example leading to selection of most risky RCO**

| | ΔR | ΔC ($) | ΔB($) | GCAF ($m) | NCAF ($m) |
|---|---|---|---|---|---|
| RCO1 | 0.10 | 100 000 | 90 000 | 1.0 | 0.10 |
| RCO2 | 0.01 | 9 000 | 8 500 | 0.9 | 0.05 |

In this case, both RCOs are acceptable since both have their GCAF and NCAF below $3m. Also, RCO2 is superior to RCO1 in terms of both criteria. However, RCO1 reduces fatality risk ten times more than RCO2, meaning that in this case the RCO that is expected to reduce risk ten times less would be ranked in a higher position than the other, and may, in fact, be the one recommended for selection.

To explain the paradox, we note that being ratio tests, both the GCAF and the NCAF ignore the absolute value (or scale) of risk reduction ΔR. *ΔR should always be taken into account as a criterion in and of itself.* If nothing else, comparisons should be made among alternatives that have comparable ΔRs.

As an endnote, it is clear that both the CAFs are vulnerable to manipulation so as to produce estimations that satisfy or do not satisfy the $3M criterion, or rank a certain RCO higher or lower than others. The NCAF is more vulnerable in that respect, since it involves three variables (ΔR, ΔC and ΔB), as opposed to just two for the GCAF (ΔR and ΔC). Furthermore, the ΔB of the NCAF has proved particularly problematic in the past FSAs where several "benefits" are being invented or inapplicable benefits applied (e. g. benefits to totally unrelated "stakeholders").

## Environmental criteria deficiencies

In all recent FSA studies, cost effectiveness is limited to measuring risk reduction using the $3m criterion. This criterion is to cover fatalities from accidents and implicitly, also, injuries and/or ill health from them. There are two other criteria that were submitted at the same time with the above-mentioned criterion to the IMO but were never used. One of the criteria is to cover only risk of fatality, and another to cover risk from injuries and ill health. Both have a value of $1.5m. However, thus far no FSA study has tried to assess environmental risk. Lately, the IMO tried to deal with this aspect (see for instance documents MSC81/18 and MEPC55/18) and made reference to a recent report from a project co-funded by the European Commission (Skjong et al, 2005). Much analysis is reported, and the report properly identifies the difficulties necessary to overcome in order to arrive at a single environmental criterion. Environmental damage and clean-up costs vary tremendously depending on which part of the world the spill occurred. Furthermore available data is primarily from spills in developed areas of the world where of course clean-up costs are high. In the end, this report implies a figure as high as $60 000 as the so-called 'Cost of Averting one Tonne of Spilled oil' (CATS). However, as a broad multitude of factors enter into damage estimation of oil pollution, the adoption of any single figure as the per tonne cost of oil spills is bound to be problematic, particularly as regards regulatory policy formulation. For more comments on this see Kontovas and Psaraftis (2006a) and the initial reaction of Greece to this approach in MSC's 81st session, urging caution on the matter (document MSC81/18/2). Also, Japanese submission MSC 81/6/3 includes the results of several prior studies as reported by the International Ship and Offshore Structure Congress which would shed serious doubt on any metric that consists only of the volume of oil spilled and the reported clean-up costs.

The IMO has adopted a similarly cautionary stance on this issue, with MSC's 81st session turning the matter over to MEPC. In MEPC's 55th session an invitation was issued to *"members and international organizations to consider the draft environment risk evaluation criteria during the intersessional period and submit comments thereon to MEPC 56, for further consideration prior to referring the agreed text to the MSC for appropriate action."* (see also documents MEPC 55/18, MEPC 55/23, MSC 82/24 and MEPC 56/18). In response to this invitation, Greece submitted document MEPC 56/18/1 on FSA, with a focus on environmental risk evaluation criteria (see also Kontovas et al (2007)). After discussion, in MEPC's 56th session (July 2007) it was agreed to form a 'correspondence group', coordinated by the second author of this paper, and tasked to look into the matter in more detail and report back in time for MEPC's 57th session (April 2008).

Whatever the outcome of these deliberations, in our opinion the process of assessing environmental risk is a very complex subject and many tasks -such as the development of a risk index and environmental risk acceptance criteria- have to be carried out before coming up with sensible, cost-effectiveness criteria that can be used for policy making or other regulatory purposes[4].

[4] If the $60 000 figure is used in some actual past accidents, the resulting damages come out astronomical: The damage of the *"Prestige"* oil spill would be $4.9 billion and that of the *"Atlantic Empress"* $19.7 billion. If one actually translates these figures in terms of equivalent fatalities, and assuming the $3 million per fatality yardstick, the latter spill would be considered as catastrophic as 6,567 deaths!

## What is a tolerable risk level?

The final Step of the FSA is aimed at giving recommendations to the relevant decision makers for safety improvement taking into consideration the findings during all four previous steps.

The RCOs that are being recommended should

- ✓ Reduce Risk to the "desired level"
- ✓ Be Cost Effective

The IMO Guidelines suggest that, both, the Individual and Societal Types of risk should be considered for the members of the crew, passengers, and third parties. Individual Risk can be regarded as the risk to an individual in isolation, while Societal Risk is regarded as the risk to the society of a major accident – an accident that involves more than one person. In order to be able to further analyze these categories of risk and their acceptance criteria, we must have a look at the levels of risk.

According to the Health and Safety Executive's (HSE, United Kingdom) Framework for the tolerance of risk, there are three regions in which risk can fall into (HSE, 2001). Unacceptable Risk (for example resulting from high accident frequency and high number of fatalities) should either be forbidden or reduced at any cost.

Between this region and the Acceptable Risk region (where no action to be taken is needed) the ALARP (As Low As Reasonable Practicable) region is defined. Risk that is falling in this region should be reduced until it is no longer reasonable (i.e. economically feasible) to reduce the risk. Acceptance of an activity whose risk falls in the ALARP region depends on cost-benefit analysis.

These regions are illustrated in the following figure.

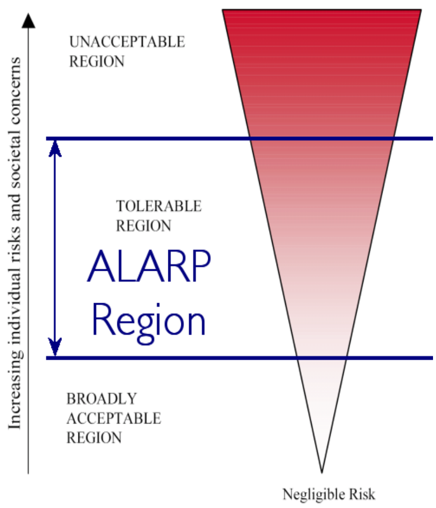


**Fig. 1: The ALARP Concept**

There is no single universal level of acceptable individual risk. The IMO's guidelines provide no Risk Acceptance Criteria; currently decisions are based on those published by the UK Health & Safety Executive (HSE, 1999). The HSE's criteria define the intolerable and the negligible risk for a single fatality as follows:

| | |
|---|---|
| Maximum tolerable risk for crew members | $10^{-3}$ annually |
| Maximum tolerable risk for passengers | $10^{-4}$ annually |
| Maximum tolerable risk for public ashore | $10^{-4}$ annually |
| Negligible risk | $10^{-6}$ annually |

Risks below the tolerable level but above the negligible risk (for crew members, passengers and third parties) should be made ALARP by adopting cost-effective RCOs.

We first note that in the recently adopted amendments to the FSA guidelines (see Annex 1 of document MSC 81/WP.8), it was made clear that all of these numbers are only indicative. Incredible as it may seem, neither the IMO nor any other rule-making body has yet reached a conclusion on what the values of these numbers should be. Therefore, the crucial issue of what are acceptable risk criteria for the safety of maritime transport is still very much open.

More fundamentally, we further note that the expression of these risk limits on an annual basis (instead, for instance, on a per trip basis) does not account for the number of trips per year undertaken by a person who travels by ship, a number that may vary significantly and one that surely would influence the level of risk someone is exposed to. The ratio of 10 to 1 between the maximum tolerable risk for crew members vis-à-vis the equivalent risk for passengers implicitly assumes that the former category makes roughly 10 times more trips than the latter, for the acceptable risk to be equivalent on a per trip basis. (Note that the crew willingly accepts the job-related risks.)

Another comment is that these risks, formulated in this way, seem to compare unfavorably to air transport, in which the most recently estimated probability of being involved in a fatal air crash is about 1 in 8 million per flight for 'First World' airlines (Barnett, 2006). This means that a maritime transport passenger is allowed an annual risk which is 100 times higher than that of an airline passenger who takes an average of 8 flights during the year (or, one roundtrip every 3 months), or even more than 100 times higher, when comparing with less frequent air travelers. Among some, such a comparison might raise the question if maritime transport travelers are second-class citizens as compared to air transport ones.

In any event, it is clear that additional analysis is necessary to define the risk acceptance criteria and to ascertain if a better 'risk exposure variable' can be found in maritime transport. If the expression of tolerable risk on an annual basis may present problems, as noted above, the fact that the number of flights (trips) was chosen as the most appropriate exposure variable for air transport does not necessarily mean that this should be adopted for maritime transport as well. Variables such as journey length or journey time may be more relevant for shipping, and these variables are something that should be examined.

## Conclusions

We believe that this paper has provided sufficient arguments noting that caution is necessary before the Safety Level Approach is fully integrated within the rule making process for maritime transport safety.

When the limitations of tools such as FSA are realized and measures are taken to improve the process , the full benefits will be reaped. In particular, the extension of FSA to environmental protection issues has to be performed with a view of these limitations, and a view to find ways to alleviate them, particularly if the results will be used for policy formulation.

Ongoing IMO work on the GBS methodology aspires to remove many of the current shortcomings of the scientific approach to maritime safety. In particular, the debate of how to bring the "Safety Level" (or "Risk-Based") approach within the GBS framework is only just starting. While it is still too early to draw conclusions, maybe the recommendations of this paper can be useful in such a process. From our part, caution is recommended, as we think it would be a mistake to rush through the GBS process before potential deficiencies in the FSA and other Risk-Based methodologies such as those identified in this paper are dealt with successfully.

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