GBS vs “Safety Level Approach”: contributing to the debate

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The debate

- Should a “safety level approach” be used in GBS?
- Should GBS be “risk based”?
- Should FSA be used in GBS?
- Should SRA be used in GBS?
- What are the linkages?
- Etc, etc
The debate

- Should a “safety level approach” be used in GBS? **YES**
- Should GBS be “risk based”? **YES**
- Should FSA be used in GBS? **YES**
- Should SRA be used in GBS? **YES**
- What are the linkages? **MANY**

- THE REAL QUESTION: **HOW, and WHEN?**
The need to be proactive

- **Proactive** safety regulations should be based on advance identification of risks and sound scientific justification before the policies are adopted.

- Much of the story thus far is quite the opposite, as many regulations have been adopted ad hoc in the aftermath of a catastrophic accident (e.g. after *Exxon Valdez*, *Estonia*, *Erika*, *Prestige* and so on).

- **The road from reactive to proactive:** FSA & GBS
FSA

- No doubt: FSA has been the premier scientific method to support proactive maritime safety regulation, at IMO and elsewhere

- BUT: Are there areas where FSA exhibits deficiencies (or glitches), which should be rectified?

- Answer: Of course!

- in what follows, only a sample will be presented
FSA steps (IACS – MSC 75)

FSA - a risk based approach

Preparatory Step

Step 1
Hazard Identification

Step 2
Risk Analysis

Step 3
Risk Control Options

Step 4
Cost Benefit Assessment

Step 5
Recommendations for Decision Making

presented at MSC 81, May 10, 2006
FSA Step 1 (HAZID)

OBJECTIVES

- to identify all potential hazardous scenarios which could lead to significant consequences, and
- to prioritize them by risk level
Possible “glitches”

- Use of frequency instead of probability breaks down if little or no data is available

- Risk index approach has “glitches”
In FSA, “frequency” is used instead of “probability”

BUT:

- Frequency ≠ Probability!
- Frequency = Probability only if historical data sample is large
- Basing analysis on historical data is not proactive
- What if there is no data?
- Eg, what is the probability of structural failure of a tanker built according to IACS’s new CSR?
## Frequency and severity indices

(MSC Circ. 1023)

### Frequency Index

<table>
<thead>
<tr>
<th>FI</th>
<th>FREQUENCY</th>
<th>DEFINITION</th>
<th>F (per ship year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Frequent</td>
<td>Likely to occur once per month on one ship</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Reasonably probable</td>
<td>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</td>
<td>0.1</td>
</tr>
<tr>
<td>3</td>
<td>Remote</td>
<td>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</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>1</td>
<td>Extremely remote</td>
<td>Likely to occur once in the lifetime (20 years) of a world fleet of 5000 ships.</td>
<td>$10^{-5}$</td>
</tr>
</tbody>
</table>

### Severity Index

<table>
<thead>
<tr>
<th>SI</th>
<th>SEVERITY</th>
<th>EFFECTS ON HUMAN SAFETY</th>
<th>EFFECTS ON SHIP</th>
<th>S (Equivalent fatalities)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minor</td>
<td>Single or minor injuries</td>
<td>Local equipment damage</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>Significant</td>
<td>Multiple or severe injuries</td>
<td>Non-severe ship damage</td>
<td>0.1</td>
</tr>
<tr>
<td>3</td>
<td>Severe</td>
<td>Single fatality or multiple severe injuries</td>
<td>Severe damage</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Catastrophic</td>
<td>Multiple fatalities</td>
<td>Total loss</td>
<td>10</td>
</tr>
</tbody>
</table>
Possible deficiencies

- 10 severe injuries equivalent to 1 fatality?
- No distinction for > 10 fatalities
- This means that 50, 100, 1000, 3000, or more fatalities are somehow equivalent to 10?
Risk index RI = FI + SI
(MSC Circ. 1023)

- Risk = frequency X severity

<table>
<thead>
<tr>
<th>FI</th>
<th>FREQUENCY</th>
<th>SEVERITY (SI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Frequent</td>
<td>Minor: 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Significant: 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Severe: 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Catastrophic: 4</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Reasonably probable</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Remote</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>Extremely remote</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>
Risk Index problematic

- Once a month (FI=7), an accident leads to an injury (SI=1). This means that RI=8.

- Within a year in a 1,000-ship fleet (FI=3), an accident leads to more than 10 deaths (SI=4). This means that RI=7.

Why is 2\textsuperscript{nd} scenario less serious than 1\textsuperscript{st}?
Diagnosis

- Concept of risk is inherently 2-dimensional (probability, consequence)
- But Risk Index is 1-dimensional
- Collapsing to 1 dimension loses much of relevant information
- Risk matrix assigns more importance to high-frequency, low-consequence events, and less to low-frequency, truly catastrophic events
The “Political risk”...

- is that regulations that are promulgated may be more tailored to high-frequency, low-consequence scenarios than to low-frequency, truly catastrophic scenarios.

- One would need a way to cover both cases.
Suggestions for FSA Step 1

- Use probability instead of frequency
- Use probabilistic modelling (from 1st principles) for cases with little or no historical data
- Use Bayesian approaches to update probabilities as data becomes available
- Maintain two-dimensional aspect of risk, or
- Revise/refine risk matrices (esp. for environmental consequences—see later)
FSA Step 4 (Cost benefit assessment)

- Most crucial and vulnerable step in FSA
- If one wants to manipulate FSA’s results, this is the usual step to do it

- $\Delta C =$ cost per ship of the RCO under consideration.
- $\Delta B =$ economic benefit per ship resulting from the implementation of the RCO.
- $\Delta R =$ risk reduction per ship, in terms of fatalities averted, implied by the RCO.
- $GCAF = \frac{\Delta C}{\Delta R}$
- $NCAF = \frac{(\Delta C - \Delta B)}{\Delta R}$
The $3M yardstick

An RCO is acceptable if

- GCAF < $3M
- NCAF < $3M

Among alternative RCOs that pass this test, the RCO with the lower CAF is preferable
Use caution!

- Hypothetical example

<table>
<thead>
<tr>
<th></th>
<th>ΔR</th>
<th>ΔC ($)</th>
<th>ΔB ($)</th>
<th>GCAF ($m)</th>
<th>NCAF ($m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCO1</td>
<td>0.10</td>
<td>100 000</td>
<td>90 000</td>
<td>1.0</td>
<td>0.10</td>
</tr>
<tr>
<td>RCO2</td>
<td>0.01</td>
<td>9 000</td>
<td>8 500</td>
<td>0.9</td>
<td>0.05</td>
</tr>
</tbody>
</table>

- both RCOs are acceptable, since GCAF<$3m and NCAF<$3m.
- RCO2 is superior to RCO1 in terms of both criteria.
- However, RCO1 reduces fatality risk ten times more than RCO2!
- The RCO that is selected as best is 10 times more risky than the one that is rejected!
Suggestions for FSA Step 4

- **Extreme caution** in calculating $\Delta R$, $\Delta B$, $\Delta C$!
- GCAF should have a hierarchically higher priority than NCAF.
- Examine NCAF, only if GCAF satisfies criterion.
- Caution with NCAF, especially if <0.
- Interaction among RCOs needs re-calculation of CAFs.
- **Utmost caution** in calculating environmental consequences! (more on this later)
FSA Step 5 (recommendations for decision making)

- What is a desired risk level?
- ALARP principle
## Individual risk acceptance criteria

The following criteria are broadly used in other industries and have been also published in HSE (1999).

<table>
<thead>
<tr>
<th>Decision Parameter</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower bound for ALARP region</td>
</tr>
<tr>
<td></td>
<td>Upper bound for ALARP region</td>
</tr>
<tr>
<td></td>
<td>Negligible (broadly acceptable) fatality risk per year</td>
</tr>
<tr>
<td></td>
<td>Maximum tolerable fatality risk per year</td>
</tr>
<tr>
<td>Individual Risk</td>
<td>to crew member</td>
</tr>
<tr>
<td></td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>to passenger</td>
</tr>
<tr>
<td></td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>to third parties, member of public ashore</td>
</tr>
<tr>
<td></td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>target values for new ships (*)</td>
</tr>
<tr>
<td></td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>Societal Risk</td>
<td>to groups of above persons</td>
</tr>
<tr>
<td></td>
<td>To be derived by using economic parameters as per MSC 72/16</td>
</tr>
</tbody>
</table>

Table 1: Quantitative risk evaluation upper and lower bounds
Comparison to air transport

- Chance of being involved in a fatal air crash: 1 in 8 million per flight on 1st world airlines (Barnett, 2006)
- Take a flight every day: expected time until death is 22,000 years
- Take 8 flights a year: annual risk of death is $10^{-6}$
- A ship passenger is allowed an annual risk 100 times higher? ($10^{-4}$)

- Are maritime transport travellers second class citizens?
FSA Steps 2 & 3 (Risk analysis and RCOs)

- Much of the same problems if based on frequency
- \( F = \text{No. of casualties}/ \text{Shipyears} \)
- \( PLL = \text{No. of fatalities}/ \text{Shipyears} \)
Example on how to link SRA and GBS

Failure mode: Longitudinal bending, hull girder failure, sagging (not a full ultimate strength assessment)

Analysis extensive
In fact..

- There is no “standard” SRA technique for ships yet
- Ships are not stationary. Their load variations are many
- Even though the example examines a very limited scope problem, the uncertainties and complications are many, requiring a large number of assumptions to arrive at some results
Risk analysis on ships

- Much more difficult problem than for stationary structures
- Calculating probabilities and consequences is not an easy task
- Same is true for translating these into risk acceptance criteria for all failure modes
MSC 81/6/3 by Japan

- Annex: Risk assessment committee, ISSC 2000
- Difficulty to model and quantify ship risk exposures (page 9)
- Inadequacy of data (page 12)
- Difficulty to quantify impact of human element (page 19 – Perhaps THE most important element for Safety)
- Similar observations from ISSC 2003

presented at MSC 81, May 10, 2006
Linking Risk Analysis with GBS
(for ship design & construction)

- GBS deals with individual failure modes
- A total “safety level” number as the goal must be developed and agreed.
- To do that we need to develop “safety levels” (risk acceptance criteria) for the individual failure modes.
- As stated this is not an easy task. It will involve a large project (much “simpler” RAC turn out not so simple and tricky – see the $ 60,000 for CATS)
Linking Risk Analysis with GBS cont’d

- Without risk acceptance criteria for individual failure modes there can be no real link with GBS.
- The results must be compared/calibrated with present knowledge (which is large for Tankers and Bulkers).
- To set the total goal “safety level”, the current “safety level” must be calculated first (not a small or easy task).
- The human element must be incorporated in the analysis in quantifiable terms.
To be meaningful and verifiable

- Any safety level number placed at the top of the pyramid as a goal has to be linked through a clear and transparent process all the way down to ship level.

- Thus, the safety requirements have to be linked clearly to the technology requirements for the design and construction of the ship.
According to Sørgård et al (1999)*, the likelihood of polluting the shores, in cases of structural failure, is 9.23%.

The failure mode subjected to analysis is failure in sagging condition, which corresponds to loaded condition of the ship.

The Cost of Averting a Tonne of oil Spilled (CATS), is taken to be $60,000.

*Sørgård et al (1999) was a joint DNV-NTUA report from EU project SAFECO II.
Environmental impacts as a function of accident type (1960 – 1997) (SAFECO II report, Fig. 38, page 61)
What is 9.23%?

- It is the probability of shore pollution given a structural failure AND an oil spillage.

- Structural failure can be in hull girder, side shell, bottom plate, etc, and mode can be bending, shear, torsional, etc.

- It is NOT the probability of shore pollution given a hull girder failure due to sagging (as per MSC/81.INF6).

- We actually expect the latter probability to be <9.23%.
The $60,000/tonne figure

- Cost to Avert one Tonne of Spilled Oil (CATS)
- A project SAFEDOR report estimates CATS at $60,000/tonne
- Lots of assumptions are used, and an extensive analysis is reported
- But the $60,000 figure stands out
- $60,000 is used in the Cost-Benefit Analysis of MSC 81/INF.6
Examples of assumptions used to arrive at $60,000 (SAFEDOR report page 55)

Per tonne cleanup costs assumed:
- constant with spill size
- independent of oil type, ie, a generic oil type is assumed
- constant within certain locations
- independent of all other factors!

None of these assumptions can really be justified
What $60,000/tonne means

- Prestige 4.9 billion dollars (1,633)*
- Braer 6 billion dollars (2,000)*
- Torrey Canyon 8.5 billion dollars (2,833)*
- Haven 9.9 billion dollars (3,300)*
- Amoco Cadiz 16 billion dollars (5,333)*
- Castillo de Bellver 17.8 billion dollars (5,933)*
- Atlantic Empress 19.7 billion dollars! (6,567)*

*equivalent fatalities
Suggestion

- The $60,000/tonne figure for CATS is totally unrealistic (or any other single figure for that matter)

- Additional work is required to develop environmental risk assessment criteria
Greece’s position

- GBS and “Safety Level Approach” should continue to run in parallel until
  - GBS for Tankers and Bulkers is finalized, so it can be used as the “testing ground” for the developed risk based approach
  - Issues on possible FSA deficiencies are dealt with satisfactorily
  - Risk analysis techniques for ship design (or its rulemaking) are further developed, tested and calibrated with present experience.

- Doing the opposite now runs the risk that progress on both GBS and FSA / Risk approach is delayed
References (selected)

- various MSC documents
For more info:

- [www.martrans.org](http://www.martrans.org)
- Section ‘document search’
- Page ‘maritime safety’
Thank you very much!