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FORMAL SAFETY ASSESSMENT

Report of the Correspondence Group on Environmental Risk Evaluation Criteria

Submitted by Greece, on behalf of the Coordinator of the Correspondence Group

SUMMARY	
Executive summary:	This document reports on the outcome of the correspondence group on environmental risk evaluation criteria
Strategic direction:	12.1
High-level action:	12.1.1
Planned output:	12.1.1.1
Action to be taken:	Paragraph 29
Related documents:	MEPC 59/17, MEPC 59/17/1, MEPC 59/17/2, MEPC 59/INF.21, MEPC 59/24 and MSC 83/INF.2

Introduction

1 At its fifty-ninth session, the Committee recalled that MEPC 56 had noted that the one matter that needed consideration within the context of the Formal Safety Assessment Guidelines relevant to its work was the draft Environmental Risk Evaluation Criteria. In this connection, the need was recognized to carry out a more in-depth analysis of the proposed environmental risk evaluation criteria for the purpose of the Formal Safety Assessment (FSA) before inclusion of such criteria in the IMO FSA Guidelines (MSC/Circ.1023-MEPC/Circ.392, as consolidated in MSC 83/INF.2).

2 The Committee recalled further that MEPC 56 had recognized that environmental risk assessment criteria are still under development and there was limited experience in their practical application and subsequently had agreed to establish a correspondence group, under the coordination of Greece to further the work.

3 The Committee also recalled that while progress had been made on this subject since MEPC 56 through work carried out by the correspondence group, MEPC 58 recognizing that divergent views still remained on some key issues had agreed to retain this agenda item for MEPC 59, and for this purpose, had re-established the correspondence group under the coordination of Greece.

4 The Committee noted that MSC 85 had agreed, in principle, to establish an FSA Experts Group at MSC 86 and had invited Member Governments and international organizations to submit, to MSC 86, comments on the FSA studies for review and proposals regarding the terms of reference of the FSA Experts Group.

5 MEPC 59 considered the following four documents: MEPC 59/17 (Greece) which contained the work carried out in the intersessional period by the correspondence group; MEPC 59/17/1 (Japan), which provided comments on the draft report of the correspondence group and updated its earlier study presented at MEPC 58 (MEPC 58/17/1); MEPC 59/17/2 (Secretariat) which provided information on the progress made at MSC 86 within the context of Formal Safety Assessment which is relevant to the work of the Committee; and MEPC 59/INF.21 (Norway) which contained an analysis of various environmental risk evaluation criteria currently in use or proposed to be used in the future based on an analysis of the available oil spill costs and a comparison made between the existing cost estimation models.

6 The chairman of the correspondence group when reporting on the work undertaken in the intersessional period underlined that further progress had been made. Within the context of the CATS criterion, he pointed out that the group was able to reach an agreement in favour of criteria that are expressed on a cost-per volume of spilled oil. The group also agreed that a volume-dependent non-linear scale of a CATS threshold would be preferable to a single CATS threshold. He noted that apparent agreement had also been reached on the frequency matrix in the Hazid step, as well as on the issue of how to handle the issue of collection and reporting of relevant data. However, divergent views still remain on issues such as the severity matrix and the specific non-linear CATS scale, and more time was required to reach convergence on the key issues that are still open. As a result, no single set of recommendations could be proposed at the time which will address all the key TORs of the group and to which all the group members subscribe. There is general recognition among members of the correspondence group that more time is needed to discuss the various proposals with some members suggesting that the establishment of a Working Group during MEPC would be beneficial.

7 Taking into account the Committee's need to complete this work as early as possible in 2010, the Committee agreed to establish a Working Group on Environmental Risk Criteria at MEPC 60.

8 MEPC 59 noted that more time was needed to discuss the issues which seemed more complex than originally thought and so as to pave the way for the work of the working group at MEPC 60, also agreed to re-establish the correspondence group to prepare a basic document under the coordination of Professor Harilaos N. Psaraftis (Greece), with the following Terms of Reference:

> Using documents MEPC 59/17, MEPC 59/17/1 and MEPC 59/INF.21 as a basis, as well as taking into account the comments received at MEPC 59, the correspondence group was instructed to:
>
> .1 recommend in Step 4 of the FSA an appropriate volume-dependent CATS global threshold scale or function for ascertaining if a specific Risk Control Option (RCO) is cost-effective, including its integration within the FSA methodology;
>
> .2 recommend a way of combining environmental and safety criteria for those RCOs that effect both environmental and fatality risks;
>
> .3 conclude on an appropriate risk matrix or index for environmental criteria;

.4 recommend an appropriate ALARP region and F-N diagram, including an appropriate value for the slope of the F-N curve;

.5 address the issue of collection and reporting of relevant data;

.6 prepare draft terms of reference for a working group at MEPC 60; and

.7 submit a written report to MEPC 60.

9 MEPC 59 invited Member States and other interested parties, in particular members of the FSA Expert Group established at MSC 86, to participate in the work of the correspondence group so that a report with concrete recommendations can be prepared for MEPC 60 with a view to reaching well-founded conclusions.

10 Following MEPC 59, the following Member States participated in the work of the correspondence group: China, Denmark, France, Germany, Greece, Japan, Malaysia, the Netherlands, New Zealand, Spain, Turkey, the United Kingdom and the United States. The following non-governmental organizations also participated: BIMCO, IACS, INTERTANKO and OCIMF.

Method of work

11 Work after MEPC 59 involved two rounds of submissions. The members-only website already created for the work of the correspondence group since MEPC 57 was maintained, with submissions and supporting material added for its work for MEPC 60. A draft version of the report was circulated to its members for final comments or corrections before the compilation of the final report.

First round of submissions (MEPC 59 to 26 October 2009)

12 First round submissions were received by Japan, the United States and Greece. These are included in their entirety in annex 1 to this document and are summarized as follows.

13 Japan commented on TOR 1 and stated that a function-type CATS threshold is reasonable and effective and that the value of the assurance factor should be discussed. Japan also offered some comments on Norway's document MEPC 59/INF.21, stating that the SAFECO data used in the analysis should be disclosed, raising the concern that the value of 54,551 USD/tonne (expected value of total spill cost), being the 80th percentile of the log-normal distribution, is less appropriate to use than the distribution's median. As regards the TOR for the working group that would convene at MEPC 60, Japan proposed that the TOR of the correspondence group be forwarded to the working group, without precluding additional TOR. Japan also suggested that TOR 3 and 4 should be discussed before TOR 2.

14 The United States commented on Japan's document MEPC 59/17/1 and on Norway's document MEPC 59/INF.21. On Japan's document, the United States supported Japan's recommended use of volume-dependent CATS approach and found the proposed formula to be reasonable, but expressed concern over the low volumetric valuation used in the formula. The United States also expressed the opinion that a step-type CATS can be more expedient to use and verify, but agreed that a function-type would potentially be more accurate. As regards Norway's document, the United States expressed concern on the use of the 63,338 USD/tonne value as opposed to the 81,585 USD/tonne value derived by Norway, stating that values as high as 407,000 USD/tonne have been encountered in US spills. The United States also commented on some of the assumptions used by Norway, on the use of 1.5 for the ratio of compensation to clean-up cost, and on the value of 1.5 proposed for F, to include the insurance factor.

15 On TOR 1, Greece stated its preference for a function-type criterion versus a stepwise approach and expressed its support for the type of function proposed by Japan. On TOR 2, Greece agreed with Japan that TOR 2 should be discussed after TOR 3 and 4 have been agreed, and recalled that a proposal on TOR 3 had already been put forward by the coordinator of the correspondence group: use the same frequency matrix as already used in FSA and for the severity matrix, use spill volume as the severity variable. Greece proposed that all TOR should remain for the working group to be established at MEPC 60. Greece also commented on Norway's submission, questioning the 54,390 USD/tonne figure, the average of the ratio "spill cost/spill volume" for a log-normal distribution. As this corresponds to the 80-percentile of the distribution, Greece agreed with Japan that this is not realistic. What should be looked at is not the average of the ratio, but the ratio of averages, that is, total spill cost by total spill volume, which Greece speculated to be much lower. The fallacy of using E(c/v), the average of the ratio of spill cost by spill volume, instead of E(c)/E(v), the ratio of the averages was pointed out.

16 In addition to the above, the coordinator of the correspondence group circulated to the correspondence group, as this was considered relevant to its deliberations (and in particular to TOR 1), an NTUA research paper (Kontovas, *et al.*, 2009) reporting on empirical analyses of IOPCF data. Regression analyses of clean-up costs and total costs have been carried out, after taking care to convert to current prices and remove outliers. This document is included in annex 2 to this document.

Second round of submissions (27 October to 25 November 2009)

17 Second round submissions were received by IACS, the United States, Greece, the United States again, and Japan in that order. These are included in their entirety in annex 3 to this document and are summarized as follows.

18 IACS expressed the belief that there is now consensus that the associated costs of an oil spill, when expressed in terms of per tonnes spilt, change with the volume spilt and that the Japanese calculations present a reasonable investigation in to what these post-spill costs are. However, IACS also expressed concerns that the data Japan used may be under reporting the cost primarily because of their provenance. IACS believes there is still some way to go in discussing the utility function that should be applied in order to best encapsulate the risk aversion of society to oil spills. IACS suggested several forms of such a utility function.

19 The United States agreed with IACS regarding the results of the Japanese calculations and on the recommendation that the correspondence group look at willingness to pay as a function of spill volume. It recommended further that members of the group be prepared to present data and research on the nature of this relationship at MEPC 60. The United States also posed some questions on the NTUA paper (see annex 2) and made some additional comments on Japan's document MEPC 59/17/1, by referring to four spills in the United States with costs per unit volume much higher than those presented by Japan.

20 Greece commented on the United States submissions by pointing out that we are looking for a global average and it is clear that one cannot use extreme values or even regional averages (which for the United States are expected to be very high). Also designing for the worst case is not within the scope of IMO or even class rules. A hypothetical threshold of 400,000 USD/tonne would certainly lead to radical changes in tanker design. Greece also commented on the IACS submission, by agreeing on the need to look into society's risk aversion, but expressing the concern that this may detract from the immediate work of the correspondence group. Greece also noted the similarity of the three regression formulae, by Japan, Norway and the NTUA research team, and wondered if the final formula would converge in this neighbourhood.

21 A response on the issues raised by the United States as regards the paper set out in annex 2 was circulated by the coordinator (see annex 3).

22 After a question by Japan, the United States provided a table of the four US spills cited in their latest submission, showing spill volume, cost, and other relevant information.

23 Japan proposed that member countries provide references or other examples as regards the assurance factor. It also supported comments by Greece on using extreme values or even regional averages and that designing for the worst case is not within the scope of the FSA framework at IMO. It also shared the view by Greece, that the three regression formulae seem to converge and the final formula may be close to them. Japan also commented on the use of IOPCF data and welcomed the submission by the United States of the four spill cases, noting that it would be appreciated if this could be done for all spills occurring in the United States. Japan provided some comments on the frequency and severity matrices (TOR 3) and on the F-T curve (TOR 4), suggesting that more information and discussion are necessary to resolve these issues. Japan proposed that the ALARP region can be determined in a consistent way with safety FSA, that is, taking into account the economic magnitude of an intended activity (such as oil transport by tankers).

Conclusions

24 Just before the start of the work of the Working Group on Environmental Risk Evaluation Criteria that will convene at MEPC 60, it is fair to say that no final conclusions have been reached by this correspondence group that can be put for approval by MEPC 60. However, it is also fair to say that substantial progress has been accomplished by the correspondence group since MEPC 56 in terms of identifying the most important issues on this difficult topic and paving the way for the deliberations of the working group. In addition to the present document, documents MEPC 57/17, MEPC 58/17 and MEPC 59/17 capture what transpired within the correspondence group since MEPC 56. In that respect, the coordinator wishes to express his sincere appreciation to the members of the correspondence group for their contributions thus far and to the IMO Secretariat for their assistance.

25 In terms of what was mainly achieved, this can be summarized as follows:

.1 after extensive exchanges, the correspondence group has reached consensus that environmental risk evaluation criteria should be expressed on a cost per volume of spilled oil basis. These were long and difficult because the pros and cons of other factors such as oil type, spill location and others were also discussed extensively;

.2 also after much discussion, the correspondence group agreed that a volume-dependent non-linear scale or function of a global CATS threshold is preferable to a single CATS threshold. This, in and of itself, may be the most important point of convergence within the correspondence group since its inception. It is also the one that more than highlights the degree of difficulty of the overall problem;

.3 apparent agreement has also been reached on the frequency matrix in the Hazid step, which was proposed to be the same as in the safety FSA; and

.4 there is also general consensus on the issues pertaining to the collection and reporting of relevant data.

26 In terms of the specific TOR of this correspondence group for MEPC 60, further convergence seems to have been reached on the form of the non-linear function of total spill cost versus volume (TOR 1). The work of Japan, Norway, as well as that of the NTUA research group, all conducted independently but leading to very similar functions, may form the basis of the discussion within the working group, particularly as regards TOR 1, which is still the most important point of contention. The points raised by IACS and the United States on the second round of submissions are also noteworthy, although a concern was raised by Greece that consideration of these points should not prolong a discussion that is already ongoing and is approaching three years. No objection was also raised to the proposal of Greece on TOR 3, to use the same frequency matrix as used in the safety FSA. But there was insufficient discussion to conclude on all these points and all of the remaining issues seem to merit additional discussion.

27 The correspondence group was also tasked (TOR 6) to prepare draft Terms of Reference for the Working Group that will convene at MEPC 60. Japan and Greece proposed the same TORs as those for the correspondence group (with the obvious exception of TOR 6), with additional TORs not being excluded. As no delegation objected, this is hereby being put forward as a proposal to the Committee. To that effect, it is proposed that the working group to be formed at MEPC should have draft Terms of Reference that include the following:

> "Using documents MEPC 59/17, MEPC 59/17/1 and MEPC 59/INF.21 as a basis, as well as taking into account the comments received at MEPC 59, the discussion within the CG after MEPC 59, as well as any other relevant information, the Working Group is instructed to:
>
> .1 recommend in Step 4 of the FSA an appropriate volume-dependent CATS global threshold scale or function for ascertaining if a specific Risk Control Option (RCO) is cost-effective, including its integration within the FSA methodology;
>
> .2 recommend a way of combining environmental and safety criteria for those RCOs that effect both environmental and fatality risk;
>
> .3 conclude on an appropriate risk matrix or index for environmental criteria;
>
> .4 recommend an appropriate ALARP region and F-N diagram, including an appropriate value for the slope of the F-N curve;
>
> .5 address the issue of collection and reporting of relevant data; and
>
> .6 submit a written report to MEPC 60."

28 There was a proposal by Japan (seconded by Greece) that TOR 3 and TOR 4 should be discussed before consideration of TOR 2. There was insufficient discussion on this issue and it is being suggested that this proposal be put forward to the working group for its consideration. It is recalled that a proposal on TOR 2 has already been put forward (see MEPC 59/17, paragraph 22).

Action requested of the Committee

29 The Committee is invited to consider the information in this document and decide as appropriate. In particular, the Committee is invited to approve the proposed draft Terms of Reference for the Working Group on Environmental Risk Evaluation Criteria that will convene at MEPC 60.

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ANNEX 1

FIRST ROUND OF SUBMISSIONS (MEPC 59 to 26 October 2009)
Listed by chronological order of receipt
(receipt dates are in parentheses, text reproduced as received)

Japan (22/10/2009)

TOR 1 recommend in Step 4 of the FSA an appropriate volume-dependent CATS global threshold scale or function for ascertaining if a specific Risk Control Option (RCO) is cost-effective, including its integration within the FSA methodology;

1. $CATS_{thr}$ criteria

As for TOR 1 Japan and Norway has already submitted the documents (MEPC 59/17/1, MEPC 59/INF.21), which describe discussion about volume-dependent $CATS_{thr}$ criteria.

TOR 1 says to "recommend an appropriate volume-dependent $CATS_{thr}$ global threshold scale or function for ascertaining", this means to focus on (a) function-type $CATS_{thr}$ or step-type $CATS_{thr}$., (b) reasonable environmental/assurance factor.

For the purpose, we believe that we could concentrate our discussion on the figure 1 of MEPC 59/17/1, which includes function type $CATS_{thr}$ and factor, and which could describe any appropriate step type CATS on that figure. So, we would suggest the figure could be work sheet for TOR 1 for members' discussion.

As for item (a) Japan believes a function-type $CATS_{thr}$ is reasonable and effective, detail of which is well discussed in Japanese submission (MEPC 59/17/1). Although a value of 1.5 is proposed as an assurance factor by SAFEDOR. Japan would think that we should discuss whether 1.5 is reasonable or not. Moreover, Japan would like to seek another proposal or idea about these factors. Therefore, Japan would like to suggest to ask CG members to make comments to these documents as well as these topics as a starting point of the discussion.

2. Comments to MEPC 59/INF.21

As for MEPC 59/INF.21, Japan would like to appreciate the contribution by Norway since the paper would contribute a lot to our discussion with regard to environmental risk evaluation criteria. Japan would like to make several comments about MEPC 59/INF.21.

(a) Japan has submitted IOPCF report to the last FSA-CG as a verification basis of Japanese submission (MEPC 58/17/1). Since IOPCF report is open to public, Japan would understand that to use IOPCF database makes our discussion transparent. MEPC 59/INF.21 fitted cost of oil spills per unit ton (C/W) with lognormal distribution. However, we could not verify the analysis since they added another database (SAFECO) on IOPCF database. Therefore it is needed that all the SAFECO data should be disclosed to IMO as an official document in order that CG members could verify the results.

(b) This document carried out similar regression analysis as carried out by Japan (MEPC 58/17/1). Moreover this document showed that costs of oil spill per unit ton is volume-dependent (Figure 5) and similar regression formula as Japan (Eq.6) was derived. However results of this paper do not adopt a volume-dependent $CATS_{thr}$ but propose constant $CATS_{thr}$. Since investigation of statistical data shows oil spill volume dependency of oil spill costs, and since application of a volume dependent CATS is concretely proposed in the submission by Japan (MEPC 59/17/1), Japan would believe it is reasonable to use a volume dependent $CATS_{thr}$. Moreover, a volume dependent CATS has already been agreed by majority of members in the last CG as well as MEPC 59. Moreover, TOR 1 of the present CG is "to recommend in Step 4 of the FSA an appropriate volume-dependent CATS global threshold scale or function for ascertaining if a specific Risk Control Option (RCO) is cost-effective, including its integration within the FSA methodology". Therefore Japan would think that it is reasonable to adopt a volume-dependent $CATS_{thr}$.

(c) In MEPC 59/INF.21 the cost of oil spill per unit ton is assumed to follow a lognormal distribution and an expected value of the lognormal distribution is estimated (=54,551US$/ton). Moreover, the value of 54,551 US$/ton is proposed as a basic $CATS_{thr}$ value. However, if we think about lognormal distribution, it can be pointed out that expected value is not always representative value of the distribution as described by many statistics text book. Instead the median can be used as a representative value of lognormal distributions mainly due to characteristics of lognormal distributions. In fact expected value of the present lognormal distribution corresponds to about 80th percentile as shown in figure 6 of MEPC 59/INF.21 (see following figure). This means that 80% of data is below this expected value. That is, very few irregular values might make expected value high. It is noted that even median of the distribution is adopted as $CATS_{thr}$, this is not a volume dependent $CATS_{thr}$ but constant $CATS_{thr}$.

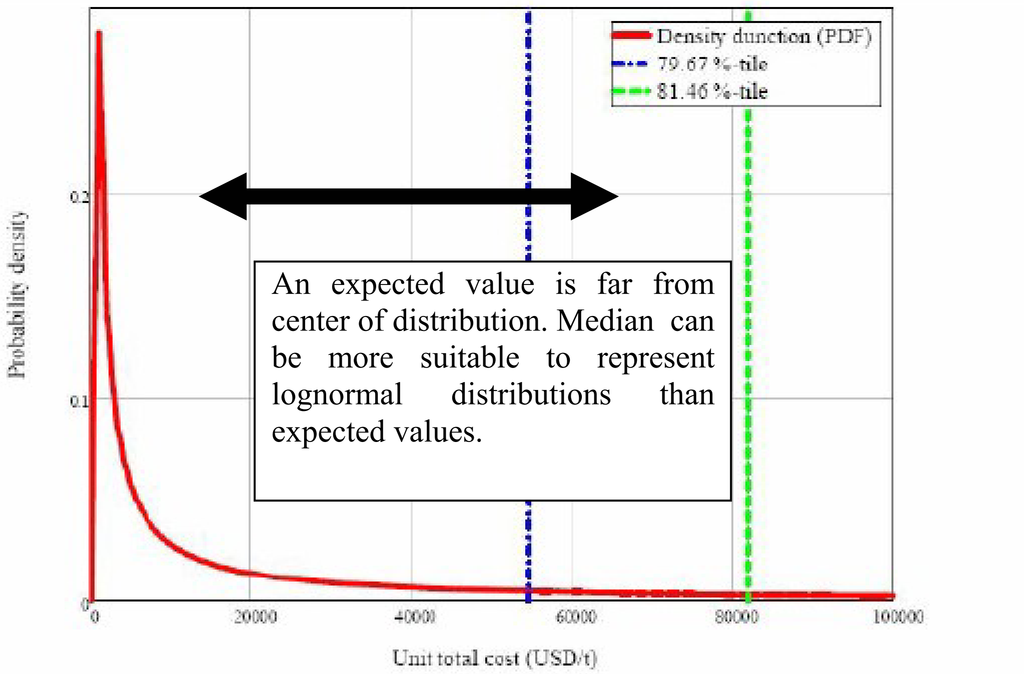

Figure 6. Percentiles of the lognormal distribution

Figure 1: Figure from MEPC 58/INF.21

(d) Based on statistical analysis of IOPCF data as well as previous research, it is apparent that the costs of oil spill per unit ton decrease as the weight of spilt oil increases as shown in figure 2. That is, larger oil spills are less expensive per unit ton oil spilt than smaller oil spills. An updated regression formula derived from IOPCF report (2007) is described below. According to the regression formula $CATS_{thr}$ value of 54,551 [US$/ton] corresponds to relatively very small oil spills (W=0.108 [ton]), which means that using constant $CATS_{thr}$ of 54,551 [US$/ton] would impose too excessive $CATS_{thr}$ value against larger oil spills. Therefore Japan would think it is reasonable to use oil volume-dependent $CATS_{thr}$ instead of constant $CATS_{thr}$. Derivation of volume-dependent $CATS_{thr}$ and its application to FSA are described in MEPC 58/17/1 and MEPC 59/17/1, respectively.

regression formula: $\dfrac{dC}{dW} = 25441 \cdot W^{-0.34}$

if W =1 ton dC/dW = 25,441[US$/Ton]
dC/dW = 54,551 [US$/ton] corresponds to W = 0.108 [ton]

(Example)
<u>Volume-dependent CATSthr</u>

If we are thinking about an oil spill risk of 20,000[ton], the cost of oil spill per unit ton can be dC/dW = 877 [US$/ton], consequently risk R1 [US$] can be calculated as 20,000 x 877 = 17,540,000[US$]. Assuming that an RCO could reduce risk of 20,000 [ton] to 10,000 [ton], the corresponding cost of oil spill per unit ton can be dC/dW = 1,100 [US$/ton]. Consequently risk R2 [US$] can be calculated as 10,000 x 1,100 = 11,000,000 [US$]. This RCO is regarded as cost-effective if the cost of this RCO is less than the benefit of R1-R2 = 17,540,000 - 11,000,000 = 6,540,000 [US$].

<u>Constant $CATS_{thr}$ = 54,551</u>

R1-R2=(20,000[ton]-10,000[ton]) x 54,551 [US$/ton] = 545,510,000 [US$]

This RCO is regarded as cost-effective if the cost of RCO is less than 545,510,000 [US$]

A ratio of 545,510,000 [US$] and 6,540,000 [US$] is about 83. This means that the cost of RCO in using constant $CATS_{thr}$ would be 83 times larger than that in using volume dependent $CATS_{thr}$ although the RCO is the same. It is pointed out that this ratio would increase as risk reduction [ton] obtained by the RCO increases.

Japan would believe it is important to reduce the risk of oil spill from ships, at the same time, Japan would believe it is very important to identify the difference between these two methods since the effect of $CATS_{thr}$ on the judgment of RCOs is significant. Considering (i) the cost of oil spill per unit ton decreases as the oil amount decreases based on statistical analysis, (ii) the difference between these two methods is significant, Japan would believe that it is reasonable to adopt volume dependent $CATS_{thr}$ in environmental risk evaluation criteria.

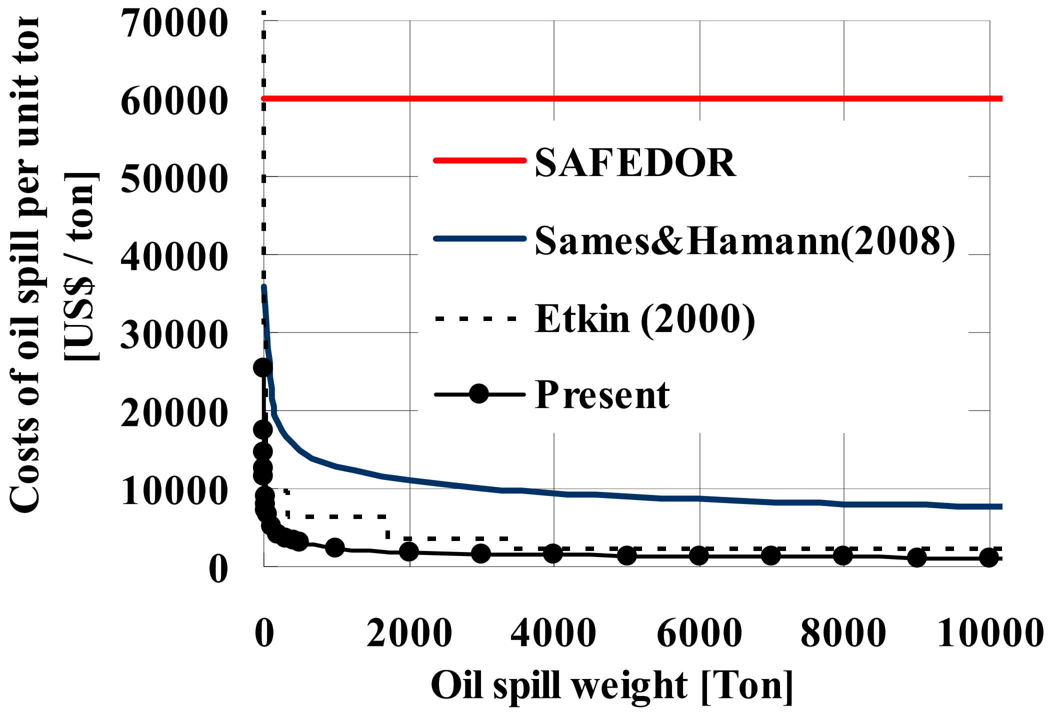

Figure 2: Costs of oil spill per unit ton

TOR 2 recommend a way of combining environmental and safety criteria for those RCOs that effect both environmental and fatality risk;

TOR 3 conclude on an appropriate risk matrix or index for environmental criteria;

TOR 4 recommend an appropriate ALARP region and F-N diagram, including an appropriate value for the slope of the F-N curve;

TOR 5 address the issue of collection and reporting of relevant data; and

TOR 6 prepare draft terms of reference for a working group at MEPC 60.

3. Proposal of TOR of the MEPC 60 FSA-WG

Japan would think that TOR which were not solved in the present correspondence group should "at least" be directly forwarded to the TOR of MEPC 60 FSA-WG. However, it should be noted that another TOR should be still open to discussion.

When we look at TORs, we suppose that TOR 3 and TOR 4 should be discussed before consideration of TOR 2. That is, severity index and ALARP region should be solved before combining environmental and safety criteria. In the case that CG members would share the view, Japan would try to make further contribution on SI and ALARP within the correspondence group.

United States (26/10/2009)

United States Comments to MEPC 59/17/1 – Submitted by Japan

We appreciate the work of Japan and value the opportunity to comment. The United States believes that our comments provided on 11 February 2009, comments to MEPC 58/17/1, still apply, and would like to add the following to that submission.

1. Volume dependent approach

The United States supports Japan's recommended use of the volume dependent "costs of averting a ton of oil spilt (CATS)" approach. We believe this approach to be consistent with the recommendations of the correspondence group and previous submissions by the United States.

2. Proposed volume-dependent formula

The United States finds the proposed volume-dependent formula to be reasonable and consistent with concepts we've seen in terms of fixed versus variable costs. However, while the formulation is believed to be appropriate, we do have concern over the low volumetric valuation used in the formula.

Additionally, we recommend that Japan demonstrate that all of the assumptions necessary of a regression analysis (e.g., independence, normality, homoscedasticity) hold in this case.

3. Use of "function-type" for volume-dependent CATS

While the United States concurs that a "function-type" CATS is more accurate, it has been our experience that a "step-type" CATS can be more expedient to use and verify. The United States recommends that the correspondence group evaluate the advantages and disadvantages of each approach, considering other IMO practices, and make recommendations.

United States Comments to MEPC 59/INF.21 – Submitted by Norway

1. CATS Value

We appreciate the work of Norway and value the opportunity to comment. The United States agrees that the higher CATS value/range recommended by Norway to be more accurate than that recommended by others, and we have submitted some results of US research in this regard to the correspondence group. However, this strictly monetary approach may be flawed if it does not account for damaged resources and potential lost profits, etc. (which are typically not captured in recovery and clean-up costs).

We further agree with Norway's recommendation of a CATS value that is dependent on accident type. It is the experience of the United States that different event types have differing spill costs. Additionally, while the shape or form of distribution (lognormal) is somewhat logical, the parameters (mean) are low compared to US historical evidence.

Furthermore, it is unclear why Norway recommended using the lower CATS target value of USD$ 63,338/t vice the USD $ 81,585/t developed in the Norway research (page 9 of the annex). Specifically, Norway notes, "it is advisable that the lower alternative as provided by Skjong, *et al*. should be preferred," but does not provide any justification. This value is dramatically below some of the US' experiences, which include the Tank Barge Bouchard No.120 and M/V Cosco Busan, which had costs of $121K/t and $407K/t respectively, as relayed in the correspondence group report, annex 1, page 5.

In addition, we identified oil spill incidents (2002-2007, 672 incidents) that required expenditures from the Coast Guard's Oil Spill Liability Trust Fund. This revealed an average expenditure of about USD $80,630/t. This estimate also does not include all costs, such as damage resources and lost profits, etc.

2. Assumptions

The list of assumptions provided by Norway appears to be incomplete. Other assumptions that appear to be missing include:

(a) The use of the ratio of Marine P&I Premiums to Claims as a proxy for societal premium on preventing oil spills.

(b) Total spill cost is made up of clean-up and compensation costs only. The United States approaches to characterizing spill prevention include cost components that include: market value of lost oil, response costs, damage to the vessel, environmental damages, third party costs, and legal damages. As noted in the 2004 USCG report provided to the correspondence group, one cause for variation between studies in estimates for total costs is that no single study (researched in the 2004 report) included each of these cost components in developing their estimates.

3. Use of compensation to clean-up ratio of 1.5

There are several aspects associated with the use of the compensation to clean-up ratio to estimate total spill cost. First, the data presented in Table II on page 8 (Sirkar and Liu & Wirtz) show the ratio of Compensation to Clean-up to be greater than 3, however, the end conclusion (text accompanying Table II and Figure 7) points to the ratio of Compensation to Clean-up to be approximately 1.5, without explaining why the lower value was used. It should be noted that in our research (USCG 2004), we looked at 5 studies, 2 of which had Compensation to Clean-up ratios greater than 1.5, 2 of which had Compensation to Clean-up ratios less than 1.5, and one at 1.5 (the average across the 5 studies we looked at was 1.56).

However, the even bigger concern is the use of this ratio of Norway represents Compensation to Clean-up as 1.5, which translates to Compensation = 1.5 * Clean-up. When that relationship is inserted into the formulation for Total Cost of an Occurred Spill, the value would appear to be underrepresented. Specifically, if Total Cost of an Occurred Spill = Clean-up Cost + Compensation Cost = Clean-up Cost + 1.5 * Clean-up Cost, then Total Cost of an Occurred Spill should = 2.5 * Clean-up Cost, and not the 1.5 * Clean-up Cost recommended by Norway. The United States welcomes clarification on this point.

4. <u>The value of 1.5, proposed for F, to include the insurance factor</u>

The proposal by Norway to use the ratio of Insurance Premiums/Claims to represent societal willingness (premium of Cost to Avoid/Cost Experienced) to pay to avoid a spill, bears further deliberation as it is not clear that this is a reasonable proxy. Insurance claims are representative of the risk tolerance of insurers to exposure to total loss (i.e. focusing on the expected net claim as a function of event likelihoods and outcomes as well as offsetting premiums), and not to societal risk tolerance., which may include this insurance factor is part of it, but would likely include other variables.

The underlying characteristics of insurance premiums understate societal willingness to pay. Insurance premiums reflect finite risk or the liability limit faced by the insured, versus infinite risk or the short and long-term consequences faced by society. Insurance premiums also ignore other factors such as income, which has a noteworthy role in societal willingness to pay to avoid these consequences.

Greece (26/10/2009)

TOR 1 recommend in Step 4 of the FSA an appropriate volume-dependent CATS global threshold scale or function for ascertaining if a specific Risk Control Option (RCO) is cost-effective, including its integration within the FSA methodology

In the opinion of Greece the TOR, by ***requiring*** a volume-dependent CATS, excludes any single figure. That is what MEPC 59 decided (correctly in our opinion). A single figure is a constant CATS; not a volume dependent CATS. This is also pointed out by Japan in their recent contribution to CG.

Thus our options are practically two:

a) a step function (e.g., a figure for 0-10 mt spill, another for 10-100 mt, etc.); or
b) a function type criterion.

On this subject Greece, about a year ago, expressed the following thoughts:

Quote

The view from Greece is as follows:
It seems all agree on at least 2 things:
1. We need at least a stepwise threshold function
2. This is mainly because small spills are more expensive per ton.
Obviously we have not agreed on values yet.
However, as we expressed in our previous message to the WS participants, we also think that using a nonlinear formula, such as that by Japan, will be more appropriate and easier to use in FSAs.
For one thing, whatever stepwise values are decided, say 1-100 mt, 100 -1,000 mt, 1,000-10,000 mt etc., there will always be the problem how to treat a hypothetical spill near the steps e.g. a spill of 1,000 mt or abt 1,000 mt. Will it be in the 100-1,000 CATS value range or the reduced 1,000-10,000 mt value?
This problem is not there if a formula is used.

Unquote

Following the encouraging work by Japan which demonstrated to our satisfaction the accuracy of their regression analysis, we would support the <u>type of function</u> proposed by Japan. A function derived from a correct regression of <u>appropriate</u> dataset, seems the most realistic/accurate criterion and it will be simple to use in FSA. In examining potential RCO's, the authors of FSA would simply plug in expected or investigated spill sizes to obtain the appropriate cut-off value.

This will also allow examination of RCOs which may be cost effective for small spills but not cost effective for large ones and vice versa.

On the results of the Japanese function: As we stated above, one single figure for CATS has been rejected by MEPC 59. Nevertheless we want to remind that all analyses we have seen from various studies (as well as the preliminary analysis of Greek spills which we mentioned in the past) suggest a CATS figure for medium and large size spills of an order of magnitude smaller than the originally proposed figure of $60,000/mt. Figure 2 of the contribution by Japan is quite revealing.

TOR 2 recommend a way of combining environmental and safety criteria for those RCOs that effect both environmental and fatality risk

We also agree with Japan here, that in order to address this TOR, we first must agree on TOR 3 and TOR 4, i.e. conclude on a risk matrix and ALARP region. Only then can these be combined with the current safety criteria.

To that effect for TOR 3 we remind the past proposal by our Chairman which Greece supported:

TOR 3 concluded on an appropriate risk matrix or index for environmental criteria

(a) For the Frequency Matrix, use the same already used for FSA (MSC 83/INF.2):

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 1,000 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 year) of a world fleet of 5,000 ships	10^{-5}

(b) For the Severity Matrix, use one in which the severity variable is oil spill volume.

Below is an example.

Severity Index		
SI	SEVERITY	DEFINITION
1	Minor	Oil spill volume < 10 tonnes
2	Significant	Oil spill volume between 10-100 tonnes
3	Severe	Oil spill volume between 100-1,000 tonnes
4	Catastrophic	Oil spill volume between 1,000-10,000 tonnes
5	Disastrous	Oil spill volume >10,000 tonnes

(volume scales to be finalized once the scales of the CATS thresholds are finalized).

We also feel that all TORs should remain for the MEPC 60 Working Group.

Comments on Norway's submission MEPC 59/INF.21

We appreciate and fully agree with Japan's comments and analysis of Norway's paper. We have some additional comments:

Norway's regressions confirm the non-linearity between spill costs and spill volume. The database they use is a mixture of IOPCF data and data from EU project SAFECO (which we understand is rather dated). In principle, there is no objection on merging databases. But whereas the IOPCF data are there for everybody to see, nobody really knows what is included in the SAFECO database. In the interest of transparency, we would like to see this database fully disclosed (we assume there is no overlap with the IOPCF database).

We are really puzzled by the 54,390 USD/tonne figure derived by Norway's analysis, which we understand to be the average of the ratio "spill cost/spill volume" for a log-normal distribution. As this corresponds to the 80-percentile of the distribution, we agree with Japan that it is not realistic. Nor do we think it is statistically correct to look at this average ratio. What should be looked at is not the average of the ratio, **but the ratio of averages**, that is, total spill cost by total spill volume, which we speculate to be much lower. If A and B are two random variables, the average of the ratio (A/B) is **not** equal to the ratio of average (A) divided by average (B).

The fallacy of using E(c/v), the average of the ratio of spill cost by spill volume, instead of E(c)/E(v), the ratio of the averages, can be understood by the following simple example:

> we have 3 spills:
> spill 1: 10 tons, cost $1,000,000
> spill 2: 100 tons, cost $2,000,000
> spill 3: 1,000 tons, cost $5,000,000
> (one can see a decreasing unit cost as spill volume increases)
> total volume = 1,110 tons, total cost = $8,000,000, **E(c)/E(v) = $7,207/ton**
> then we can use the $7,207 figure in the FSA calculations: multiply by E(v) = 370 tons to get E(c) = $2,666,667/spill
>
> by contrast, here is what the E(c/v) calculation would do:
> unit cost spill 1: $100,000/ton
> unit cost spill 2: $20,000/ton
> unit cost spill 3: $5,000/ton
> average of these 3: 125,000/3 = **E(c/v) = $41,667/ton**
> if we then multiply this with E(v) = 370 tons to get E(c) = $15,416,790/spill (a gross error).
>
> This is the risk of using Norway's $54,390 figure, which is a E(c/v) figure (let alone the $82,000 one).

As a second comment, Norway's analysis arrives at a marginal cost of USD 9,025 per tonne (see page 5 of the annex to the submission). But the authors provide no information on their claim why this value cannot be considered as an alternative to CATS.

Actually, the authors proceed to multiply 54,390 by the assurance factor of 1.5, to produce a figure of 81,585 USD/tonne, which they then immediately drop in favour of the original 60,000 USD/tonne figure (in their words, "it is advisable that the lower alternative as provided by Skjong, *et al*. should be preferred"). It seems there is a "magic" fixation with the 60,000 figure, more than 2 years after this whole discussion was initiated, and after all this discussion in between. This is definitely non-Bayesian, and please note that MEPC 59 has decided to pursue a volume-based CATS approach.

***

ANNEX 2

PAPER SUBMITTED TO CORRESPONDENCE GROUP VIA THE COORDINATOR (26/10/2009)

An Empirical Analysis of IOPCF Oil Spill Cost Data (Abridged Version)

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26 October 2009

ABSTRACT

This paper reports on recent analysis of oil spill cost data assembled by the International Oil Pollution Compensation Fund (IOPCF). Regression analyses of clean-up costs and total costs have been carried out, after taking care to convert to current prices and remove outliers. The results of this analysis may be useful in the context of the ongoing IMO/MEPC discussion on environmental risk evaluation criteria in Formal Safety Assessment (FSA).

1. Introduction

1.1 A big chapter in FSA that has only recently opened concerns environmental risk evaluation criteria. At the 55th session of MEPC (October 2006), the IMO decided to act on this subject. A major topic in annex 3 of document MEPC 55/18 was the definition and analysis of risk evaluation criteria for accidental releases to the environment, and specifically for releases of oil. Discussion on this matter was sparked to a significant extent by a report of EU research project SAFEDOR, which defined the criterion of CATS (for "Cost to Avert one Tonne of Spilled oil") as an environmental criterion equivalent to CAF ("Cost to Avert a Fatality"), which is already used in FSA. According to the CATS criterion, a specific Risk Control Option (RCO) for reducing environmental risk should be recommended for adoption if the value of CATS associated with it (defined as the ratio of the expected cost of implementing this RCO divided by the expected oil spill volume averted by it) is below a specified threshold, otherwise that particular RCO should not be recommended.

1.2 The issue of primary importance that triggered the debate at the IMO on environmental criteria was the very CATS criterion and its suggested threshold value of 60,000 USD/tonne. At the 56th session of MEPC (July 2007) a correspondence group (CG), coordinated by the second author of this paper on behalf of Greece, was tasked to look into all related matters, with a view to establishing environmental risk evaluation criteria within FSA. More than 2 years after, and after some considerable debate and generally divergent views (see docs. MEPC 57/1, MEPC 58/1, MEPC 59/1) the issue is far from closed, and a working group on this subject is planned for MEPC 60 (March 2010). Worthy of note in the same context has been research done in Japan (doc. MEPC 58/17/1, Yamada (2009), doc. MEPC 59/17/1). Its relevance was mainly in terms of quantifying the non-linearity of spill costs with respect to volume. A recent submission by Norway (doc. MEPC 59/INF.21, Psarros, *et al*. (2009)) presented a similar regression analysis. Also, an FSA study on crude oil tankers that used the above threshold was conducted by project SAFEDOR and submitted to MEPC by Denmark (docs MEPC 58/17/2, MEPC 58/17/INF.2). The study recommended, among other things, increased side-tank widths and double-bottom depths for tanker new buildings. At the 59th session of MEPC (July 2009) it was decided to pursue a volume-dependent approach for CATS, that is, proceed by explicitly taking into account the non-linear relationship between spill volume and spill cost.

1.3 The purpose of this paper is to report on recent regression analyses of oil spill cost data provided by the International Oil Pollution Compensation Fund (IOPCF). These analyses have been carried out by the authors and are in the same spirit as those carried out by Yamada (2009) (primarily) and Psarros, *et al*. (2009) (secondarily) but differ from them on several points. We believe that these analyses and their results can provide useful insights to the discussion within the IMO on environmental risk evaluation criteria.

1.4 It is not the purpose of this paper to comment on what has already been the subject of extensive discussion as regards CATS, within the MEPC CG and elsewhere. Rather, we focus on our own analyses. In that sense, section 2 reports on the data used, section 3 describes the results, section 4 talks about other studies using IOPCF data and section 5 presents the conclusions. It has to be noted that this is the abridged version of a more extensive report providing more details on the analysis.

2. Data used

2.1 Compensation for oil pollution caused by tankers is governed by four international conventions: the 1969 and the 1992 International Convention on Civil Liability for Oil Pollution Damage ("CLC 1969" and "CLC 1992") and the 1971 and 1992 conventions on the Establishment of an International fund for Compensation for Oil Pollution Damage ("1971 Fund" and "1992 Fund"). These conventions together create an international system where reasonable costs of clean-up and damages are met, first by the individual tanker owner up to the relevant CLC limit through a compulsory insurance and then by the international IOPC Funds, if the amounts claimed exceed the CLC limits. The IOPCF Annual report (2007) presents the claims that the IOPC Fund dealt with in the past. This report includes 107 accidents that are covered by the 1971 Fund and 33 by the 1992 Fund. For each accident the time and the place of accident are known and for most of the cases the volume of oil split, as well as, the costs claimed and eventually covered by the Fund are recorded. Damages are grouped into the following categories:

.1 Clean-up;
.2 Preventive measures;
.3 Fishery-related;
.4 Tourism-related;
.5 Farming-related;
.6 Other loss of income;
.7 Other damage to property; and
.8 Environmental damage/studies.

2.2 Where claims are shown in the table as settled this means that the amounts have been agreed with the claimants, but not necessarily that the claims have been paid or paid in full. In our analysis we refer to clean-up cost as the cost that has been agreed (excluding cases where claims are pending) for clean-up of the damage and to total cost as the sum of all costs that are presented in the report. Figure 1 presents a sample of the IOPCF 2008 Annual Report.

2.3 As one may notice, there are cases where clean-up cost is the only category that appears and, thus, the total cost is equal to the clean-up cost. Given the volume of oil spill (V), the clean-up cost (CC) and the total cost (TC), we present the results of regression analyses of CC=f(V) and TC=f(V). Entries from which at least one parameter is unknown were removed from the analysis.

Ref	Ship	Date of incident	Place of incident	Flag State of ship	Gross tonnage (GRT)	Limit of shipowner's liability under 1969 CLC	Cause of incident	Quantity of oil spilled (tonnes)	Compensation (amounts paid by 1971 Fund, unless indicated to the contrary)	
1	*Irving Whale*	7.9.70	Gulf of St Lawrence, Canada	Canada	2 261	Unknown	Sinking	Unknown		
2	*Antonio Gramsci*	27.2.79	Ventspils, USSR	USSR	27 694	Rbls 2 431 584	Grounding	5 500	Clean-up	SKr95 707 157
3	*Miya Maru N°8*	22.3.79	Bisan Seto, Japan	Japan	997	¥37 710 340	Collision	540	Clean-up Fishery-related Indemnification	¥108 589 104 ¥31 521 478 ¥9 427 585 ¥149 538 167
4	*Tarpenbek*	21.6.79	Selsey Bill, United Kingdom	Federal Republic of Germany	999	£64 356	Collision	Unknown	Clean-up	£363 550

Figure 1: Excerpt of the IOPC 2007 Annual Report (IOPCF, 2007)

2.4 In order to get the necessary data to perform our analysis we followed the steps below:

1. Removed all incomplete entries
2. All claims for the clean-up and the total cost categories (in the case of multiple claims) were added up by converting them to US Dollars at the time of the accident. We note that we are aware of the fact that the year of the accident and the year when the amount agreed was paid are not the same but this was the only available information. Furthermore the exchange rates used in these conversions were found in various CIA Factbooks and in a list of foreign currency units per dollar that is compiled by Antweiler (2009)
3. The cost of the previous step were capitalized into 2009 US Dollars by using conversion factors based on the Consumer Price Index (CPI).

2.5 This way we arrived at two datasets, one having data on the Clean-up Cost (CC) and the Volume (V) and another on the Total Cost (TC) and the Volume (V). These datasets were not disjoint. In fact, the first dataset contained 84 entries, the second had 91 entries, and 68 spills reported both CC and TC.

2.6 According to Friis-Hansen and Ditlevsen (2003), the logarithm of the oil spill volume and the logarithm of the total spill cost are positively correlated, having a very high correlation coefficient. This is also observed by Hendrickx (2007) and Yamada (2009). Our analysis of possible fits concluded that the double logarithmic, the multiplicative and the double reciprocal have the highest correlation coefficients and R-squared values. Therefore, Costs (TC and CC) and Volumes (V) were Log-transformed and a linear regression was performed for the two cases.

2.7 The necessary conditions for a linear regression to be valid (e.g., the normal distribution of the x values and the homoscedasticity condition) were tested and an analysis of variance (ANOVA) was also performed. Furthermore an identification of outliers was performed by carefully examining studenized residuals greater than 3. The regression analysis was repeated until no outliers could be found. Finally, the linear regression formulas in double logarithmic form were transformed into non-linear regression curves.

3. Results

3.1 Clean-up Cost (CC)

3.1.1 After removing incomplete entries, a dataset of N=84 spills for the period 1979-2006 was used for this regression analysis.

3.1.2 The minimum volume is 0.2 tonnes and the maximum is 84,000 tonnes. The average spill is 4,055.82 tonnes with a standard deviation of 14,616.15 tonnes and the median is just 162.5 tonnes. Even without a histogram one can easily realize that most claims come from relatively small spills. There are only 10 spills above 5,000 tonnes and, thus, one should be very careful when using the regression formulas to estimate the cost of large spills.

3.1.3 Furthermore, an average per tonne oil spill clean-up cost using the IOPCF database can be calculated by dividing the total amount paid by the Fund for clean-up by the total amount of oil that was spilled. According to our analysis, this value comes to **1,639 USD (2009) per tonne**. The equation of the fitted model using linear regression is:

$$\text{LOG10(Clean-up Cost)} = 4.64773 + 0.643615\ \text{LOG10(V)}$$

or,

$$\text{Clean-up Cost} = 44{,}435\ V^{0.644} \qquad (1)$$

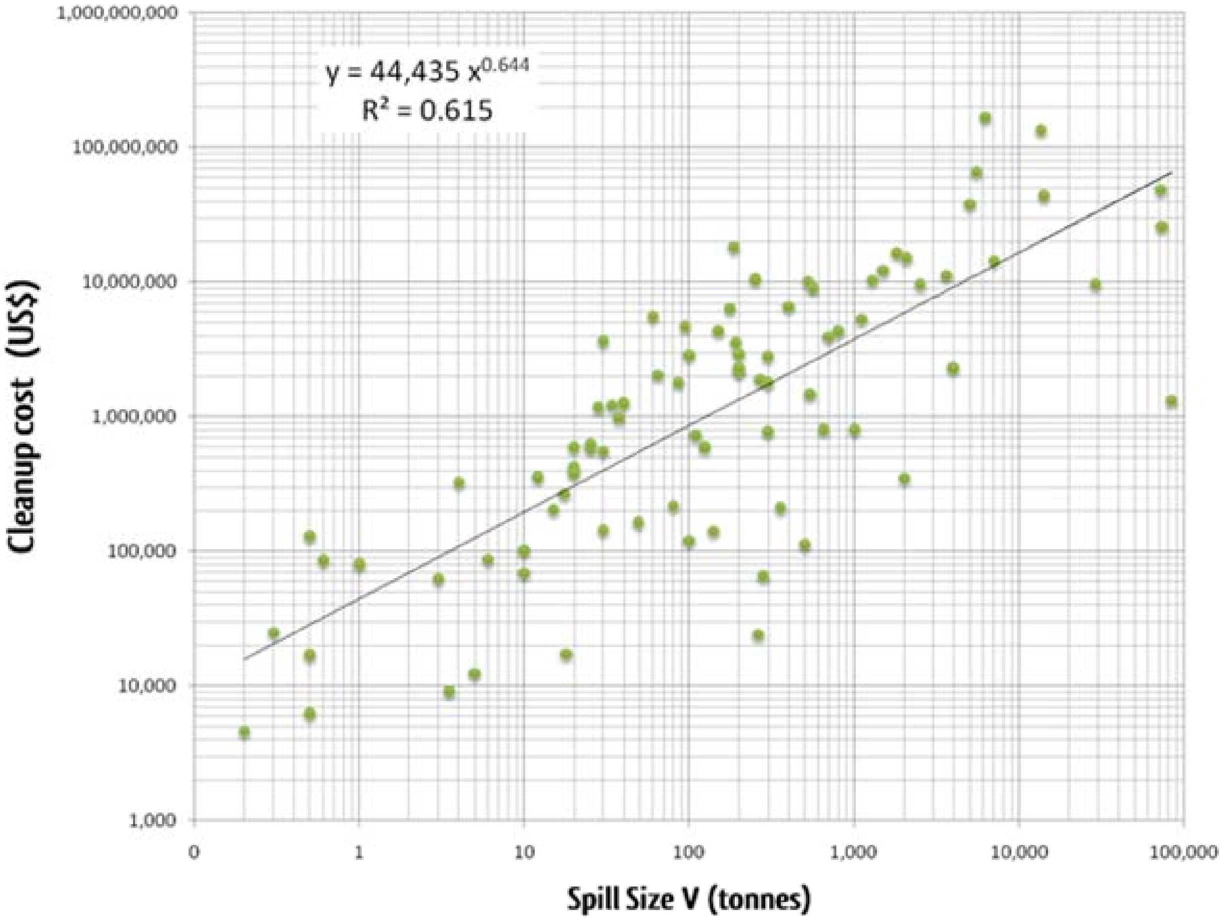

Figure 2: Linear Regression of Log (Spill Size) and Log (Clean-up Cost)

3.1.4 The R-Squared statistic indicates that the model as fitted explains 61.5254% of the variability in LOG10(Clean-up Cost). The correlation coefficient (Pearson's correlation coefficient p) equals 0.784382, indicating a strong relationship between the variables. We also performed an analysis of variances (ANOVA) which indicated that there is a statistically significant relationship between LOG10(Clean-up Cost) and LOG10(V) at the 95.0% confidence level.

3.2 Total Cost (TC)

3.2.1 Following the same methodology as in the previous step a regression analysis of log(Total Cost) and log(Spill Size) was performed initially for N=91 spills (for the period 1979-2006). The analysis of the studenized residuals revealed the existence of a total number of 8 possible outliers. These outliers were removed. After three consecutive regressions we arrived at the final dataset of N=83 spills.

3.2.2 The minimum volume here is 0.1 tonnes and the maximum is 84,000 tonnes. The average spill is 4,854.29 tonnes with a standard deviation of 16,064 tonnes and the median is just 140 tonnes. There are only 11 spills above 5,000 tonnes.

3.2.3 The equation of the fitted model using linear regression is:

$$\mathrm{LOG10(TotalCost)} = 4.71123 + 0.727567\ \mathrm{LOG10(V)}$$

or,

$$\text{Total Cost} = 51{,}432\ V^{0.728} \qquad (2)$$

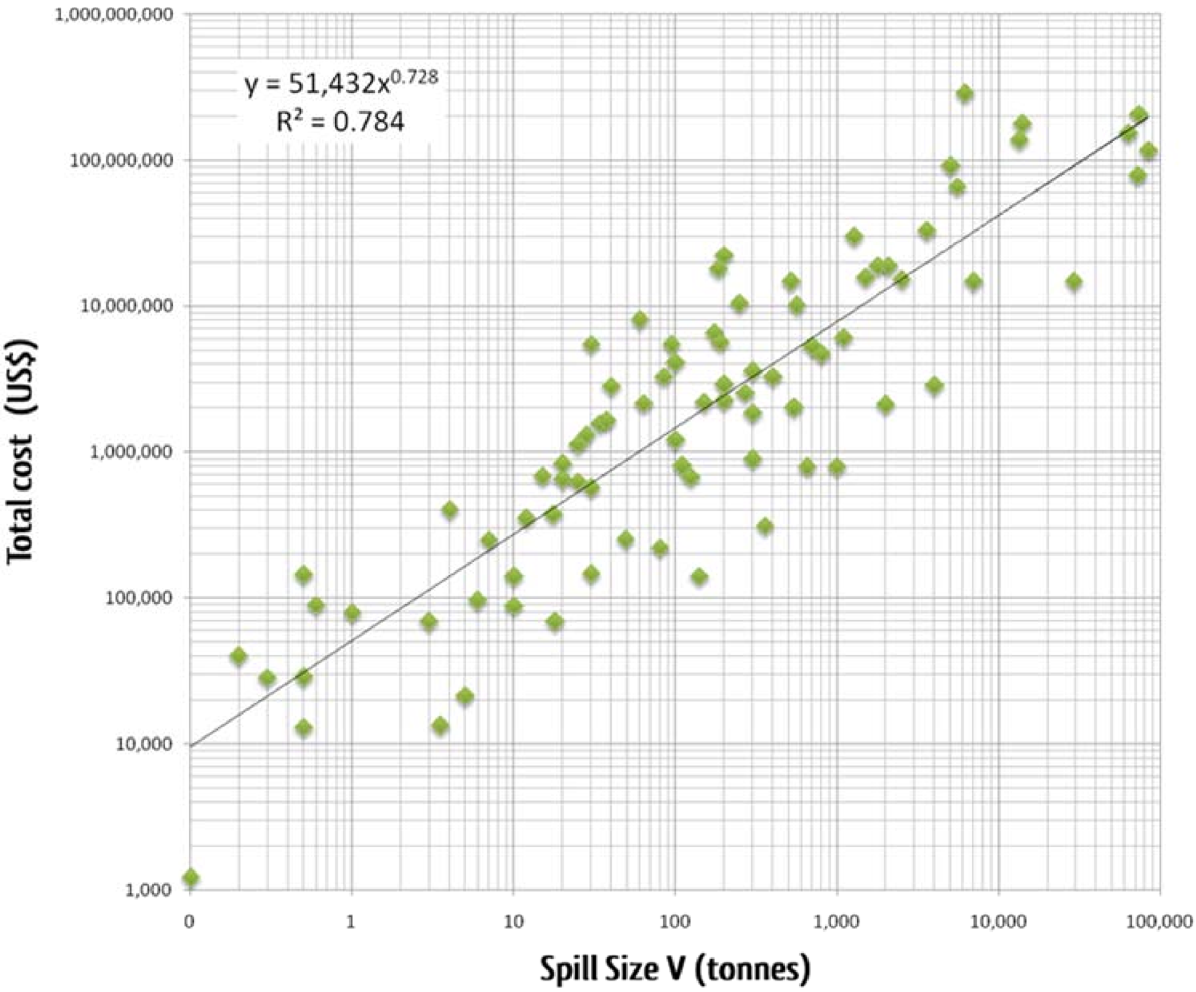

Figure 3: Linear Regression of Log(Spill Size) and Log (Total Cost)

3.2.4 The R-Squared statistic indicates that the model as fitted explains 78.26% of the variability in LOG10(Clean-up Cost). The correlation coefficient (Pearson's correlation coefficient p) equals 0.8846, indicating a strong relationship between the variables. Again, the analysis of variances (ANOVA) indicates that there is a statistically significant relationship between LOG10(Total Cost) and LOG10(V) at the 95.0% confidence level.

3.2.5 As before, an average per tonne oil spill total cost using the IOPCF database can be calculated by dividing the total amount paid by the Fund by the total amount of oil that was spilled. According to our analysis, this value comes to **4,118 USD (2009) per tonne**.

3.2.6 It has to be noted that our regression analysis was very carefully performed in order to identify possible outliers given the high sensitivity of the outcome on the dataset that we chose. **Outliers at both end of the spectrum were removed**, that is, both for very low and for very high total spill costs per unit volume. In order to illustrate the sensitivity of including or not including such spills, we present the following for a hypothetical cost for a one tonne spill. The total cost given by the regression formula for a hypothetical oil spill of 1 tonne is 51,437 USD. The results would have changed dramatically if some outliers had not been removed. For example, let us have a look at two extreme accidents both caused by mishandling of oil supply in Japan. The **Kifuku Maru** accident in 1982 resulted in a spillage of 32 tonnes. The amount of money (converted into 2008 USD) that was paid for compensation was just 165 USD per tonne, a very low value. On the other hand, in 1997 the accident of **Daiwa Maru No.18** resulted in an one tonne spillage that costed more than 4.5 million USD. If the extremely high cost value of the **Daiwa Maru No.18** had been included in the regression the formula would produce a total per tonne cost for the hypothetical spill of one tonne of 56,058 USD. On the other hand, the extremely low, in terms of cost, case of **Kifuku Maru** would have pushed the same value to as low as 46,706 USD.

3.2.7 By dividing regression formulas (1) and (2) by V one can obtain the **unit costs** as follows:

Unit Clean-up Cost = UCC= 44,435 $V^{-0.356}$ (3)
Unit Total Cost = UTC= 51,432 $V^{-0.272}$ (4)

One can see that both unit costs are decreasing functions of V, as expected.

Also, by differentiating regression formulas (1) and (2) with respect to V one can obtain the **marginal costs** as follows:

Marginal Clean-up Cost = MCC= 28,616 $V^{-0.356}$ (5)
Marginal Total Cost = MTC= 37,442 $V^{-0.272}$ (6)

The marginal costs MCC and MTC are interpreted as the additional cost if one more tonne of oil is spilled. As expected, these are decreasing functions of V too.

3.2.8 The following table shows values of these per-tonne costs for some representative values of V. V is in tonnes and the per-tonne values are in USD/tonne.

Table 1: Unit and marginal cost values

V	UCC	UTC	MCC	MTC
1	44,435	51,432	28,616	37,442
10	19,576	27,494	12,607	19,957
100	8,624	14,697	5,554	10,644
1,000	3,799	7,857	2,447	5,677
10,000	1,674	4,200	1,078	3,028
100,000	737	2,245	475	1,615

3.2.9 The precise way such figures can be used in an FSA study is yet to be determined, and it is among the subjects of discussion at the IMO how the volume-based approach will be integrated within the FSA method. The general framework of Psaraftis (2008) might be useful in that regard, but other approaches may also be of interest.

3.2.10 It is also worthy of note that the data provided by the 2007 IOPCF Annual report can be used to estimate an average spill total cost/spill clean-up cost ratio, for the sample of spills for which the values of both CC and TC are available. Since we are only interested in the ratio, there is no need to do the conversions discussed before (i.e. to use the exchange rate and the CPI index). Furthermore, accidents for which the claimed costs were only clean-up costs had to be removed. If clean-up cost is the only cost category available, this means that the total cost (as in the analysis performed above) would be equal to the total cost and in this case the ratio will be equal to 1. In order to remove this bias, **all ratios equal to 1 were removed**, although this probably biases the analysis towards higher total cost to clean-up cost ratios. A ratio of 87,547 (eighty seven thousand, **Braer** accident) was also removed as an outlier. The dataset of the N=68 ratios that were left (see Figure 4), has a minimum ratio of 1.002, a maximum of 10.01, a mean of 1.929 and a median of 1.287. The median is the measure of center (location) of a list of numbers. Unlike the mean, the median is not influenced by a few very large values in the list and may be a more appropriate criterion for this purpose.

Figure 4: Total Cost/Clean-up Cost Ratio (Data from IOPCF)

3.2.11 Speaking of ratios, one should be very careful with their use. Two statistics that one should be particularly careful with are (a) the average of the ratio "clean-up cost/spill volume", and (b) the average of the ratio "total cost/spill volume". For our data, these average ratios are estimated at **23,085 USD/tonne** and **33,425 USD/tonne** respectively.

3.2.12 It is perhaps tempting to use the above average ratios in an FSA study. But we think that caution should be exercised if anything like this is contemplated. If X and Y are two random variables, then:

$$E[X/Y] = E[X]E[1/Y] + Cov[X, 1/Y]$$

where E is the expectation operator and Cov is the covariance operator. Note that **only if X and Y are independent**, it is $E[X/Y] = E[X]E[1/Y]$. Note also that $E[1/Y]$ is not equal to $1/E[Y]$ in general. This means that **E[X/Y] is not equal to E[X]/E[Y] in general**, even if X and Y are independent.

3.2.13 In our case, let X=CC and Y=V. Even if CC and V were independent (which they are not), the average ratio of spill clean-up cost divided by spill volume **is not** necessarily equal to the ratio of the average spill clean-up cost divided by the average spill volume. This is precisely the reason why the average ratios of **23,085** and **33,425** USD/tonne reported above are different (in fact in our case significantly higher) than the respective averages of **1,639** and **4,118** USD/tonne computed earlier.

3.2.14 What this means is that **one should be careful not to mistake averages of ratios as ratios of averages**, as significant miscalculations may occur otherwise. In an FSA, the way such averages would be used could be in the event trees in the Risk Analysis step, where for each branch an average spill volume would have to be multiplied by an appropriate per tonne spill cost. In that sense, it would be inappropriate to multiply E[CC/V] by E[V], as this could seriously miscalculate E[CC]. The right way to arrive at E[CC] would be to multiply {E[CC]/E(V)} with E[V]. The same is true for TC versus V.

3.2.15 In an FSA we think that one should either use the non-linear relations derived by equations (1) and (2) if a volume-based approach is used, or the averages of 1,639 USD/tonne for clean-up cost and 4,118 USD/tonne for total cost if single average global values are used.

3.2.16 Similar considerations pertain to the possible use of medians as statistics. In our case, the median clean-up cost is **10,467 USD/tonne** and the median total cost is **14,082 USD/tonne**. A median has the advantage over the mean that it is not influenced by a single large or small value, so the possible use of such statistics in FSA should be explored. But caution should be exercised here as well, so as to avoid possible pitfalls.

4. Other studies using IOPCF data

4.1 Four recent cases where IOPCF data was analysed were known to the authors prior to their own analysis. It is not our purpose to comment on these in detail here. Friis-Hansen and Ditlevsen (2003) used the 1999 Annual Report (except those accidents that belonged to the categories “loading/unloading”, “mishandling of cargo”, and “unknown reason” which were removed from their analysis) and converted all amounts into Special Drawing Units (SDR) by an average annual exchange rate taken from the International Financial Yearbook. Then, historic national interest rates for Money Market Rates were applied to capitalize all costs into year 2000 units followed by a conversion into 2000 USD.

4.2 Hendrick (2007) performed an analysis based on data of the 2003 Annual Report and analysed 91 cases by converting each compensation amount into US Dollars using for each accident the exchange rate on 31 December of the year of occurrence. Exchange rates of the Bank of England were used for the currencies available and for the others an online website (OANDA.com) was used. There is no report that an inflation rate was used to bring these amounts into current Dollars.

4.3 Yamada (2009) performed a regression analysis of the amount spilled and the total cost by using the exchange rated provided in the Annual Report itself. These rates can be use for conversion of one currency into another as of 31 December 2007 and do not take into account the time of the accident. Furthermore, no inflation rate was used capitalize the costs into 2008 dollars. His analysis formed the basis of Japan’s submissions to the MEPC and, to a large extent, the basis of the MEPC decision to recommend a volume-based approach.

4.4 Last but not least, Psarros, *et al*. (2009) used combined data from two datasets, namely the IOPCF report and the accident database developed by EU research project SAFECO II (a project that antedated SAFEDOR), and thus performed a regression analysis in 183 oil spill incidents. It is not immediately clear from their analysis what the SAFECO II database is and what (if any) biases it introduces to the analysis. The amounts were converted into 2008 US Dollars taking into account the inflation rate.

4.5 The following table summarizes the various oil spill total cost volume-based regression formulas and the corresponding R-squared values.

Table 2: Comparison of Total Cost Formulas

Study	Total Cost = f (V)	R^2
Kontovas, *et al*. (2009) – this study	Total Cost = 51,432 $V^{0.728}$	0.782
Psarros, *et al*. (2009)	Total Cost = 60,515 $V^{0.647}$	0.507
Yamada (2009)	Total Cost = 38,735 $V^{0.66}$	0.460

4.6 What is perhaps interesting in the able table is the higher R-squared value of our study versus those of the others, perhaps implying a better fit with the data, and possibly a more reliable representation of spill costs on a volume basis. This is mainly explained by the removal of the outliers as mentioned earlier.

5. Conclusions

5.1 Some regression analyses of IOPCF oil spill cost data have been performed, and indicative values of clean-up and total costs, as well as unit costs, marginal costs and median costs were derived. It is hoped that these analyses and the points made in this paper will be useful in the context of the discussion on environmental risk evaluation criteria in FSA, in the IMO and elsewhere.

References:

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IOPCF (2007), "Annual report 2007". International Oil Pollution Compensation Funds, London, UK .

Psaraftis, H.N., (2008), "Environmental Risk Evaluation Criteria", WMU Journal of Maritime Affairs, Volume 7, Number 2, October 2008 , pp. 409-427(19).

Psarros, G., Skjong, R., Endersen, O. and E. Vanem, (2009)," A perspective on the development of Environmental Risk Acceptance Criteria related to oil spills", annex to document MEPC 59/INF.21.

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ANNEX 3

SECOND ROUND OF SUBMISSIONS (27 October to 25 November 2009)
Listed by chronological order of receipt
(receipt dates are in parentheses, text reproduced as received)

IACS (9/11/2009)

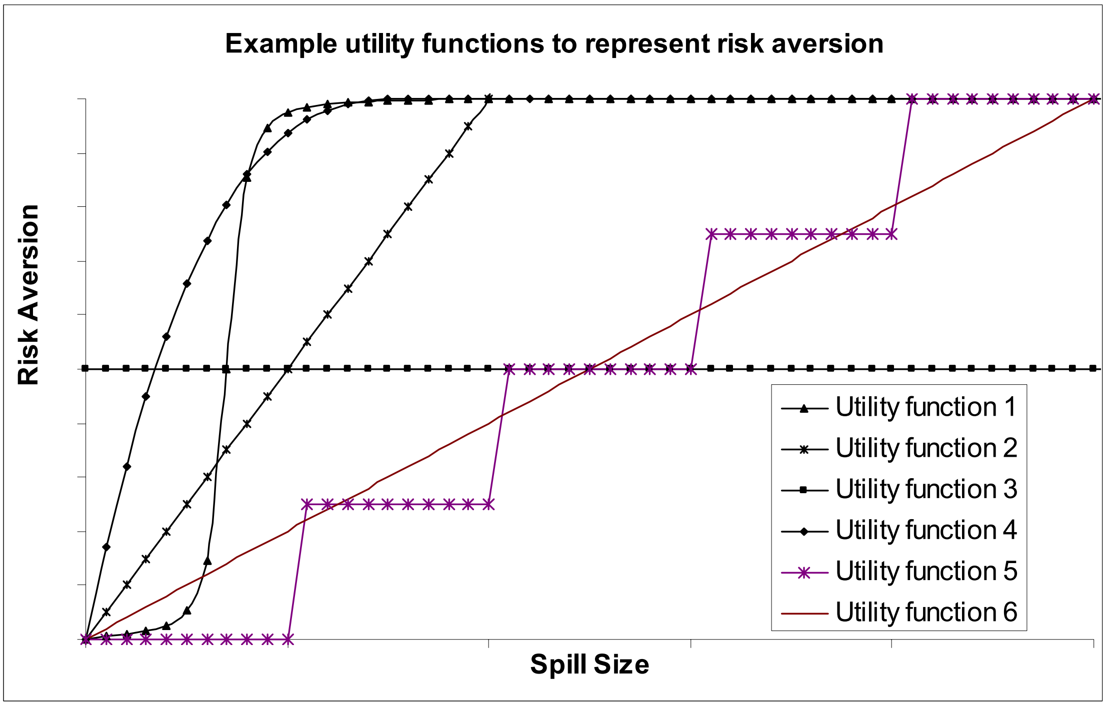
IACS believes that there is now consensus that the associated costs of an oil spill, when expressed in terms of per tonnes spilt, change with the volume spilt and that the Japanese calculations present a reasonable investigation into what these post spill costs are. IACS does have continued concerns that the data Japan used may be underreporting the cost primarily because of its provenance. However, these concerns should be debated in the WG, and are not considered here.

IACS can also agree that the formula representation of these costs is as appropriate as a stepwise approach. There is no big difference in the complication of calculation.

However, IACS believes there is still some way to go in discussing the utility function that should be applied in order to best encapsulate the risk aversion of society to oil spills. As stated previously, it is IACS' understanding that CATS is proposed as a societal willingness to pay for prevention before the spill. The concept should therefore not be directly linked to cost of clean-up and other post-spill costs.

It would therefore be advisable to study more closely the implicit willingness to pay for prevention in current regulations, and across industries prior to recommending a specific value or formula.

This risk aversion can be included in two ways. There can be some additional cost added to the oil spill costs or there can be some kind of multiplying factor. Either way would work as long as we understand what form the utility function could take. Figure 1 gives some possible options, where the utility is given as a multiplying factor.



Utility Function 1 – represents small public awareness, and therefore aversion, for small spills before rapid increase in aversion as the spill size reaches a critical point. The utility function then flattens out as the spill sizes get to a point that the public are unable to differentiate between a large and a very large spill.

Utility function 2 – represents the view that the bigger the potential spill the bigger the aversion. It is a linearly proportional function with an upper limit

Utility function 3 – represents the view that risk aversion is independent of spill size.

Utility function 4 – represents the view that the risk aversion climbs quickly with spill size. It is a simplification of utility function 1 as it simply ignores the start of the "S".

Utility function 5 – this could suit a stepwise CATS.

Utility function 6 – represents the view that the risk aversion is directly proportional to the spill size.

IACS believes the "S" Curve represented by utility function 1 is the most realistic shape for representing public risk aversion. This is because for very small spills the public will not have much aversion at all, then, as the spill size reaches some critical value, it will increase dramatically before levelling off again.

Having said this, the shape could be simplified (to utility function 4) as the beginning of the "S", the spill sizes where the public has very little risk aversion, will be very small compared the end of the "S", the full range of spill sizes.

The important idea though is, as the costs are not linear with spill volume, neither is the risk aversion.

Once we can agree what form the utility function should take, we can start to use some formulae to combine it with the Japanese cost equation.

United States (13/11/2009)

1. Response to IACS comments

.1 We agree with IACS' concerns regarding the results from research presented in MEPC 59/17/1. As we've stated previously, we have concern over the low volumetric valuation used in the formula.

.2 We agree with IACS' input regarding CATS needing to not only capture the incurred costs associated with spill response, clean-up, environmental damage and other components, but also societal willingness to pay to avoid those costs.

*** Focus at IMO is on the extraordinary spills, not the small spills. In United States risk-planning and regulation development, we also focus on the reasonable worst case scenario.

.3 We agree with IACS' recommendation that the correspondence group look at willingness to pay as a function of spill volume, and we recommend further that members be prepared to present data and research on the nature of this relationship at MEPC 60.

2. Response to *An Empirical Analysis of IOPCF Oil Spill Cost Data* dated 26 October 2009

.1 Does the IOPCF data include spills in US waters?

.2 It appears that data points where cost components other than clean-up costs are missing are discarded. Were any analyses made to see if this skewed the results (i.e. were volumetric clean-up costs significantly different for these spills than for those same costs from spills that were retained)?

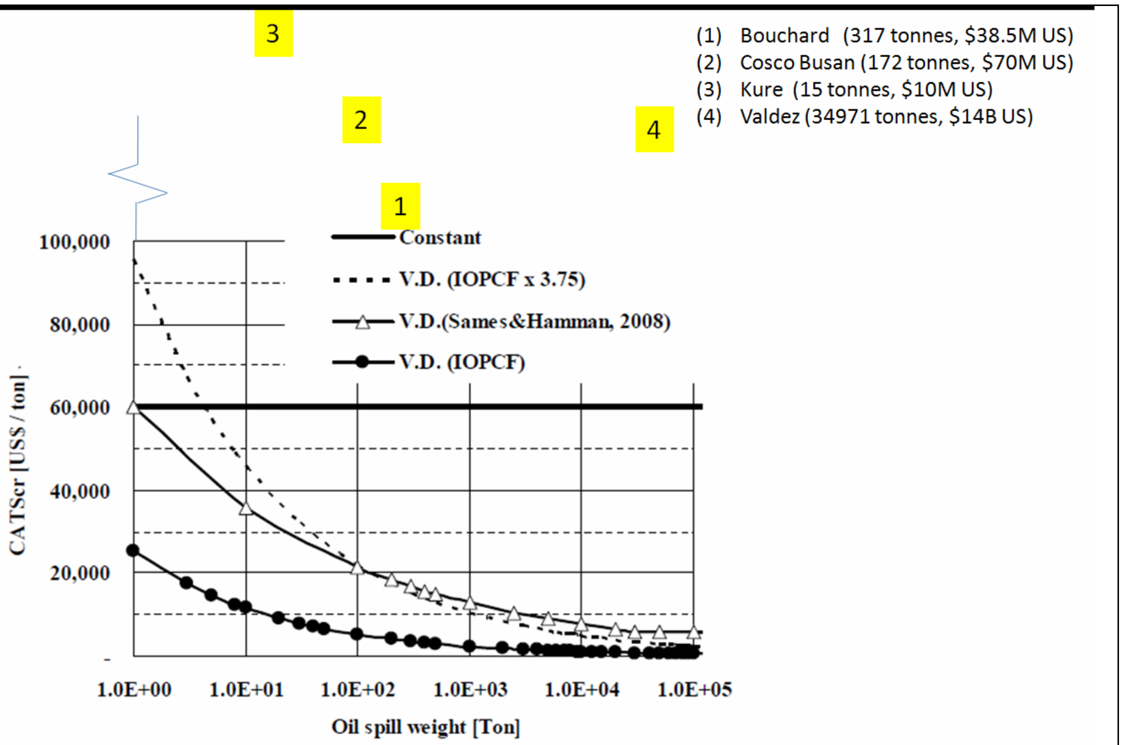
.3 The basis and justification for removing outliers was not clear, with the result that significant data points were removed. This is particularly concerning given the already limited data used in the analysis.

.4 While the addition of Marginal Costs is academically interesting, we are unclear what the authors see as their use in this application, and would welcome further discussions.

3. Response to Japan's input

.1 Per previous submissions, the United States is concerned over the low volumetric valuation used in the formula which results in Figure 1 of MEPC 59/17/1.

As an example of the concerning difference between proposed oil spill valuations and actual spill cases, we have annotated the figure presented by Japan in MEPC 59/17/1 with some U.S. spill cases. It should be noted that the costs presented are clean-up costs only, and do not capture environmental damage, lost use and other potentially major costs, and so very likely significantly under-represent actual costs, let alone societal willingness to pay to avoid such spills.



Note: "*V.D.*": Volume-dependent CATS.
"*IOPCF*": Regression curve based on IOPCF data ($CATS_{cr} = 25441 \cdot W^{-0.34}$)

Figure 1 – Comparison of different $CATS_{cr}$

.2 Per previous submissions, we are also unsure of the value of 1.5 as proposed as an assurance factor by SAFEDOR.

4. <u>Response to Greece's input</u>

.1 Per previous comment, the United States is concerned over the low volumetric valuation used in MEPC 59/17/1.

Greece (16/11/2009)

1. <u>On the United States submissions</u>

The United States, commenting on Norwegian submission MEPC 59/INF.21, questions the recommended value of around $60,000/tonne for CATS on the ground that it is dramatically below some of the US experiences, for instance the Cosco Busan spill around $400,000/tonne, etc.

We feel Greece (and Japan) sufficiently pointed out some fallacies in computing the average (spill/cost) ratio in coming up with $82,000/tonne. In other words both the $82,000 and the $60,000 figures are more than an order of magnitude higher than what they should be according to the proper analysis of the data.

On the point made by the United States, we should say that here we are looking for a global average and it is clear that one cannot use extreme values or even regional averages (which for the US are expected to be very high) to arrive at that average. Designing for the worst case scenario is not within the scope of IMO or even class rules. A hypothetical value of CATS of $400,000/mt would certainly render quadruple hulls as cost effective. Such a high value would certainly lead to radical changes in tanker design.

That would be fine if it was justified by the data. But Japan's analysis and the last paper forwarded to us by the coordinator, even the Norwegian analysis, looking at worldwide data, show that it is not.

(Such high values can also have unsought side effects, e.g., the loss of a human ($3 million) is valued only as much as 7.5 tons of oil.)

In the latest response by the United States to Japan, 4 spills are used as examples. The **Cosco Busan**, **Exxon Valdez**, **Bouchard** and **Kure**. All but one (the **Valdez**) are very small spills. Cost wise they are extreme cases. Nevertheless, we agree with the United States that small spills can be hugely expensive on a per ton basis and we are willing to discuss how to best incorporate that in the function proposed.

Finally, the United States posed some questions on the *Empirical Analysis of IOPCF data*, the paper sent by the coordinator. We found the paper very informative and would be grateful to have the authors' replies to the questions raised by the United States.

2. <u>On the IACS submission</u>

IACS recommends looking into society's risk aversion to respond to big oil spills, so as to come up with an appropriate "assurance factor" F to weigh spill costs with. We certainly agree with that. However trying to tackle this issue now seems like putting the cart before the horse. We think first we have to agree on the clean-up costs then discuss about a factor to account for perhaps other related costs and "assurance". We hope we are not detracted now from the immediate work of the CG. Let's try to finalize things we agree with first.

3. <u>Other comments</u>

The three regression formulae presented thus far, one by Japan, one by Norway, and one in the Kontovas, *et al.* (2009) paper sent to the CG by our chairman, look very similar.

Japan's – Yamada (2009): Total Cost = 38,735 $V^{0.66}$
Norway's – Psarros, *et al.* (2009): Total Cost = 60,515 $V^{0.647}$
Kontovas, *et al.* (2009): Total Cost = 51,432 $V^{0.728}$

The merits of each approach can be debated, but could it be that the final formula to which this CG (or the WG at MEPC 60) would converge should be around this neighbourhood?

Via Coordinator (21/11/2009)

<u>Response of NTUA to US comments of 13/11/2009 on "*An Empirical Analysis of IOPCF Oil Spill Cost Data*" by Kontovas, *et al*. (2009)</u>

1. Does the IOPCF data include spills in US waters?

The analysis is based on data published in the Annual Report of the International Oil Pollution Compensation Fund and all of them are spills in member states that are party to the Fund Conventions. No spills in US waters are included, as the United States is not party to the Fund Conventions.

2. It appears that data points where cost components other than clean-up costs are missing are discarded. Were any analyses made to see if this skewed the results (i.e. were volumetric clean-up costs significantly different for these spills than for those same costs from spills that were retained)?

These data points were not discarded. In all cases, the total cost equals the sum of the available cost components. In cases where only one cost component is available (e.g., clean-up cost) the total cost is equal to that one. Furthermore, there is a separate analysis of clean-up cost vs total cost.

3. The basis and justification for removing outliers was not clear, with the result that significant data points were removed. This is particularly concerning given the already limited data used in the analysis.

One of the first steps towards obtaining a coherent regression analysis is the detection of outlaying observations. In statistics, an outlier is an observation that is numerically distant from the rest of the data. In the presence of outliers, the least squares estimation is inefficient and biased, dragging predictions towards the outliers. Thus, any robust regression analysis should try to identify and remove the outliers from the dataset. In our analysis, potential outliers where identified based on the studenized residuals (the quotient resulting from division of a residual by an estimate of its standard deviation). Thus, there is a strong theoretical basis and justification for all removals.

4. While the addition of Marginal Costs is academically interesting, we are unclear what the authors see as their use in this application, and would welcome further discussions.

The notion of marginal cost is commonly used in economics. In our case, the marginal total cost measures the change in total cost that arises when the quantity of oil spilled changes by one unit. How these can be used can be further discussed at MEPC 60.

United States (24/11/2009)

1. <u>Oil Spill Cost Estimates</u>

Below is a table with data on the four spills from our 13 November 2009 submission, including source for volume and cost estimates. Please note that some (**Valdez** in particular) have several cites as there were separate sources for damage and response estimates, which were exclusive and therefore added.

	Bouchard	Cosco Busan	
Date	2003	2007	
Volume (gal)	98000	53000	
Volume Source	http://www.buzzardsbay.org/oilspillcosts.htm	http://www.uscg.mil/MarineSafetyProgram/docs/USCG_Prevention_Task_08-53%2025%20April%2009.pdf	
Cost	$ 38,500,000	$ 70,000,000	
Cost Source	http://www.buzzardsbay.org/oilspillcosts.htm	http://www.uscg.mil/npfc/docs/PDFs/Reports/Liability_Limits_Report_2008.pdf	
$/gal	$ 392.86	$ 1,320.75	
	http://www.buzzardsbay.org/oilspillcosts.htm	http://www.mercurynews.com/topstories/ci_11734488	
	http://www.buzzardsbay.org/oilspillcosts.htm	http://www.uscg.mil/MarineSafetyProgram/docs/USCG_Prevention_Task_08-53%2025%20April%2009.pdf, http://www.uscg.mil/npfc/docs/PDFs/Reports/Liability_Limits_Report_2008.pdf, http://www.mercurynews.com/topstories/ci_11734488	
Spill	**Kure**	**Valdez**	
Date	1997	1989	
Volume (gal)	4500	10,800,000	
Volume Source	http://restoration.doi.gov/pdf/finalrestorationplans/ca_kurehumboldtbay_oilspill_07-08.pdf	http://www.uscg.mil/history/articles/EV.pdf	
Cost	$ 10,300,500	$ 10,065,000,000	3,311,496,000
Cost Source	Etkin, D.S. 2002. Response Cost Modeling For Oil Spills From Tanker/Freighter Groundings on Rock Pinnacles in San Francisco Bay	http://www.gao.gov/htext/d071085.html, http://www.fws.gov/contaminants/Documents/ExxonValdez.pdf, http://en.wikipedia.org/wiki/Exxon_Valdez_oil_spill	
$/gal	$ 2,289	$ 931.94	306.62

	http://restoration.doi.gov/pdf/finalrestorationplans/ca_kurehumboldtbay_oilspill_07-08.pdf, Etkin, D.S. 2002. Response Cost Modeling For Oil Spills From Tanker/Freighter Groundings on Rock Pinnacles in San Francisco Bay,	http://www.uscg.mil/history/articles/EV.pdf, http://www.gao.gov/htext/d071085.html, http://www.fws.gov/contaminants/Documents/ExxonValdez.pdf, http://en.wikipedia.org/wiki/Exxon_Valdez_oil_spill,	
	$ 4,820,000		
	http://www.dfg.ca.gov/ospr/spill/nrda/nrda_kure.html		

Japan (25/11/2009)

In order to effectively carry out FSA-WG at MEPC60, Japan believes that it is beneficial for us that member countries would provide information with regards to following items in documents to be submitted to MEPC60. Moreover, Japan believes that it would be beneficial for us that those documents would be shared by present CG members in advance so that we could proceed to FSA-WG at MEPC effectively.

1. $\underline{CATS_{thr}}$ (TOR 1)

In order to utilize assurance factor in combination with the regression formula, which is proposed by Japan as well as the other countries, it is important to consider the concept of assurance factor (factor for willingness to pay), and to gather more information about assurance factor in reducing oil spill risk from ships. However, so far we do not have any academic references or examples about assurance factor. Therefore, Japan believes that it is highly appreciated that member countries would provide any references to and/or examples of the assurance factors, where assurance factor might be determined from an engineering point of view and so on.

Japan supports comments made by Greece on 16 November that "we are looking for a global average and it is clear that one cannot use extreme values or even regional averages (which for the United States are expected to be very high) to arrive at that average. Designing for the worst case scenario is not within the scope of (FSA framework in) IMO".

Japan also shares the same view made by Greece on 16 November that so far we have three regression formulas (Japan, Norway and Greece) and the final formula to which this correspondence group (or the WG at MEPC 60) converge might be around this neighbourhood.

With regard to the U.S. comments on 13 November, IOPCF data does not include oil spill accidents which took place in U.S. territory since the United States is not a party to the IOPCF Convention and did not provide any data so far. It is noted that, as pointed out by Greece, IOPCF data is one of the most transparent, world-wide and reliable oil spill accidents database, since it is open to anybody, free of charge, and compensations have been consistently paid according to IOPCF rules. However, Japan believes that updating and enhancing oil spill accidents database is beneficial to develop reasonable global $CATS_{thr}$.

In this meaning, Japan believes that combining oil spill accidents in US and IOPCF databases enhance coverage of oil spill accidents database (used in the present CG as well as IMO) to more world-wide. Therefore, in order to establish global $CATS_{thr}$ Japan believes that it is highly appreciated that the United States would provide all oil spill accidents database/information in the United States preferably in the same detail as IOPCF data. Moreover, it is expected that detailed costs components considered in US database might be utilized in order to consider assurance factor as well as environmental damage factor. We sincerely appreciate that the United States has submitted data on four cases which were described in the comments on 13 November, under communication with Mr. Yoshida. Again, we would express our much appreciation when the United States would show us all data, not only the four cases concerned, for members' consideration about components of cost concerned in the United States waters.

2. <u>Severity Index (TOR 3)</u>

With regard to FI and SI, the following table is shown in MEPC 59/17. With regard to SI, there is a discussion that a unit of SI should be oil spill volume or monetary basis [US$]. Moreover, it might be possible to use both oil spill volume and monetary basis utilizing regression formula between costs and oil spill volume. Japan believes that more information and discussion are necessary to solve this issue.

(a) For the Frequency Matrix, use the same already used for FSA (MSC 83/INF.2):

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 1,000 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 year) of a world fleet of 5,000 ships	10^{-5}

(b) For the Severity Matrix, use one in which the severity variable is oil spill volume.

Below is an example:

Severity Index		
SI	SEVERITY	DEFINITION
1	Minor	Oil spill volume < 10 tonnes
2	Significant	Oil spill volume between 10-100 tonnes
3	Severe	Oil spill volume between 100-1,000 tonnes
4	Catastrophic	Oil spill volume between 1,000-10,000 tonnes
5	Disastrous	Oil spill volume >10,000 tonnes

3. <u>ALARP, F-T Curve (TOR 4)</u>

Japan believes establishing the F-T curve is one of the most difficult topics in the present correspondence group, and thinks it is important to share the same philosophy within the member Governments. Considering the consistent way taken in case of safety FSA, we need to first decide the allowable and unallowable regions taking into account the economic magnitude of the intended activity (such as oil transport by tankers). Consequently, we could get an ALARP region. Japan would believe that it is necessary to gather relevant information in order to derive a reasonable ALARP region in case of oil spill risk.

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