Formal Safety Assessment in Wonderland

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1 Introduction

Formal Safety Assessment (FSA) is the procedure by which most proposed regulation at IMO must be evaluated. FSA consists of a set of carefully prescribed steps ultimately resulting in a quantitative ranking determining which proposed safety measures are most cost-effective.

The basic premise of FSA is everything can be reduced to numbers. FSA in fact is little more than a detailed prescription for producing the numbers FSA needs to do this evaluation. Bureaucrats love FSA for it produces lots of workshops, expert groups, and mountains of paperwork. Special interests love FSA for anyone facile in the methodology can manipulate it to produce whatever result is desired. For the rest of us, FSA is a problem; for FSA has completely lost touch with reality.

Consider the latest offering: FSA–Crude Oil Tankers, submitted by Denmark, which will be considered at the meeting of IMO's Marine Environment Protection Committee in London, 6-10 October. This effort is an outgrowth of the EU Safedor project.

Among other things, it concludes that society should expend the resources needed to making tanker double bottoms higher and double sides wider. How did we get to this conclusion?

- We hide the real facts of tanker casualties behind a secret casualty database.
- We pretend that fire, collisions and groundings are causes not consequences.
- We make up the numbers we do not have.
- We ignore whatever collision penetration data we do have.
- We ignore basic physics in computing the cargo lost from grounding damage.
- We don't do any real structural analysis to determine the cost of these changes.
- We do no seakeeping analysis to determine the operational impact of these changes.
- We assume that killing one tanker man is the same as spilling 50 tons of oil.

Let's take a look at this process in a little more detail.

2 Hidden Data

The Danish FSA's major source of statistical data is the SAFEDOR tanker casualty database. But this data cannot be inspected or audited by any third party. This violates one of the most basic principles of science, including IMO's own guidelines for FSA. If anyone publishes some sort of summary or analysis of the casualty data, then anyone else should be able to go to the data and reproduce the same summary. If he can't, we don't have science; we have advertising.

This is not a hypothetical issue. One of the major results of the SAFEDOR database is that structural failure is not a particularly important cause of tanker deaths or spillage. One of the few public worldwide tanker casualty databases is that maintained by the Center for Tankship Excellence (CTX). [1] The CTX database claims that structural failure is by far the single most important cause

[1] The CTX database can be accessed at www.c4tx.org/ctx/job/cdb/prod/search.html.

of both tanker deaths and spillage. ***Why this fundamental, critically important difference?*** Anyone can examine the CTX database and see if they agree with the cause assignment casualty by casualty. No third party can do the same for the SAFEDOR data. We don't even know which casualties are in this database.

3 Confusing Cause and Effect

The designers of the SAFEDOR database made a fundamental error. The SAFEDOR database divides all tanker casualties into six major categories: collision, contact, grounding, fire, explosion, and the strangely named Non-Accidental Structural Failure (NASF). Then they treat these categories as "initiative events", in plain English, causes.[2]

There are two basic problems with this approach.

1. In the real world, casualties don't partition themselves into neat categories. Many casualties involve combinations of structural failure, fire, grounding, etc. The sequence: collision, fire, grounding is not uncommon. The NASSIA casualty in the Bosporus which killed 42 includes this sequence. Is the NASSIA a collision, or a fire, or a grounding? The correct answer is "all of the above'. And the correct answer for cause is "none of the above". The cause was a black out on the bulk carrier BC Shipbroker. Without electrical power, the Shipbroker had no steering, and turned into the Nassia.
2. Far more importantly, ***collision, grounding, fire/explosion are consequences, not causes.*** Something always happened first. The key question in any casualty is not whether it involved a collision, or a grounding, or fire but what caused these events. Treating something like grounding as a cause is doubly irrational. It shifts regulatory focus away from preventing the grounding in the first place and towards mandating grounding-proof ships, an impossibility. Blaming a spill on grounding is like blaming the earth for an airplane crash.

According to the SAFEDOR data, fire and explosion are very important "causes" both for deaths and spillage. But since we don't know what caused these fires/explosions, we can say nothing about how to prevent them. The CTX database claims that the most important cause of tanker fire/explosion is structural failure. Could it be that some of the missing NASF failures are listed as fire/explosion? Until we see the data, we simply don't know.

In the SAFEDOR data, collision is a surprisingly important "cause" of deaths. This might lead one to focus on improving bridge management and the like. But most of their 55 collision deaths must be from the NASSIA-BC Shipbroker (42 killed) and the NAGASAKI SPIRIT-Ocean Blessing (51 killed) collisions. [3]

In the former, the cause was a machinery failure on the BC Shipbroker. In the latter, the cause was piracy. The Ocean Blessing had been boarded by pirates. She was not under control. Her crew had either locked themselves in to avoid the pirates, or been locked in by the pirates. Either way they all fried in the fire, which occurred when she T-boned the Nagasaki Spirit. Almost all of the crew of the Spirit were then murdered for their watches and wallets after abandoning ship. We need to go beyond simple categorization. And that means examining individual casualties.

An extremely important result of SAFEDOR's confusion of cause and effect is that it totally obscures the importance of machinery failure in tanker spillage. According to the CTX database, machinery failure is second most important cause of tanker spillage. According to the guys who know, machinery failure is getting worse not better.[4] Listen to Captain Pierre Woinin of the Belgian Maritime Administration, talking about his 40 years at sea:

[2] The Safedor project was following standard practice in this regard. See Uses and Abuses of Ship Casualty Data for the sad history.

[3] In a strange bit of bureaucratic consistency, the FSA simply ignores people killed on non-tankers. 49 non-tankermen were killed in these two collisions.

[4] Almost all machinery failures do not make in into the worldwide databases. The frequency of machinery failures in the USCG MIX database in vessels under American pilotage is roughly 100 times higher than that in the worldwide databases. Numbers like this make a mockery of statistical analysis.

> During the first ten years of my career, we had very little trouble with our engine; a black out was exceptional and we spoke months about it. During the last ten years, I was happy if there was no black out for one week.

But according to the Danish FSA, we can ignore machinery failure because it cannot lead to loss of watertight integrity (LOWI), a stunningly obtuse statement which will come as a surprise to all the French oyster fishermen who were impacted by the by the AMOCO CADIZ, the Shetland Islanders whose sheep were sprayed by the BRAER, and all the volunteers struggling to clean up the Baltic after the BALTIC CARRIER/Tern collision; not to mention the dead seamen on the NASSIA, ESSO BRUSSELS, and others. Since machinery failure cannot lead to LOWI, there is no point in examining measures such as twin screw which would improve machinery reliability 1000-fold, not to mention improve low speed manoeuverability drastically, lack of which is implicated in a number of killer casualties including the ALVA CAPE andf CORINTHOS and big spills such as the OCEAN EAGLE andf AEGEAN SEA The Queen of Hearts would approve.

4 Making up Numbers

FSA is based on the premise that everything can be reduced to numbers. But for many of the most important marine safety issues, we don't have the numbers.

FSA's solution to this dilemma is simple. Make them up. This is done by the aptly named Delphi Method. A group of self-proclaimed experts is convened, and asked a question such as: what would be the percentage reduction in fatalities if we enforced additional hot work training? They each individually pull a number out of the air, and then they argue about it until they agree on a single figure. In this case, the figure they ended up with was 43. Then that figure is used just as if were a real number, as if we had a hundred thousand ship-year sample in which ships with the extra training had experienced 43% less fatalities than ships without. This number becomes crucial in determining whether the estimated benefits outweigh the estimated costs. Instead of open discussion and debate, society turns over important decisions to a handful of people operating behind close doors, who are responsible to no one, except possibly their employers.

Who were the experts that were asked the above and other questions in the Danish FSA? They were four mid-level DNV employees. I had never hear of any of these gentlemen; but, since they were experts, I figured I'd find all kinds of material on them on the web. In fact, I learned that one had been involved in a hydrodynamics patent application, another is an electronics service engineer with many years of experience, and nothing on the other two. Only one of the four, an ex-Master, is even claimed to have any special expertise in fire safety.

I have no reason to believe that these four guys are not honest professionals. But I don't understand why society should base important resource allocation decisions on their, or anybody elses, unsupported guesses. And the potential for manipulation is obvious.

5 Penetration

In attempting to analyse the impact of wider double sides on collision spillage, the first thing any reasonable person would do is examine whatever collision penetration data we have. As far as we know, the Safedor database has no penetration data, and the data that the Classification Societies have is hidden behind Class/Owner confidentiality agreements. One possible source is the CTX database.

Table 1 shows all the collisions in the CTX database for which we have an estimate of the depth of penetration.[5]

The sample size is very small, but the numbers are consistent with the fact that almost all tanker collisions fall into one of two categories:

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[5] A plus sign in the DOP column means "at least". I means the hull was indented but not penetrated. It is important to note one of the worst biases in this data. If the collision is so bad that the ship is sunk, we almost never have penetration data.

Table 1: Depth of Penetration in CTX Collisions

Struck Ship	D.O.P. m	Angle	Impact	Own Spd	Other Spd	Dead	Volume m3
eleni v	22		MS	14		0	5320
stolt dagali	21	80	AP			19	Y
nagasaki spirit	15		MP			51	14100
british vigilance	15	135	AP	14.5	12	0	0
agip abruzzo	14	110	AS	0	18	140	2800
esso greensboro	+14	90	MP	15	15	44	7000
tekton	11		M			0	600
burmah agate	11	35	AS	1	12	32	40500
maersk navigator	+10		MP			0	29400
arctic	9	90	A			4	?
tullahoma	8	90	AP		15	1	?
keytrader	6.1	50	FS			16	2790
jambur	+6		FS			?	3800
baltic carrier	6	50	AS			0	2900
venpet	+5	150	AS	15	13.5	2	34800
esso brussels	4.6	60	MS	A	15.5	16	5000
alva cape	3.6	90	FS	4	3	33	2066
high endurance	3	20	AP			0	0
genmar kestrel	+3		AS			0	1400
kaminesan	2	10	BP			0	0
esso chittagong	1	15	FP	1	7	?	Y
eagle milwaukee	I				6	0	0
bergitta	I		TP	12	18	0	0

- Low energy tug contact and the like in which the penetration if any is a good deal less than 2 m.
- High energy ship to ship in which case the penetration is almost always 5 m or more.

The Alva Cape/Texaco Massachusetts is an instructive exception. The Texaco Massachusetts a 16,000 dwt tanker in ballast moving at less than 3 knots hit the Alva Cape a 15,000 dwt tanker moving at less than 4 knots. It is hard to imagine a lower energy tanker to tanker collision, but even in this case we had nearly 4 m penetration.

The Danish FSA investigated the following double side tank widths.

SIZE	DWT	Current	Alt 1	Alt 2
Panamax	60,000	2.1	2.5	2.9
Aframax	100,000	2.2	2.6	3.0
Suezmax	150,000	2.5	2.9	3.3
VLCC	300,000	3.4	3.8	4.1

According to the CTX database, in the last 50 years there has been exactly one tanker collision where we know the depth of penetration in which these changes might have made a difference in the amount of oil spilled. That was the Genmar Kestral/Trijata side-swipe which spilled about 1200 tons.

But the FSA is not interested in facts. Instead it substitutes an IMO model which does not reflect this bimodal nature of penetrations. Worse this model assumes that the depth of penetration is proportional to the beam of the struck ship. In other words, a Panamax tanker (beam = 32.2m) has the same probability of 2 m penetration as a VLCC (beam = 58 m) has of a 3.6 m penetration.

This is nonsense. The depth of penetration in a given collision depends on the size of the striking ship, not the struck ship.[6] There is nothing in the CTX database that suggests bigger tankers suffer larger penetrations. In fact, the larger ship will have slightly less penetration in the same collision due to its bigger scantlings.

Why would anybody make such a crazy assumption? The IMO model was originally based on penetration data supplied by the Classification Societies. But Class would not furnish the data in its raw form for fear of breaching Owner-Class confidentiality. So they *non-dimensionalized* the data. In the case of transverse penetration, this meant dividing the real penetration by the struck ship's beam. In this manner, the ship's identity was hidden. No one outside a small portion of the IMO priesthood has ever seen the raw data. This means that the data is both unauditable and unusable. But IMO decided to use the data anyway. The only way they could do that was to make the totally unrealistic assumption that collision penetration is proportional to the size of the struck ship.

Until we have a completely public and open tanker casualty database, we will end up with regulation based on such twisted logic.

6 Grounding Outflow

The Danish FSA treatment of bottom penetration is doubly unrealistic. It is also based on unauditable, non-dimensionalized Class penetration data. This time, if the ship is twice as tall, the depth of penetration in the same grounding is twice as high. This bit of Wonderland is compounded by a badly misleading method of computing the outflow if a tank is breached. When the bottom of a double hull cargo tank is holed in a grounding, oil will flow into the double bottom until hydrostatic balance is reached in the cargo tank. The IMO mandated methodology that the Danish FSA uses to estimate the cargo tank outflow is not quite correct, but it is not seriously misleading for present purposes. [7]

The problem is in modelling what happens next. Like IMO, the Danish FSA simply assumes that 50 percent of the outflow is captured in the double bottom. In fact, almost none of the oil will stay in the double bottom. It will be displaced by heavier water. The oil in the double bottom will either be pushed out into the sea or up into the double sides depending on the height of the damage at the sides.[8] This phenomenon is independent of the height of the double bottom. But it is not independent of the width of the double sides. Wider double sides allow more oil to be captured. Paradoxically, double bottoms are nearly useless as a spill collection device in groundings, but double sides can be quite effective, even when the double bottom is badly damaged.

If society is really contemplating changing double bottom heights and double side widths, this fact should be front and central in the discussion.

7 Cost Estimates

To evaluate the cost of wider double sides and/or deeper double bottoms, we must estimate the life cycle cost of the additional steel, maintenance, power etc. To do this, a real world owner would ask a yard to do a preliminary design of the alternative ship and then compare that with the base ship. The owner would have to give the yard some guidance such as I want the same deadweight on the same draft at the same speed without any increase in air draft. The yard would then do the preliminary design work for a new ship whose overall dimensions would be different from the old. This would include a finite element analysis. The results would then be presented in detail together with some basic drawings, the additional steel, coated area, power etc. The owner's technical staff would then review all this for correctness.

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[6] The IMO model claims that it is impossible to have penetration deeper than 30% of the struck ship's beam. In fact, many of are worst collisions involve deeper penetrations. The 22 m beam Eleni V was cut in two.

[7] More precisely, not badly misleading for strandings. The FSA assumes all groundings are strandings. In the CTX database, roughly 20% of all tanker groundings are not strandings.

[8] See The Physics of Tank Spillage for details.

It is not clear exactly what the FSA did for it is not properly documented, nor checkable and certainly not repeatable. It appears they asked a naval architecture firm for an estimate of the additional steel weight associated with an extra half meter of double bottom and an extra 0.4 meter of double side for each of their four size categories. They got back eight numbers. Then they simply doubled these numbers for the 1m/0.8m increase.

This does not work for a number of reasons.

- A 0.5m increase in double bottom height or 0.4 increase in each double side is a massive change. The whole ship changes. Obviously, some combination of increase in depth, beam or length will be required to maintain deadweight and draft. Terminal restrictions may constrain one or more of those dimensions, especially depth. A change in any of these dimensions will affect scantlings all over the ship.[9]
- Even if this were not the case, you cannot assume that, if a 0.5 m increase in double bottom costs 100 tons of steel, a 1.0 m increase will cost 200. Very roughly, double bottom/side structure goes as the square of the double bottom/side height/width.
- Changes such as these will have a substantial impact on ship motions, especially roll. This is not good news, at least not for the double bottom. Double hull tankers already have poor roll characteristics. In the inelegant words of a senior Chevron STS mooring master "Double hulls roll like pigs". This is much more than a matter of crew comfort. Any additional motion imposes increased dynamic forces on the structure throughout the ship, may force course/speed changes and cost additional fuel/time, and poses a real problem for offshore lightering. The FSA did not examine this issue at all.

The most polite thing that can be said about the FSA's cost estimates is that they are amateurish and incomplete. Real engineering rarely plays much of a role in FSA's.

8 Valuing the Benefits

To evaluate the benefits, the Danish FSA values a life saved at $3,000,000 and a ton of oil not spilled at $60,000. Think about that for a minute. The FSA is acting as if a tankerman is worth 50 tons of spillage. [10] I have this vision of a crewman escaping from a breached tank only to look up and see the Mate closing the tank lid. The Mate says "Sorry, Fernando, but, if I don't close the lid now, we will lose another 51 tons of oil. So society is better off with you dead." Darkness.

No one in his right mind would make this decision. The authors of this study would not make this decision. Yet this is the valuation scheme on which the FSA is based. [11] At this point, the FSA has lost whatever tenuous grasp on reality it ever had. At this point, the FSA is no longer a horribly flawed study. It is just plain silly.

Unfortunately, this FSA is representative of most Formal Safety Assessments. FSA is as much an attitude as a methodology. It is the attitude of the accountant, not the naval architect. FSA

[9] This works both ways. The FSA also looked at additional sub-division, an excellent idea. This is much more than just adding a bulkhead as the FSA assumes. Shorter tanks means smaller sloshing loads. Narrower tanks imply shorter spans, reduced shear lag, and big savings in horizontal stringers and other transverse structure.

[10] This is a lot better than a non-tanker man who apparently is worth nothing at all.

[11] The result is that any tanker FSA is totally dominated by spillage. According to the CTX CDB, over the last 50 years, we have on average spilled 126,000 tons of oil annually and killed about 47 people in pure tanker, non-war casualties. Suppose RCO A can claim to reduce spillage by 2000 tons per year, less than 2% with no change in fatalities. Suppose competing RCO B could magically reduce deaths by 50% with no change in spillage. For similar costs, A is the clear winner with an annual benefit nearly double that of B. There is little point in even attempting to estimate lives saved in a tanker FSA. Lives simply don't count given this anthrophobic set of values.

Don't believe me? Suppose you have a tanker safety measure that costs a million dollars per ship. To install this RCO on the 5300 tankers over 10,000 dwt will cost 5.3 billion dollars. Assume a ship life of 20 years. For your RCO to survive the FSA Cost/Benefit analysis, you must be able to argue that the RCO will save 1767 lives in 20 years. But according to the CTX Casualty Database (CDB) in the last 20 years we've killed 592 people in casualties involving pure tankers over 10,000 dwt. So even if your RCO would save every life lost on tankers, it would not come close to qualifying. The costs are more than the benefits. To put it still another way, any proposed tanker safety measure that costs more than $335,000 per ship can immediately be thrown out, since even if it resulted in eliminating all tanker deaths, it would not meet the FSA Cost/Benefit test.

spends a great deal of time attempting to quantify the unquantifiable. FSA would have us focus on data we don't have, rather than the technology we do have. FSA emphasizes bureaucratic procedure over engineering, dubious numbers over judgement. FSA deflects attention and effort away from real problems and concrete solutions to barren and often non-disinterested manipulation of suspect statistics.

Let's ditch FSA and get back to real work.