

An Updated Analysis of IOPCF Oil Spill Data: Estimation of the Disutility Cost of Tanker Oil Spills

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ABSTRACT: Beyond any doubt, the cost of an oil spill is very difficult to be estimated. The approach used in this work is based on the assumption that the cost of an oil spill can be approximated by the compensation eventually paid to claimants. A series of regression analyses of the total costs have been carried out based on the latest available data. These analyses and their results can provide useful insights to the discussion on environmental risk evaluation criteria and in policy evaluation regarding the oil pollution of the marine environment by estimating the damage cost of oil spills and, thus, the benefit from relative regulations that deal with the prevention of oil pollution in cost effectiveness and cost benefit analysis.

1 INTRODUCTION

A downward tendency is apparent in the total annual quantity of oil spilt by crude oil carriers during the last decade as well as in the number of oil spills worldwide, see ITOPI (2010) and Kontovas et al. (2010). However, there is a constant need for designing and operating ships that will lead to minimal consequences to the environment and the society in the case of an accident. A crucial parameter in evaluating designs and policy measures to reduce pollution is the estimation of the cost of an oil spill.

The reduction of oil pollution is one of the stated goals of new regulations, including the implementation of double hulls for tanker vessels. The management of safety at sea is based on a set of accepted rules that are, in general, agreed upon through the International Maritime Organization (IMO) which is a United Nations organization that deals with all aspects of maritime safety and the protection of the marine environment. Many of these regulations aim at reducing environmental risk and, more precisely, the risk that relates with accidental oil spillage. A big chapter that has only recently opened concerns environmental risk evaluation criteria. At the 55th session of Marine Environment protection Committee (MEPC) that took place in 2006, the IMO decided to act on the subject of environmental criteria. At the 56th session of MEPC (July 2007) a correspondence group (CG), coordinated by the third 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

Formal Safety Assessment (FSA). FSA is the major risk assessment tool that is being used for policy-making within the IMO. An issue of primary importance was found to be the relationship between spill volume and spill cost and its uses within FSA.

The analysis reported in this paper is an attempt to shed some light into this issue and describes recent regression analyses of oil spill cost data. These analyses have been carried out by the authors and are in the same spirit as those carried out by Yamada (2009) and Psarros et al. (2011) but differ from them on several points. In fact, this work is an updated analysis of a previous work of the same authors that has recently been adopted by the IMO/MEPC as a basis for further discussion on environmental risk evaluation criteria.

These analyses and their results can provide useful insights to the discussion on environmental risk evaluation criteria and in policy evaluation regarding the oil pollution of the marine environment by estimating the damage cost of oil spills and, thus, the benefit from relative regulations that deal with the prevention of oil pollution in cost effectiveness and cost benefit analysis.

The rest of the paper is organized as follows. Section 2 presents a review on the recent literature on oil spill valuation based on compensation data, Section 3 describes the results of the regression analyses and the formulas that can be used to estimate the cost of an oil spills. Section 4 reports on the possible uses of these cost functions and section 5 presents the conclusions.

2 LITERATURE REVIEW

There is a general agreement (Etkin, 1999; Grey, 1999; White and Molloy, 2003) that the key factors that influence the cost of oil spills are the type of oil, location, weather and sea conditions and the amount spilled and rate of spillage. Given that the above parameters are highly variable and cannot be predicted in advance, a usual approach taken in the literature is to connect the cost of an oil spill to its volume. In that sense, a larger oil spill is expected to have a higher cost, all else being equal. Estimates of the cleanup cost and the total oil spill costs which may include the costs for response, third party claims and environmental damages as a function of the oil spill size have been extensively analyzed in the literature and substantial work has been performed over at least the last 30-35 years, mostly in the context of analyzing the economic impact of oil spills and contemplating measures to mitigate their damages. For a short literature review the reader is referred to a previous work of the authors, see Kontovas et al. (2010).

Lately, the subject of estimating the cost of oil spills has been in the center stage of discussions at the International Maritime Organization (IMO) in regards to the establishment of Environmental Risk Evaluation Criteria within the context of Formal Safety Assessment (FSA).

One way to estimate the total cost of oil spills is by using compensation data. For more on the other ways that can be used to derive the total cost the reader is referred among others to Kontovas and Psaraftis (2008). Back on compensation data, the most widely accepted public source that covers compensations paid is provided by the International Oil Pollution Compensation Funds (IOPC Fund).

Among the first recent analyses was the one performed by Grey (1999). A couple of recent cases where the IOPCF data was analyzed 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.

Hendrickx (2007) performed an analysis based on data of the 2003 Annual Report and analyzed 91 cases by converting each compensation amount into US Dollars using for each accident the exchange rate on Dec. 31 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.

The work done in Ventikos et al. (2009) gives a clear picture of oil spill response cost in Greece. In this outline the aforementioned paper takes into account a number of variables to draft a model for the estimation of clean-up cost; namely type of oil, quantity of oil, and impact to shoreline. The results show that oil confrontation in Greece appears to be rather expensive, with a value of about 25,000 euro for the abatement of a spill of one ton of oil.

Yamada (2009) performed a regression analysis of the amount spilled and the total cost by using the exchange rate provided in the IOPCF Annual Report. These rates can be used for conversion of one currency into another as of Dec. 31, 2007 and do not take into account the time of the accident nor is any inflation taken into account. Note that spills less than 1 tonne were excluded by the analysis. 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.

Last but not least, Psarros et al. (2011) used combined data from two datasets, namely the IOPCF report and the accident database developed by EU research project SAFECO II, 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.

3 DERIVING COST FORMULAS

3.1 *Original IOPCF regression formulas*

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 cleanup 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. More on compensation for oil pollution damage can be found in Jacobsson (1994 and 2007), ITOPIF(2010) and Liu and Wirtz(2009).

The 2008 IOPCF Annual report (IOPCF, 2008) 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. In order to perform our analysis we followed the steps below:

1. We removed all incomplete entries (cases were no information regarding other the compensation paid or the oil spill size).
2. All claims for the cleanup 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).

This way we arrived at two datasets, one having data on the Cleanup 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.

3.1.1 Cleanup Cost (CC)

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

The minimum volume was 0.2 tonnes and the maximum was 84,000 tonnes. The average spill was 4,055.82 tonnes with a standard deviation of 14,616.15 tonnes and the median was just 162.5 tonnes. There were only 10 spills above 5,000 tonnes and, thus, one should be very careful when using the regression formulas to extrapolate the cost of large spills. The equation of the fitted model using linear regression was:

$$\text{Cleanup Cost} = 44,435 V^{0.644} \quad (1)$$

The R-Squared statistic indicates that the model as fitted explains 61.5254% of the variability in LOG10(Cleanup Cost). The correlation coefficient (Pearson's correlation coefficient p) equals 0.7844, indicating a strong relationship between the variables. Furthermore, an average per tonne oil spill cleanup cost using the IOPCF database was calculated by dividing the total amount paid by the Fund for cleanup by the total amount of oil that was spilled. According to our analysis, this value came to 1,639 USD (2009) per tonne.

3.1.2 Total Cost (TC)

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 studentized 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 (see Fig.4).

The minimum oil spill size was 0.1 tonnes and the maximum was 84,000 tonnes. The average spill was 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.

The equation of the fitted model using linear regression was:

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

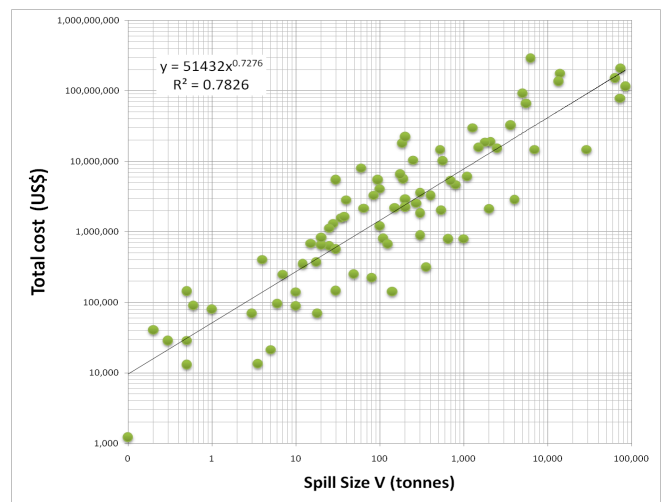


Figure1. Regression of Log(Spill Size) and Log (Total Cost).

The R-Squared statistic indicated that the model as fitted explains 78.26% of the variability in LOG10(Cleanup Cost). The correlation coefficient (Pearson's correlation coefficient p) equals 0.8846, indicating a strong relationship between the variables. As before, an average per tonne oil spill total cost using the IOPCF database was 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 Updated Total Cost Formulas

Note that in July 2007 a correspondence group (CG) was tasked to establish environmental risk evaluation criteria within FSA. At the latest meeting of the MEPC (MEPC 60, March 2010), a Working Group was formed after considerable debate, among the three non-linear regressions proposed, the one proposed by the authors of this paper (see Eq. 2) was considered as more conservative and was proposed as a basis.

Following a submission of the United States to the IMO, we reported on recent analysis of oil spill cost data assembled by Oil Spill Liability Trust Fund (OSLTF), see document MEPC 61/18/2. Regression analysis of the cleanup cost is performed arriving at a non-linear function that is compared with the one produced by using data from the IOPC Fund. These analyses are very important since the United States is not a member of the IOPC Fund and, therefore, the IOPCF report contains no information regarding US spills.

The above dataset of US spills includes only the response cost. In order to arrive at the total cost of an oil spill a total cost to cleanup cost ratio can be used. In a submission of the US to the MEPC, see MEPC 61/INF.11, a value of \$ 40,893.64 (in 2005 USD) was given as the ‘best estimate’ of the avoided volumetric response cost and \$ 102,287.95 for the total avoidance cost. This total cost ‘best estimate’ is based on literature review. The 4 sources that were used are ICF Kaiser (1997), Brown & Savage (1996), Helton & Penn (1999) and Mercer Management Consulting (1992), which are rather dated papers. Although it is out of the scope of this work to comment on the literature, the ‘best estimate’ for the per ton response cost (\$40,893.64) is based on the median spill size of 0.16 tonnes. The median, as well as, the average of ratios should be used with caution, see Psaraftis (2011). In our opinion, these statistics do not make too much sense. Nor does it make sense to extrapolate to large spills cost statistics derived from very small spills.

In any case, the total cost to response cost ratio for this ‘best estimate’ is 2.501. Therefore, based on this ratio a ‘best estimate’ total cost of each oil spill in the IOSLTF dataset can be estimated by multiplying the response cost by this figure. This is in line with Vanem et al. (2007a, 2007b) who taking into account the work of Jean-Hansen (2003), McCay et al (2004) and Etkin (2004), concluded that a ratio of 1.5 should be assumed for the ratio of socioeconomic and environmental costs divided by cleanup costs. Thus, the total oil spill cost is 2.5 times the cost of cleanup, according to their analysis.

In addition compensation data from 17 spills in Norwegian water is available in a document submitted by Norway to IMO, see doc. MEPC 60/17/1. These are extremely costly cases but it was decided to keep them in our analysis.

A combined dataset of these 3 sources has been jointly developed by a group of researchers from Germany, Greece, Japan and the United States, after a specialized workshop hosted by Germanischer Lloyd in February 2011 and a series of discussions among the group. This paper presents some regression analyses, based on this combined dataset, that was performed by the authors and submitted by Greece to the IMO, see doc. MEPC 62/18/1. Greece's intent was to participate in a joint submission

to MEPC 62, but this proved impossible due to lack of time in processing a joint submission.

Note that minor late adjustments in the combined database produced minor differences in some relevant results that were submitted to the IMO by Germany, Japan and the United States, see doc. MEPC 62/INF.24.

Going back to the consolidated dataset, we arrived at a dataset of 357 spill with a minimum oil spill size of 0.0003, average of 12.79 and a maximum of 1,747.55. The median is just 0.16 which means that this dataset consists of extremely small spills. Therefore the combined dataset consists of 476 spills. The min spill size is 0.0003 tonnes and the maximum 144,000. The median is 0.3 and the average 1,251 tonnes. Therefore the dataset consists of very small spills. The equation of the fitted model using linear regression was:

$$\text{Total Cost (2009 USD)} = 68,779 V^{0.593} \quad (3)$$

Given that the IOPC Fund contains spills greater than 0.1 tonnes, regression analysis for the spills greater than 0.1 tonnes was also performed. The final dataset consists of 343 spills, having a median of just 2.27 tonnes. Obviously there is a great influence of the small spills that dominate the US dataset. The regression formula derived from spills above 0.1 tonnes of the combined dataset is the following:

$$\text{Total Cost (2009 USD)} = 42,818 V^{0.7294} \quad (4)$$

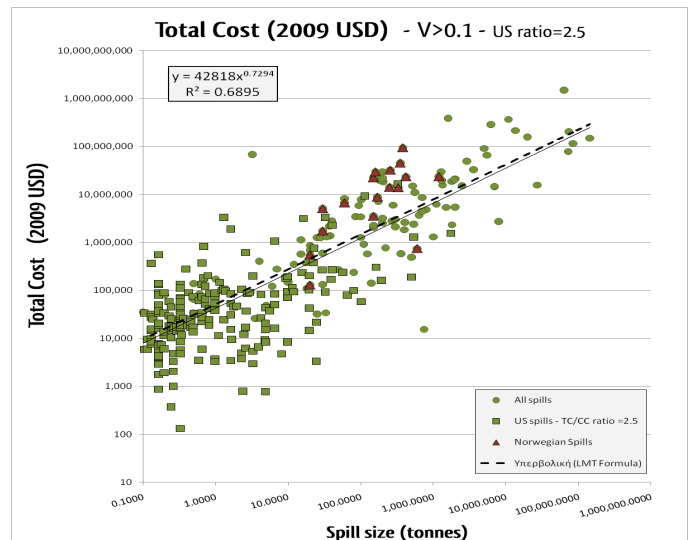


Figure 2. Linear Regression of Log(Spill Size) and Log(Total Cost) – US TC/RC ratio of 2.5.

Furthermore, various analyses were carried out. Regression formulas were derived for the whole dataset (Fig.2) and subsets that contain spills greater than 0.1 tonnes (Fig.3), spills that happened after 1990, and spills that are over 0.1 tonnes and happened after 1990. Although it is not the purpose of this paper to comment on these analysis the main conclusions are (a) based on Figure 2 it seems that the updated formula given by Eq. 3 (based on the combined dataset) underestimates the total cost in comparison to the

original regression formula (eq. 2) for spills greater than 10 tonnes and

(b) the original regression formula lies above all regression formulas derived from the combined dataset (at least for big spill) which means that it overestimates the total cost, see Figure 3.

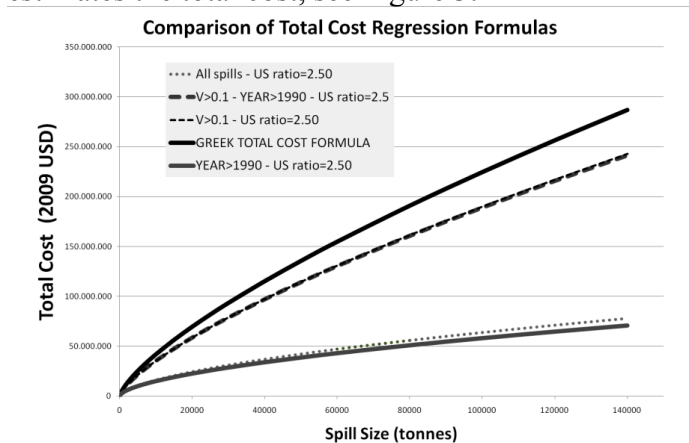


Figure 3. Comparison of various regressions

4 USES OF THE COST FORMULA

4.1 Formal Safety Assessment

Formal Safety Assessment (FSA) was introduced by the International Maritime Organization (IMO) as “a rational and systematic process for accessing the risk related to maritime safety and the protection of the marine environment and for evaluating the costs and benefits of IMO’s options for reducing these risks” (IMO, 2007). FSA aims at giving recommendations to relevant decision makers for safety improvements under the condition that the recommended measures reduce risk to the “desired level” and are cost-effective. FSA is, currently, the major risk assessment tool that is being used for policy-making within the International Maritime Organization (IMO), however, until now its main focus was on assessing the safety of human life. No environmental considerations have been incorporated thus far into FSA guidelines. Also note that FSA exhibits some limitations and deficiencies. The reader is referred to Kontovas (2005), Kontovas and Psaraftis (2006a, 2006b and 2009), Kontovas et al (2007a,b), Zachariadis et al (2007) and Giannakopoulos et al (2007) for a discussion on these issues.

The fourth Step of a Formal Safety Assessment is to perform a Cost-Benefit Analysis (CBA) so as to pick which risk control options (RCOs) are most cost effective. According to the FSA guidelines, one stage of this Step is to “estimate and compare the cost effectiveness of each option, in terms of the cost per unit risk reduction by dividing the net cost by the risk reduction achieved as a result of implementing the option”.

Up to now in most FSA studies cost effectiveness is assessed by using the so-called Cost Effectiveness Analysis (CEA) and not Cost Benefit Analy-

sis(CBA) both of which will be briefly discussed below. CEA may be considered to be particular form of CBA, where the benefits are usually not monetized, and therefore, net benefits cannot be calculated, see Mishan and Quah(2007) and Krupnick (2004).

Usually, in CEA, one calculates the costs per unit of an effectiveness measure (such as lives saved). Therefore, while CEA cannot help in determining whether a policy increases social welfare, it can help in the choice of policy that achieves the specified goal with the smallest loss in social well-being and can help rank alternative policies according to their cost-effectiveness (Krupnick, 2004).

In theory, the analytical tool of Cost Effectiveness Analysis is the **incremental cost-effectiveness ratio** (ICER), also called marginal cost-effectiveness ratio, given by the difference in costs between two actions divided by the difference in outcomes between these two, with the comparison typically being between an action that is proposed to be implemented and the current status.

Currently only one such index is being extensively used in FSA applications. This is the so-called “Cost of Averting a Fatality” (CAF) and is expressed in two forms: Gross and Net. In a similar way, Skjong et al. (2005) and Vanem et al (2007a,2007b) presented an environmental criterion equivalent to CAF. This is nothing new, but an incremental cost effectiveness ratio to assess the case of accidental releases of oil to the marine environment that measures risk reduction in terms of the number of tonnes of oil averted. This criterion was named CATS (for “Cost to Avert one Tonne of Spilled oil”) and its suggested threshold value was 60,000 USD/tonne. 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 the specified threshold, otherwise that particular RCO should not be recommended.

Kontovas and Psaraftis (2006) were probably the first to question the SAFEDOR approach, both on the use of any single dollar per tonne figure and on the 60,000 dollar threshold. This paper was the core of a submission by Greece on this issue (doc. MEPC 56/18/1). This submission opened a big chapter concerning environmental risk evaluation criteria and its uses within FSA. At the 55th session of Marine Environment protection Committee (MEPC) that took place in 2006, the IMO decided to act on the subject of environmental criteria. An issue of primary importance was found to be the relationship between spill volume and spill cost. Given that the cost of oil spill depends on the volume of the spill it is difficult to incorporate the regression formulas within CEA.

Besides, most Risk Control Options have multiple effects (for example both in safety and the environment) and CBA should be preferred as it can combine multiple effects. The reader is referred to Kontovas and Psaraftis (2011) for a discussion in this issue.

4.2 Incorporating a non linear function within FSA

First of all, assume that the spill cost function is given by Eq. 2; the formula produced after regression analysis of IOPCF data which is as follows (Kontovas et al., 2010):

$$\text{Cost}(V) = 51,432V^{0.728} \quad (\text{in USD, if } V \text{ is in tonnes})$$

The use of this particular function causes no loss of generality, as any other function of volume can be tried. The updated formula (Eq.4) could also be used. RCO evaluation by comparing the benefits (derived by using a function) and the costs is, in theory, presented in Psaraftis (2008) and Kontovas et al. (2010). Yamada (2009), Hammann and Loer (2010) and Yamada and Kaneko (2010) presented a way to incorporate a non-linear cost function within FSA. The latter paper forms the basis of a relevant submission to the IMO, see doc. MEPC 59/17/1 that was submitted by Japan. In reality things are a little bit more complicated as it will be shown in the following example.

In most FSA studies an event tree is presented. For each sequence of the event tree the expected number of tonnes that will be averted is calculated as the product of the frequency of the event (P_i) and the average consequences (V_i) and is presented as $E[V]$. This is the so-called Potential Loss of cargo (PLC) value for each sequence. This value should then be multiplied with the per tonne cost (which is a function of the spill volume) to estimate the risk (denoted as $E[C_i]$) and by summing all the relevant sequences the total risk may be obtained. Another equivalent way to estimate the expected benefit of averting an oil spill by using the cost function ($\text{Cost}(V)$) is to multiply the probability P_i with $\text{Cost}(V_i)$. These two ways lead to equivalent results. What is important to stress out is that the expected cost should be estimated before the implementation of the RCO and after it.

According to Yamada and Kaneko (2010), an RCO can be regarded as cost-effective if the following formula is satisfied

$$\Delta B - \Delta S > 0$$

where ΔB is the benefit by implementing the RCO which is the risk reduction (in monetary units) and ΔS is the cost of implementing the RCO. ΔB is the expected cost of an oil spill before the implementation of the RCO ($E[C_{\text{org}}]$) and after ($E[C_{\text{new}}]$).

Therefore, the criterion becomes

$$\Delta S < \Delta B = E[C_{\text{org}}] - E[C_{\text{new}}]$$

In practice, the discounted costs and benefits should be compared. Furthermore, in most FSA studies submitted to the IMO the event trees have not been recalculated. In most cases, the RCO was assumed to erase the risk (which means $E[C_{\text{new}}]$ equal to zero) or a risk reduction as a percent of the initial risk was estimated by expert judgment. Taking these remarks into account, applying the criterion is straightforward.

4.3 Probabilistic Oil Spill Risk Analysis: Environmental Performance of Tankers

In addition the Cost Benefit Analysis presented above as a part of a Formal Safety Assessment (FSA) could also be used to evaluate the environmental performance of alternative tanker designs.

In general, to model the risk of an individual tanker spill, it may be argued that one has to:

1. Determine the probability of an accident ;
2. Determine the oil outflow volume given the accident as a probability distribution ;
3. Determine the spill consequence given the outflow volume by using the non linear formula.

This methodology has been applied in many studies performing oil spill risk analysis. For example, see Montewka (2009) and Montewka et al. (2010) who present the risk of collision and grounding as a random variable and uses the risk assessment process that is illustrated in the following diagram.

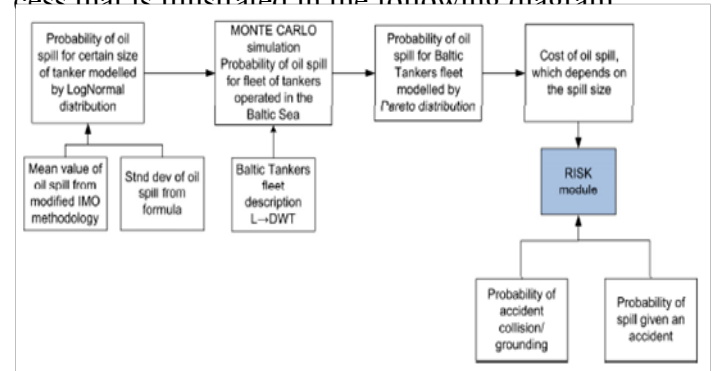


Figure 4. Block diagram of risk assessment process applied in presented study [Montewka, 2010]

According to their analysis, the risk that tankers colliding or grounding pose to the environment can be calculated using the general formula, separately for collision and grounding:

$$R = P_A \cdot P_{OS|A} \cdot P_{OS} \cdot C$$

where P_A means a probability of an accident (collision or grounding), $P_{OS|A}$ means a probability of an oil spill given an accident, P_{OS} denotes a probability density function of an oil spill volume, C stands for consequences of an accident, which refers to an oil spill clean up costs and used the non linear function derived by Yamada (2009).

Furthermore, probabilistic oil outflow models are being used in risk based optimization of crude oil carriers with respect to loss of cargo. These are in line with the IMO regulations regarding the probabilistic oil outflow for bunker tanks (applied to all spills) and cargo tanks regarding oil carriers. Indeed, MEPC has adopted a revised MARPOL Annex I/23 and 24 applicable to all new oil tankers to provide adequate protection against oil pollution in the event of grounding or collision, see IMO (2006a, 2006b, 2006c).

Regulation 23 applies to new oil tankers, which means all tankers delivered on or after 1 January 2010. The Probability density functions have been determined for the likelihood of damage being encountered at different points in the length of the ship for both side and bottom damage. An assessment is then made of the expected oil outflow from each damaged tank or group of tanks including tidal effects and accounting for any retained oil.

The mean oil outflow parameter is calculated independently for side damage and bottom damage and then combined in non dimensional value as follows:

$$O_M = (0.4O_{MS} + 0.6O_{MB}) / C,$$

where O_{MS} and O_{MB} are the mean outflows for the side damage and bottom damage respectively and C is the total volume of cargo oil in m^3 for a 98% full tank. Regulation 23 is presented into detail in Annex I.

Thus far, research on risk based ship design has mainly focused on parametric optimization in order to reduce oil-outflow probability and increase cargo carrying capacity (Papanikolaou et al., 2010). However, the economic damage of accidental oil outflow can be estimated by using a non linear function as presented above. That way, alternative designs could be judged for their environmental performance (Sirkar et al., 1997). Ventikos & Swtiralis (2011) present a probabilistic formulation of regulation 23 of MAPPOL to calculate distribution and quantities of oil outflow for all major oil tanker categories and examine numerous cargo tank configurations for tankers by simulating multiple outflow scenarios for the tanker fleet. In addition, they perform an assessment of the cost of these potential oil spills by using some of the formulas discussed above.

5 SUMMARY AND CONCLUSIONS

It is important to comment on the limitations of the compensation funds. First of all, it should point out that costs reported to the public are not 'real' oil spill costs. They refer to the amount of money that was agreed to compensate the claimants. Although the compensation figures are real and cannot be disputed, a question is if compensation figures can be

taken to reasonably approximate real spill costs, or, failing that, if they can be used as realistic 'surrogates' of these costs.

Estimates of damages calculated by applying economic valuation methodologies, claims for compensation and the compensation paid to claimants can never be equal (Thébaud et al, 2005). It is further noted that admissible claims cannot be paid in full, especially in the case of large spills, since there exists a limit in total compensation that can be paid. On the other hand, if there are any actual costs that are paid to victims of oil pollution, this is probably as good a source to document such costs as anyone. Plus, this analysis can be amended with additional data, to the extent such data becomes available.

Results of regression analyses that attempted to connect oil spill cleanup cost and oil spill total cost to oil spill size have been reported in various works, most of which were based on data from the International Oil Spill Compensation Fund (IOPCF). A lot of work has been done within the Marine Environment protection Committee (MEPC) of the International Maritime Organization. In fact, a previous work of the same authors that has recently been adopted by the IMO/MEPC as a basis for further discussion on environmental risk evaluation criteria. The current work has also been submitted by Greece to the IMO and will be discussed in the forthcoming section of MEPC (MEPC 62nd, July 2011).

These kind of analyses and their results can provide useful insights to the discussion on environmental risk evaluation criteria and in policy evaluation regarding the oil pollution of the marine environment by estimating the damage cost of oil spills and, thus, the benefit from relative regulations that deal with the prevention of oil pollution in cost effectiveness and cost benefit analysis. To that extent, these functions can be used within the Formal Safety Assessment (FSA) framework and Probabilistic Oil Spill Risk Analysis as Section 4.

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