Risk assessment and cost-benefit techniques as management tools for oil spill prevention

S. Diller

National Oil Spill Contingency Plan Advisor,
Petróleos de Venezuela, PDVSA, Caracas, Venezuela.
Email: ppipc@pdvsa.pdv.com

Abstract

In the last 15 years, and especially after remarkable large technological accidents like Bhopal, San Juanico, Tacoa, Piper Alpha, Exxon Valdez, Sea Empress, etc, the risk assessment tools have become a must for design engineers and also have been growing popular since more reliable oil spill accident analysis data has been gathered in the last ten years.

On the other hand the large investments that have been necessary to execute in order to adequate and improve old facilities, equipment, etc., and the total loss control enhancements in new projects, have created some concern on how much safe is safe and how much money is necessary to spend in order to be sufficiently preventive without getting into financial trouble and being technologically sound according the growing global concern about environmental issues.

Concepts are presented in risk prevention and oil spill risk assessment, and examples are developed in order to understand the link between different oil spill risk prevention options and the management finance decision making process.

The main conclusion relates the necessary financial justification of oil spill prevention projects and programs, and oil spill risk prevention assessment techniques as tools for better environmental and financial management decision making process.
Improving oil pollution safety through risk management

The handling, use, processing, storage and marketing of hydrocarbons and specifically crude oil and its by-products will always represent a risk in terms of fire, explosions and spills. The goal of process safety management is to consistently reduce risk to a level that can be tolerated by all related parties, e.g., by facility staff, company management, surrounding communities, the general public, industry, government and non government agencies.

In recent years, industrial standards for tolerable risk have become increasingly stringent. This trend reflects a convergence of public opinion, government regulations, and industry initiatives. In fact, to contain long-term costs and minimize liability, many of these process industries are setting standards for their own that could be well in excess of what is required. This aspect is especially true if the corporate image is strongly compromised to an “Environmental safe and friendly” policy.

The concept of risk and risk assessment

Risk can mean different things to different organizations and/or individuals. Applied not only to oil spills, in chemical-process-safety, risk is understood in terms of the likelihood and consequences of incidents or accidents that could expose people, property, or the environment to the harmful effects of a hazard of an oil spill.

Risk assessment, on the other hand is a systematic framework used to identify, describe sources, causes and consequences of a risk. Its purpose is to provide information to decision makers in a way to allow comparisons of different risk reduction alternatives and by the end associate those alternatives with costs. Risk assessment helps to answer key questions: What can go wrong?, How likely is the occurrence?, What and how serious are the consequences?, What can be done in order to minimize the effects?.

For example, an oil company develops a study of a pipeline route and concluded that the risk of an oil spill larger than 20 thousand barrels is less than 1 (one) for every 100 million barrels transported, in this case the risk is defined as a function of probability. On the other hand, if a different risk study for the same pipeline route identified the impact on
surrounding geography, such as sensitive habitats, the risk assessment is based on consequences of the oil spill, regardless of the likelihood of the event that generated the spill.

Among other things, when designing or reviewing an existing process, engineers first address the technology, chemistry, heat and material balances and basic process controls that define the core design. Once the core design has been determined, engineers explore ways in which the system could fail or break down. They look at issues concerning the reliability, safety, quality control, and environmental impact of the system. As for oil spills, engineers try to determine what types of failures might occur and their likelihood, and what effect such failures might have (often called “oil spill impact scenarios”).

Speaking ideally, oil spill safety should be a concern at each stage in a systematic design cycle: laboratory, pilot, basic and detailed design, construction, start-up, operations and final close down. But the most cost-effective solutions tend to emerge in the earliest design stage.

Steps to oil spill prevention risk-based design

The technique described here derives from engineering problem solving methods, and can be applied to all types of process-design cases, evaluate existing facilities and oil spill scenarios. The technique comprising a sequence of analysis and testing steps in the form of a decision tree provides for a disciplined approach and flexibility in its application (Figure 1). These steps are:

1-Identify oil spill hazards. Once designers have established a core process design, they can address failure scenarios that might address potential oil spills hazards.

2-Estimate the consequences. In this step, designers establish the potential consequences, e.g., fires, explosions, toxic-material releases, major equipment damage and consequent oil spills, that may result from the failure scenarios identified in step 1.

3-Determine the tolerability of the consequences. Making such an assessment requires guidance from established tolerability criteria. These include company-specific criteria; regulations, engineering codes, standards and practices (Figure 2).
4-Probability and Frequency analysis. This rests upon an understanding of the mechanism and frequency in which oil spill scenarios, such as those identified in step 1, might occur. When available, historical data can be very useful in this step.

5-Determine risk tolerability. This means if it is possible to tolerate this level of risk? Guidance on tolerable levels of risk can be gained from established risk criteria. If the criteria, when applied, indicate a tolerable level of risk, then the design of the process or the emergency system is satisfactory from a risk standpoint. If the criteria indicate intolerable
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risk, the next step is to reduce that risk through further process design (Figure 2).

6- Consider Alternative designs. In a risk based design, it is an opportunity to reconsider and to define changes to reduce the oil spill risk to tolerable levels.

7- Determine associated costs of the options developed in step 6.

8- Document results. Documenting the process-safety system and the design basis for the oil spill emergency system and incorporating the failure scenarios and associated consequences, likelihood, and risk cost estimates developed for proposed mitigation alternatives.

**TOLERANCE CRITERIA**

<table>
<thead>
<tr>
<th>RISK FREQUENCY INDEX</th>
<th>NON ACCEPTABLE RISK</th>
<th>REDUCIBLE RISK</th>
<th>MINIMUM RISK (ACCEPTABLE)</th>
</tr>
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<tbody>
<tr>
<td>10^{-1}</td>
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<th>MAJOR ACCIDENT</th>
<th>CATASTROPHIC ACCIDENT</th>
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<tbody>
<tr>
<td>FROM 1 Y 10</td>
<td>FROM 11 Y 50</td>
<td>MORE THAN 50</td>
</tr>
<tr>
<td>REVERSIBLE</td>
<td>REVERSIBLE</td>
<td>NON REVERSIBLE</td>
</tr>
<tr>
<td>IN 1 TO 5 YEARS</td>
<td>AFTER 5 YEARS</td>
<td></td>
</tr>
<tr>
<td>UP TO 100 MMUS$</td>
<td>MORE THAN 100 AND LESS THAN 500 MMUS$</td>
<td>MORE THAN 500 MMUS$</td>
</tr>
</tbody>
</table>

Figure 2.
Guidelines for oil spill risk tolerability

In most cases, risks cannot be eliminated only reduced to a level that design engineers find acceptable, when weighed against the advantages and benefits of the activity or process. Because attitudes about the tolerability of risks are not consistent, there are no universal norms for risk tolerability. What can be viewed as a tolerable risk will depend upon a number of factors, including:

The nature of the risk. Is it a voluntary risk, one that those who are at risk accept as part of a choice? Or is it involuntary? For example, risks associated with driving an automobile result from a voluntary act; risks associated with exposure to a toxic release from a nearby chemical plant are not.

Who or what is at risk? Does it affect a single person on many people? The surrounding environment? Are important water or other resources at risk? Residential neighborhoods? Hospitals, Schools?.

The degree to which the risk can be controlled or reduced. The design of process safety systems and especially oil spill preventive and emergency systems are of importance in this issue. Making the case for a “tolerable” risk requires that the methods supporting the design basis be technically sound and reasonable, clearly documented, and accurate.

Previous experiences. Uncertainty regarding the risk impact influences the decision makers’ tolerability. For example, the average person understands the risk of spilling cooking oil in a kitchen stove, but can be completely ignorant regarding the risk of an oil spill at high seas.

Risk criteria should fit with a company’s philosophy and culture and match the type of analysis its engineers normally conduct in the design stage. The selection of appropriate risk criteria is a corporate responsibility, and requires the involvement and support of senior management.

Review options. The purpose of the procedure described above is to enhance the engineer’s ability too make consistent choices about safe oil spill prevention design, and to introduce modifications where they can do the best for the least cost.
Financial aspects of oil spill events

Industries more than ever are aware of the importance of prevention of oil spill related losses. The large oil spills registered in the last 20 years has forced to justify from a financial point of view all the investments in order to demonstrate upper management the profitability of investments made in oil spill prevention. Also the economic evaluation of any investment proposal has to be based in the profits return in certain period of time. From the oil spill prevention point of view it is important to demonstrate that many investments done in this area are beneficial because they reduce the probable oil spill future costs associated that have to be spend by the corporation if no action is taken at all.

This is significantly true in the case of investments made to reduce the oil spill risks under certain situations. Those investments do not represent a direct increase in companies benefits, but a reduction in costs due to oil spill related expenditures (clean up costs, claims, etc.). Although it is impossible to predict an oil spill event, it is true that the tools used in risk assessment are particularly valuable in order to obtain different options in order to handle a potential spill and its consequences.

Determining probabilities from oil spill events

The probability of an oil spill event can be determined by various techniques, being the most common reliable the one based on real historic-statistical data collected in a period of time by different agencies. By example:

- According to ITOPF, the majority of small or intermediate spills in offshore waters are caused by loading and unloading operations (71%), while the major causes of large spills are a result of collisions and grounding of vessels.
- The U.S. Cost Guard statistics suggest that more than 80% of spills are less than one barrel, and that spills larger than 24000 barrels account for less than 1% of spill events.
- The U.S. Environmental Protection Agency reported that the majority of coastal spills occur from facilities and pipeline operations (more than 72%) compared to spills from tankers, barges and freighters.
- The American Petroleum Institute reported that more than 30% of spills occurred in coastal waters within 12 miles of U.S. shores, 42%
occurred in inland water bodies, being most of them minor events and not large catastrophic accidents.

Let’s illustrate with another example:

Assume you are in a facility and checking the oil spill records over the last 10 years, there have been 4 large oil spill related losses. Assuming that there has been no change in work force and facility design that could impact the total registered losses in those years, we could estimate the probability of an oil spill in any of those 10 years as $4/10 = 0.4$.

Now considering that each oil spill event generated expenses of U.S.$100 thousand, so in the ten year period considered, the expected cost of losses will be for a single year U.S.$100 thousand, times $0.4 = \text{U.S.} \$40$ thousand/year. This expected value represents the amount that this facility in particular should "expect to lose" any year as a consequence of an oil spill. It is important to note that this expected value means that in the next years, the yearly average oil spill related losses will approach U.S.$40 thousand per year, it does not mean that this facility will have a spill each year with a cost of U.S.$40 thousand.

If for the same facility we propose an oil spill preventive solution with an investment plus maintenance yearly cost of U.S.$25 thousand, then doubtless this proposal would be financially attractive because we are saving U.S.$15 thousand \text{year}^{-1}. If there are different oil spill scenarios, this could mean to establish priorities in these decision making process. By example lets assume in a company with three different processes called A, B and C, and with the following oil spill losses history:

<table>
<thead>
<tr>
<th>process</th>
<th>time considered</th>
<th># spills</th>
<th>cost per spill, U.S.$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5 years</td>
<td>4</td>
<td>150.000</td>
</tr>
<tr>
<td>B</td>
<td>5 years</td>
<td>22</td>
<td>25.000</td>
</tr>
<tr>
<td>C</td>
<td>3 years</td>
<td>2</td>
<td>140.000</td>
</tr>
</tbody>
</table>

Which of these processes require prior attention?

The expected value for the total annual oil spill losses for each process is the cost for each event times the yearly spill frequency:

- Process A $150.000 \times 0.8 = 120.000 \text{U.S.}$
- Process B $25.000 \times 4.4 = 110.000 \text{U.S.}$
- Process C $140.000 \times 0.67 = 93.800 \text{U.S.}$
Process A has the highest oil spill expected value and should receive prior attention, the finance savings if process A is completely corrected is U.S.$ 120.000/year. Lets assume that the decision is taken to modify process A in the next six years, what would be the future savings in the next six years if the modifications are done today?

Using financial tables, and assuming the company’s financing cost of 12% and a period of 6 years the actual value of future savings will be:

\[ 120.000 \times 4.11 = 493.200 \text{ U.S.} \$
\]

this means by example, that if correcting today completely process A with an investment of U.S.$ 200.000, the company can save U.S.$ 293.000 in the next six years, and so the investment is highly recommended.

**Annual spill costs versus Insurance**

An important issue in all the oil spill events is the one concerning insurance. By using the same financial techniques illustrated before lets develop an example:

Considering the probability that a facility worth U.S.$100 million, can be affected by a large oil spill is 0.001 in any year. The cost of the insurance for the facility is U.S.$ 600.000 per year. How would be compared the expected oil spill loss compared to the insurance cost?

Let's assume that the intangible and tangible costs for market position losses due to the large spill event is U.S.$150 million in addition to the installation cost of U.S.$100 million, so if spill happens, the probability is 0.001 and if it don’t the probability is 0.999.

If the spill occurs, (probability = 0.001)

The annual expected cost with insurance : 
\[ 0.001 \times (600.000) + 0.001 \times (150 \text{ million}) = U.S.\$ 150600 \]

The annual expected cost without insurance : 
\[ 0.001 \times (250 \text{ million}) \]

If the spill occurs, (probability = 0.999)

The annual expected cost with insurance : 
\[ 0.001 \times (600.000) \]
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The annual expected cost without insurance: 0

Annual expected cost with insurance:
\[ 0.001 \times (600,000) + 0.999 \times (600,000) + 0.001 \times (150 \text{ million}) = 750,000 \text{ U.S.}\$

Annual expected cost without insurance:
\[ 0.001 \times (250 \text{ million}) = 250,000 \text{ U.S.\$/year} \]

Annual savings if it goes for self-insurance:
\[ 750,000 - 250,000 = 500,000 \text{ U.S.}\$

From a financial point of view it would be more advisable to recommend to self-insurance the facility, this is specially true if the company has many of this facilities available in order to spread production in case of an event. On the other hand if the facility is of very significance and it is very vulnerable in case of a catastrophic event, then the decision to take the insurance is advisable even if the economics stand for self-insurance.

Conclusions

- The financial justification of oil spill prevention projects and programs, and oil spill risk prevention assessment techniques are excellent tools for better environmental and financial management decision making process.

- The importance to keep good records of spills accidents data in order to update continuously the frequency or probabilities of oil spill events.

- The risk and finance evaluation framework for oil spill prevention projects are necessary to provide the right priorities for investment resources assignment.

References

1- Risk Control Engineering Design Manual, Petroleos de Venezuela.(1996)
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5- Georges Melhelm, Peter Stickles, Enhancing safety through risk management, Chemical Engineering, October 1997, p.118.

6- Environmental Protection Agency (EPA), Technical Guidance for Hazards analysis, December 1987.