Risk Analysis Methods in Oil Spill Contingency Plans

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Abstract Risk analysis of oil spills is an essential step of developing contingency plans. It is not only the basis of oil spill risk assessment, but also the basis of decision making about treating risks. Risk analysis involves consideration of the sources of risk, their consequences and likelihood that those consequences may occur. The consequences and likelihood of each risk source determines the level of risk. It is inappropriate to assume that the quantitative is always better than qualitative analysis. Risk analysis may be undertaken to varying degrees of detail depending upon the risk, the purpose of the analysis, and the information, data and resources available. Risk analysis in contingency plans does not attempt to quantify absolute risk levels, but compares the relative risk between different geographical regions and allocates reasonably limited resources. Therefore, qualitative risk analysis is sufficient for the purpose of the developing a contingency plan. This paper describes the risk analysis methods that can be used in oil spill contingency plan, based on introducing methods of risk analysis.

Keywords ship; oil spill contingency plan; risk analysis; risk matrix

0 Introduction

China requires a large quantity of oil to develop economically. China is the third largest oil consumer country in the world now. In 2003 and 2004, the amount of imported oil had reached 100,000,000 tones each year. 90% of imported oil is transported by sea. In addition, there are approximately 200 ships along the coast of China every day, adding more and more large-size ships. These make the navigational environment more complicated. Therefore, the oil spill risk will increase.

Oil spills are directly linked to the events of ship's accidents. Oil spill risk can be reduced primarily through preventative measures. International conventions and national legislation has provided important preventative measures. These are necessary to prevent oil spills from occurring. Although these measures have been implemented, the accidents are still occurring. Therefore, we should have contingency plan in place so that we can respond to spills promptly, in order to reduce the damage from oil spills. Contingency plans continue to be established by the various organizations. These initial achievements have been an important start.

Preventing oil spills is the best strategy for avoiding potential damage to the environment. However, once a spill occurs, the best approach for containing and controlling the spill is to respond quickly and in a well-organized and effective manner. A response will be quick and organized if response measures have been planned ahead of time.

International conventions and national legislation demand that contingency plans are developed. They are also encouraged by governments，organizations and the stakeholders that may be impacted by oil spills.

Risk analysis of oil spills is an essential step to developing a contingency plan. Risk analysis involves consideration of the sources of risk, their consequences and the likelihood that those consequences may occur. The consequences and likelihood of each risk source determines the level of risk.

For developing contingency plans, the objectives of oil spill risk analysis are as follows,

Measuring the risk, understanding the nature of risk and to calculating the risk level;

Assigning priorities to risks; as it will not be possible to give equal protection to all sensitive resources, priorities need to be determined;

Providing the basis for further risk assessment and making decision of risk-reduction measures.

1 Research Methods

Literature review about the standard's documents, papers and materials of oil spill risk analysis and assessment;

Literature review about examples about ship's oil spill contingency plans;

Risk analysis methods are selected for use in developing oil spill contingency plans.

2 The steps and methods of risk analysis

2.1 Identify the risks

It is the precondition of risk analysis to identify risks. Comprehensive identification using a well-structured systematic process is critical, because a risk not identified at this step may be excluded from further analysis and assessment. Furthermore, it is not impossible to prevent and control risk. Identification of risks means knowing what might happen, where and when, why and how it can happen. It is necessary to consider possible causes and scenarios. The aim is to generate a comprehensive list of sources of risks.

Approaches used to identify risks include checklists, judgments based on experience and records, flow charts, brainstorming, systems analysis, scenario analysis and systems engineering techniques.

2.2 The risk analysis methods

Risk was defined as a measure of the probability and severity of consequences of undesirable events (Lowrance，1976). Risk analysis is about developing an understanding of the risk. Risk analysis involves consideration of the sources of risk, their consequences and likelihood that those consequences may occur. That is, the risk is analyzed by combining consequences and their likelihood. The consequences and likelihood of each risk source determines the level of risk.

There are three methods; qualitative, semi-quantitative and quantitative that can be used in risk analysis. These methods can be used separately or jointly.

2.2.1 Qualitative analysis

Qualitative analysis uses words (i.e. High medium, low) to describe the magnitude of potential consequences and likelihood that those consequences will occur. Those scales can be adapted or adjusted to suit the circumstances, and different descriptions may be used for different risks.

Qualitative analysis may be used:

□as an initial screening activity to identify risks that require more detailed analysis;

□where this kind of analysis is appropriate for decisions; or

□where the numerical data or resources are inadequate for a quantitative analysis.

2.2.2 Semi-quantitative analysis

In semi-quantitative analysis, qualitative scales are given values. The objective is to produce a more expanded ranking scale than is usually achieved in qualitative analysis, but not to suggest realistic values for risk such as is attempted in quantitative analysis. However, since the value allocated to each description may not bear an accurate relationship to the actual magnitude of consequences or likelihood, the numbers should only be combined using a formula that recognizes the limitations of the kinds of scales used.

Care must be taken with the use of semi-quantitative analysis because the numbers chosen may not properly reflect relativities and this can lead to inconsistent, anomalous or inappropriate outcomes. Semi-quantitative analysis may not differentiate properly between risks, particularly when either consequences or likelihood are extreme.

2.2.3 Quantitative analysis

Quantitative analysis uses numerical values for both consequences and likelihood. These may be estimated by modeling the possible outcomes of an event or set of events, or by extrapolation from experimental studies or past data. Because of the estimates, assumptions and extrapolations made in quantitative analysis, the outcomes are often imprecise. The quality of and validity of the risk analysis is dependent on the availability of data, and on the accuracy and completeness of the numerical values and the methods used.

In most cases, quantitative risk analysis will involve the use of computers and the need to obtain or develop appropriate software.

3 Risk analysis using in oil spill contingency plan

The contingency plan is a strategic document. Risk analysis in this document does not attempt to quantify absolute risk levels, but compares the relative risk between different geographical regions and allocates reasonably finite resources. In addition, not all the used data in the risk analysis are quantitative. Some of the data is estimation and judgment. Response to oil spill is not a discipline and it is often based on practice. Oil spill risk analyses are often qualitative or combining qualitative and quantitative values in contingency plan.

3.1 Identify oil spill risks

There is a link between oil spills and ship's accidents, such as collisions, groundings, fire and explosion and structural failure. It is relevant to refer to ship's accidents data if there is not enough spills data. The most common causes of spills are due to ship's collisions and groundings, but there are some exceptions. The spill hazards should be identified thoroughly and systematically.

Spill risk identifications are very important not only to spill risk analysis, but also to recommend risk-reduction decisions. For example, providing escort procedures after the grounding of the Exxon Valdez was successful in reducing the average oil spills from groundings, but it increased the average oil spills from collisions as the escort vessels returning from an escort assignment interacted with the tankers in the Prince William Sound. A further analysis showed that escort tugs are the highest cause of oil spills from collisions (Merrick et al., 2000).

3.2 Likelihood analysis of oil spill

The likelihood analysis of oil spills is used to determine the frequency， amount, type and the location of accidental spills from vessels in the specific geographic region. It should consider oil transport volume and type; historical spill records, which are needed over longer time spans in order to average results, traffic patterns and frequency, accident history reports and statistics, expert experiences and judgments. The frequency， amount and type of accidental spills from vessels varies widely between different locations, depending both on the amount of oil transported and combined effect of local factors which are chiefly related to navigational hazards. These local factors include traffic density, weather and sea conditions, visibility, water depth and the nature of the seabed. There are also considerations about open fishing times, locations, and duration (Stewart et al., 1986; Moller et al., 2003). The preferred method for estimating the likelihood is through the statistical analysis of data. Local past spills records are the best basis for the risk analysis. If local data are insufficient, analysis has to rely, at least in part, on other resources, like expert judgment and databases. Elicitating expert judgment is often crucial in performing risk analysis (Cooke, 1991; Moalesh et al, 1988). The data, which was used in analysis, has a significant impact on the results (Stewart et al, 1986). They will affect the reliability of outcomes and may increase the uncertainty of outcomes. The data may come from international and national databases. For example, historical spill records may come form ITOPF's spill databases. Over 30 years ITOPF have gathered some 470 pollution spill incidents of over 100 tonnes in 85 countries. Data on oil tanker shipments on specific routes may come from Lloyods Marine Intelligence Unit (Moller et al., 2003) and coastal ship reporting systems. Oil spill assessment in Australian Waters that was done by DNV calculated risks based on historical accident rates from around the world. Australian historical spill frequencies were then used to check if the results of the predictive model were similar to Australian historical experience. The results showed that the risk model is reasonably close to Australian historical data overall.

The likelihood is assigned a rating of three levels (see Table 1) ：

Table1 Likelihood ranking (three levels)

Level	Descriptor	Definition
3	High	One time per year
2	Medium	One time per ten years
1	Low	One time per 50 years

Or five levels (see Table 2):

Table 2 Likelihood ranking (five levels)

Level	Descriptor	Definition
5	Almost certain	One time per year
4	Likely	One time per 5 years
3	Possible	One time per 10 years
2	Unlikely	One time per 30 years
1	Rare	One time per 50 years

3.3 Consequence analysis

Key criteria for consequence are environmental and socio-economic vulnerability of the specific geographic region. The vulnerability analysis section of a contingency plan provides information about resources and economy that could be harmed in the event of a spill.

Amenity areas, ecologically sensitive areas, sea water intakes, fisheries, mariculture, seabirds and marine mammals and other resources likely to be threatened by oil spills should be identified. Since it will not be possible to give equal protection to all sensitive resources, priorities need to be determined. Account should be taken of the practical problems as well as the relative economic and environmental values of each resource and their sensitivity to oil pollution. Seasonal variations e.g. of beaches and breeding areas should be noted. Information on the location and sensitivity of resources and priorities for protection is frequently provided in the form of maps annexed to the contingency plan.

The chief impact of oil spills is of an economic nature, in the form of property damage, business interruption and consequential losses. Therefore, the losses can be described in monetary terms.

The consequence is assigned a rating of three levels (see Table 3)：

Table 3 Consequence ranking (3 levels)

Level	Descriptor	Losses（¥）
3	High	10 M above
2	Medium	1-10M
1	Low	0.1-1M

Or five levels (see Table 4):

Table 4 Consequence ranking (5 levels)

Level	Descriptor	Losses （¥）

5	Severe	100M above
4	Major	10-100M
3	Moderate	1-10M
2	Minor	0.1-1M
1	Negligible	0.1 M below

3.4 Risk measure (calculation)

The calculation of the level of risk can be seen utilizing the two-dimensional risk matrix combining likelihood and consequence.

$$\text{Risk}=\text{likelihood}\times\text{Consequence}$$

The final outcomes are in relative risk level values, rather than actual risks (Moller et al., 2003). Having established the comparative risk level applicable to individual impacts, it is possible to rank those risks. Three risk categories have been used: High (9), Medium (4-6), and Low (1-3) (see Table 5)or four risk categories have been used: Extreme（15-25）, High（8-12）, Moderate（4-6）, and Low（1-3）(see Table 6).

Table 5 Risk matrix (both 3 levels)

Likelihood	Consequence		
	Low	Medium	High
High	3	6	9
Medium	2	4	6
Low	1	2	3

Table 6 Risk matrix (both 5 levels)

Likelihood	Consequence				
	Negligible	Minor	Moderate	Major	Severe
Rare	1	2	3	4	5
Unlikely	2	4	6	8	10
Possible	3	6	9	12	15
Likely	4	8	12	16	20
Almost certain	5	10	15	20	25

The Risk Matrix is a qualitative tool for ranking the likelihood and consequence for oil spills accident that may occur and assigning the risk level. It is a simple and straightforward method. The value of the Risk Matrix lays not so much in establishing a specific risk level but in help to evaluate relative risks and decide risk-reduction measures as a result of subsequent prevention and /or mitigation step in developing contingency plans.

3.5 Combine existing controls

Evaluating the effectiveness, strengths and weaknesses of existing controls is part of the analysis process. It is also for improved allocation of response resources and to avoid implementing risk-reduction measures that would adversely affect system risk (Harrald et al., 1990 and Merrick et al., 2002). The risk-reduction measures include two aspects: the one is the preventative and the other is preparedness. The preventative measures can cause a decline in the accidents occurring; the preparedness measures can decrease damage from accidents. The preventative measures include the regulations of ship's navigation safety, facilities and management aimed at ship's navigation safety, such as double hulls of tanker, Vessel Traffic Systems, traffic separation scheme and area of evasion etc. Preparedness measures include the designation of a competent national authority to deal with marine emergencies, the preparation and adoption of national contingency plan, participation in regional or multilateral spill response arrangements, the provision of oil spill response equipment and materials, and the ratification of certain relevant international conventions. The level of preventative/preparedness may be ranked high (3), medium (2) and low (1). Effective preventative measures can decrease the levels of the likelihood (original level of likelihood - level of preventative); effective preparedness measures can decrease the levels of consequence (original level of consequence – level of preparedness).

3.6 Uncertainty of risk analysis

No matter which method is used, the uncertainty and variability of both consequences and likelihood should be considered in the analysis. In particular, the analysis of environmental risk, due to oil spills often produces results with a high degree of uncertainty. Reasons for this include:

□ the environment has a large number of components that interact in complex ways, and may not be fully understood;

□ the likelihood and consequence analysis of accident occurring may be based on improper data;

□ there are many factors affecting risk levels. The risk analysis consider the primary factors affecting risk levels, (e.g. the number and type of vessels, sensitive resources and the nature of oil, etc); there are other factors not considered in the risk analysis which may affect risk levels, (e.g. berth layouts, management level of company and complexity of ship routes, etc.);

□ the time scale relevant to environmental risk analysis may be long; it increases uncertainty of risk analysis.

4 Recommendations

Further research should be undertaken as follows:

(1) Establishing relevant standards for developing contingency plan, including oil spill risk analysis in order to assist organizations and related parties in planning;

(2) Researching the methods to minimize uncertainty of risk analysis;

(3) Providing special preventative and / or preparedness measures to identified areas of high risk, based on analysis results;

(4) Using geographic information system (GIS), combining computer software, construct a dynamic risk analysis model in developing contingency plans if there is appropriate numerical data.

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